BRRI ANNUAL REPORT
2021-2022

BANGLADESH RICE RESEARCH INSTITUTE

BRRI ANNUAL REPORT

For July 2021-June 2022

Bangladesh Rice Research Institute (BRRI)

Gazipur 1701, Bangladesh

Publication no. : 327
300 copies
November 2022

Published by
Director General
Bangladesh Rice Research Institute

Advisers
Dr Md Shahjahan Kabir
Dr Abu Bakr Siddique
Dr Mohammad Khalequzzaman

Edited by
Md Rasel Rana

Cover: Bangabandhu dhan100

Photography
Md Masum Rana

Suggested Citation
Anonymous (2020) Annual Report of Bangladesh Rice Research Institute 2020-2021 BRRI, Gazipur 1701, Bangladesh, 478 pp.

Contact address
Publications and Public Relations Division (PPRD)
Bangladesh Rice Research Institute (BRRI)
Gazipur 1701, Bangladesh

Telephone	:	88-02-49272061
PABX	:	88-02-49272005-14
Fax	:	88-02-49272000
E-mail	:	brrihq@yahoo.com, dg@brri.gov.bd
Website	:	www.brri.gov.bd
		www.knowledgebank-brri.org

Printed By
Tithy Printing & Packaging
28/C-1 Toyenbee Circular Road, Motijheel C/A, Dhaka-1000.

Contents

Preface

The present volume of BRRI Annual Report is a summary of research works carried out by 19 research divisions and nine regional stations of the institute during July 2021 to June 2022. This document consists of the significant portions of the research covering eight programme areas.

The programme areas such as variety development, crop-soil-water management, rice farming systems, pest management, socio-economics and policy, farm mechanization, technology transfer and regional stations representing the broader conceptual frameworks of BRRI activities.

With a target to sustain Bangladesh's achievements as a rice surplus country BRRI scientists have been engaged in developing different location specific, climate smart, stress tolerant rice varieties and some nutritionally enriched premium quality ones.

Another group of BRRI scientists dedicated their time and energy to develop and disseminate resource-saving profitable environment friendly technologies along with some management tools such as alternate wetting and drying (AWD) technique, low-cost water distribution system, rice transplanter, integrated crop management (ICM) practices, rice-based farming systems and popularization of BRRI machinery.

Furthermore, BRRI developed high yielding rice varieties along with management technologies were demonstrated in different agro-ecological zones of the country.

Above all, the present report includes various research results out of activities that attempted to minimize yield gap between research level and farmer's fields. It also includes research initiatives dedicated to finding out coping strategies to face the effects of changing climate like increased flash floods, salinity, excessive heat and drought as well as severe cold.

I acknowledge all the efforts that helped bring out the publication and special thanks for those who contributed with different capacities.

I hope the report will be useful for the scientists, extension agents, policy makers and other partners home and abroad to be updated on continuous research activities at BRRI.

(Dr Md Shahjahan Kabir)
Director General
BRRI

Personnel

Director General's Office
Md Shahjahan Kabir, *PhD*
Director General

Research Wing
Mohammad Khalequzzaman, *PhD*
Director (Research)
Munnujan Khanam, *PhD*
Coordinator for Advanced Studies and Research, TOC
Nilufar Yasmin Shaikh, *PhD*
Senior Scientific Officer
Mir Nurul Hasan Mahmud, *PhD*
Senior Scientific Officer

Administrative Wing
Md Abu Bakr Siddique, *PhD**
Director (Administration and Common Service)
Emran Hossain, *MS (BAU)*
Deputy Director (Administration and Common Service)
Kawsar Ahmad, *BSS (Hons), MSS (RU)*
Senior Assistant Director (Administration)
Md Harunur Rashid, *BA*
Assistant Director (Common Service)
Muhammad Aminur Rashid
Assistant Director (Store)
Shyamal Chandra Das
Assistant Director (Administration)
Md Manjur Kadir
Assistant Director (Administration)
Sayeda Nahida Akter
Assistant Director Administration (Additional Charge)
Shimul Barua
Assistant Director Store (Additional Charge)
*from 8 November 2020

Accounts and Finance
Md Golam Rashid, *Mcom (Acct) CMA (Int)*
Deputy Director (Accounts and Finance)
Tarique Sala Uddin, *Bcom (Hons), MCom*
Senior Assistant Director (Finance)

Aduit cell
Audit Officer

Building and Construction
Md Hasan Ali, *BScEngg (Civil)**
Executive Engineer (Additional Charge)
Md Motiur Rahman
Assistant Engineer
*From 3 January 2021

Publications and Public Relations
Md Abul Kashem, *BA (Hons), MA (MCJ)*
Technical Editor and Head
Md Rasel Rana, *BA (Hons), MA (MCJ)*
Technical Editor and Head

Planning and Evaluation
Md Monirul Islam, *MScAg (Econ)*
Principal Planning Officer
Atia Rokhsana, *MSAg (Econ)*
Principal Planning Officer and Head (CC)
Md Saidul Islam, *MSAg (Econ)*
Planning Officer

Dispensary
Dr Habiba Sultana, *MBBS*
Resident Physician
Dr Rasel Faruk, *MBBS*
Resident Physician

Library
Mahbubur Rashid Talukder, *MA (Information Sc and Lib Management)*
Senior Librarian
Thamina Ahmed
Librarian

Plant Breeding Division
A S M Masuduzzaman, *PhD*
Chief Scientific Officer
Office of the Director (Research)
Khandakar Md Iftekharuddaula, *PhD*
Chief Scientific Officer and Head
Partha Sarathi Biswas, *PhD**
Principal Scientific Officer
Md Amir Hossain, *PhD*
Principal Scientific Officer
Mohammad Akhlasur Rahman, *PhD*
Principal Scientific Officer
Mahmuda Khatun, *PhD*
Principal Scientific Officer
Md Abdul Kader, *PhD*
Principal Scientific Officer
Md Ruhul Amin Sarker, *PhD**
Principal Scientific Officer
Sharmistha Ghosal, *PhD*
Senior Scientific Officer
Ratna Rani Majumder, *MS*
Senior Scientific Officer
Md Anisuzzaman, *MS*
Senior Scientific Officer
Hasina Khatun, *PhD*
Senior Scientific Officer
Tapas Kumer Hore, *MS*
Senior Scientific Officer
Sheikh Maniruzzaman, *MS*
Senior Scientific Officer
M M Emam Ahmed, *MS***
Senior Scientific Officer
Sanjoy Kumer Debsharma, *MS*

Scientific Officer
Nusrat Jahan, *MS*
Scientific Officer
Urmi Rani Shaha, *MS*
Scientific Officer
Md Yeakub Khan, *MS*
Scientific Officer (TRB-BRRI Project)
Ribed Farzana Disha, *MS*
Scientific Officer (TRB-BRRI Project)
Zabid-Al-Riyadh, *MS*
Scientific Officer (TRB-BRRI Project)
Janantul Ferdousy, *MS*
Scientific Officer (TRB-BRRI Project)
Mahmuda Maliha Yasmin, *MS*
Scientific Officer (TRB-BRRI Project)
Afroza Awal Shoily, *MS*
Scientific Officer (TRB-BRRI Project)
Istiak Hossen Joy, *MS*
Scientific Officer (TRB-BRRI Project)
Sumi Sarkar, *MS*
Scientific Officer (SDCTR Project)
* Transfer to Regional Station
** Deputation for higher study in abroad
*** Resignation from Job

Biotechnology Division
Md Enamul Hoque, *PhD*
Chief Scientific Officer and Head
Shahanaz Sultana, *PhD*
Principal Scientific Officer
Jannatul Ferdous, *PhD*
Senior Scientific Officer
Nilufar Yasmin Shaikh, *PhD*
Senior Scientific Officer
S M Hisam Al Rabbi, *PhD*
Senior Scientific Officer
Ripon Kumar Roy, *MS*
Senior Scientific Officer
Md Arafat Hossain, *MS*
Scientific Officer
Shampa Das Joya, *MS*
Scientific Officer
Md Sentu Rahman, *MS*
Scientific Officer
Sadia Jafrin, *MS*
Scientific Officer
*Abroad for higher study

Genetic Resources and Seed Division
Mohammad Khalequzzaman, *PhD****
Chief Scientific Officer and Head
Mir Sharf Uddin Ahmed, *PhD*
Principal Scientific Officer
Md Adil Badshah, *PhD*
Principal Scientific Officer
Ebna Syod Md Harunur Rashid, *PhD*
Senior Scientific Officer
Md Abubakar Siddique, *MS**
Senior Scientific Officer
Armin Bhuiya, *PhD*
Senior Scientific Officer
Md Humayun Kabir Baktiar, *MS*
Scientific Officer
Tonmoy Chakrabarty, BS(Ag)
Scientific Officer
Nadia Akter, *BSc Ag (Hons)**
Scientific Officer
Nashirum Monir, *Bsc Ag (Hons)*
Scientific Officer
Md Ashiqur Rahman, *BSc Ag (Hons)***
Scientific Officer
* Deputation for higher studies
** Joined GRSD, BRRI
*** Appointed as Director (Research) , BRRI

Grain Quality and Nutrition Division
Muhammad Ali Siddiquee, *PhD*
Chief Scientific Officer and Head
Md Anwarul Haque, *PhD*
Principal Scientific Officer
Sharifa Sultana Dipti, *PhD*
Principal Scientific Officer
Nilufa Ferdous, *PhD*
Senior Scientific Officer
Tapash Kumar Sarkar, *PhD*
Senior Scientific Officer
Habibul Bari Shozib, *PhD*
Senior Scientific Officer
Shakir Hosen, *MS*
Senior Scientific Officer
Md Rubel Akanda, *MS*
Scientific Officer
* On deputation for higher study

Hybrid Rice Division
Md Jamil Hasan, *PhD*
Principal Scientific Officer & PD
Md Shafiqul Islam, *PhD*
Principal Scientific Officer & Head
Ashish Kumar Paul, *MS*
Senior Scientific Officer
Priya Lal Biswas, *PhD*
Senior Scientific Officer
Mosammat Umma Kulsum, *PhD*
Senior Scientific Officer
Afsana Ansari, *PhD*
Senior Scientific Officer
Anowara Akter, *PhD*
Senior Scientific Officer
Md. Hafizar Rahman, *PhD*
Scientific Officer
Laila Ferdousi Lipi, *MS**
Scientific Officer

Md Ruhul Quddus, *MS**
Scientific Officer
Farhana Rahman Shurovi, *MS*
Scientific Officer
Mithun Chandra Debsharma, *MS*
Scientific Officer
Md Solaiman Hossian, *MS*
Scientific Officer
* Deputation for in-Country PhD programme

Agronomy Division
Md Shahidul Islam, *PhD*
Chief Scientific Officer and Head
Md Abu Bakar Siddique Sarker, *PhD*
Principal Scientific Officer
Md Khairul Alam Bhuiyan, *PhD*
Principal Scientific Officer
Shah Ashadul Islam
Senior Scientific Officer
Rakiba Shultana, *PhD*
Senior Scientific Officer
Amena Sultana, *PhD*
Senior Scientific Officer
Nasima Akhter, *PhD*
Senior Scientific Officer
Md Masud Rana, *PhD*
Senior Scientific Officer
Md Zakaria Ibne Baki
Senior Scientific Officer
Md Mostafa Mahbub
Senior Scientific Officer
Romana Akter
Scientific Officer

Soil Science Division
Aminul Islam, *PhD*
Chief Scientific Officer
Md Rafiqul Islam, *PhD*[2]
Chief Scientific Officer
Umme Aminun Naher, *PhD*
Principal Scientific Officer
Muhammed Sajidur Rahman, *PhD*[2]
Principal Scientific Officer
A T M Sakhawat Hossain, *PhD*
Principal Scientific Officer
Fahmida Rahman, *PhD*
Senior Scientific Officer
Masuda Akter, *PhD*
Senior Scientific Officer
S M Mofijul Islam, *PhD*
Senior Scientific Officer
Mosud Iqbal, *PhD*
Senior Scientific Officer
Md Nazrul Islam, *MS*[1]
Senior Scientific Officer
Md Imran Ullah Sarkar, *MS*[1]
Senior Scientific Officer
Farjana Alam, *MS*[1]
Scientific Officer
Afsana Jahan, *MS*
Scientific Officer
1On deputation for higher studies

Irrigation and Water Management Division
Md Towfiqul Islam, *PhD*
Chief Scientific Officer and Head
Md Maniruzzaman, *PhD*
Principal Scientific Officer and Head
Md Mahbubul Alam, *PhD*
Senior Scientific Officer
Shahana Parveen, *PhD*
Senior Scientific Officer
ABM Zahid Hossain, *PhD*
Senior Scientific Officer
Debjit Roy, *PhD*
Senior Scientific Officer
Mir Nurul Hasan Mahmud, *PhD*
Senior Scientific Officer
Priya Lal Chandra Paul, *PhD*
Senior Scientific Officer
Md Belal Hossain, *MS*
Senior Scientific Officer
Mst Shetara Yesmin, *MS*
Senior Scientific Officer
Md Hannan Ali, *MS**
Senior Scientific Officer
Palash Kumar Kundu, *MS*
Scientific Officer
Rezoan Bin Hafiz Pranto
Scientific Officer
*On deputation for higher studies

Plant Physiology Division
Mst Salma Pervin, *PhD*
Principal Scientific Officer and Head
Md Sazzadur Rahman, *PhD*
Principal Scientific Officer
Md Mamunur Rashid, *PhD*
Senior Scientific Officer
Hirendra Nath Barman, *PhD*
Senior Scientific Officer
Salma Akter, *MS*
Senior Scientific Officer
Tuhin Halder, *MS*
Scientific Officer
Avijit Biswas, *MS*
Scientific Officer

Entomology Division
Sheikh Shamiul Haque, *PhD*
Chief Scientific Officer and Head
Md Mofazzel Hossain. *PhD**
Chief Scientific Officer

Md Mosaddeque Hossain, *MS*
Principal Scientific Officer
Md Nazmul Bari, *PhD*
Principal Scientific Officer
Md Panna Ali, *PhD*
Senior Scientific Officer
Farzana Nowrin, *MS*
Senior Scientific Officer
Sadia Afrin, *MS*
Scientific Officer
Sanjida Akter, *MS***
Scientific Officer

*Joined from regional station on 29.07.21
**Joined from regional station on 10.01.22

Plant Pathology Division

Md Abdul Latif, *PhD*
Chief Scientific Officer and Head
Tahmid Hossain Ansari, *PhD*
Principal Scientific Officer
Quazi Shireen Akhter Jahan, *PhD*
Principal Scientific Officer
Mohammod Hossain, *PhD*
Principal Scientific Officer
Mohammad Salim Mian, *PhD*
Principal Scientific Officer
Mohammad Ashik Iqbal Khan, *PhD*
Principal Scientific Officer
Shamima Akter, *PhD*
Senior Scientific Officer
Md Rejwan Bhuiwan, *MS**
Senior Scientific Officer
Bodrun Nessa, *PhD*
Senior Scientific Officer
Montasir Ahmed, *MS**
Scientific Officer
Sheikh Arafat Islam Nihad, *MS*
Scientific Officer
Md Hasibur Rahaman Hera, *MS***
Scientific Officer
Rumana Akter, *MS*
Scientific Officer
Hosne Ara Dilzahan, *MS*
Scientific Officer

* Deputation for higher studies / Transferred to regional station
** Joined from regional station / after deputation

Rice Farming Systems Division

Muhammad Nasim, *PhD*
Chief Scientific Officer
Md Ibrahim, *PhD*
Principal Scientific Officer
Amina Khatun, *PhD*
Principal Scientific Officer
S M Shahidullah, *PhD*
Senior Scientific Officer
Md Khairul Quais, *PhD*
Senior Scientific Officer
Shila Pramanik, *PhD*
Senior Scientific Officer
Satyen Mondal, *PhD*
Senior Scientific Officer
ABM Jamiul Islam, *MS*
Senior Scientific Officer
Md. Asad-Uz-Zaman, *MS*
Senior Scientific Officer
Bir Jahangir Shirazy, *MS*
Senior Scientific Officer
ABM Mostafizur, *MS*
Scientific Officer
Lipiara Khatun, *MS*
Scientific Officer

Agricultural Economics Division

Md Saiful Islam, *MS, Head*
Principal Scientific Officer
Mohammad Ariful Islam, *PhD*
Senior Scientific Officer
Md Imran Omar, *MS**
Senior Scientific Officer
Md Abdur Rouf Sarkar, *MS**
Senior Scientific Officer
Mohammad Chhiddikur Rahman, *PhD*
Senior Scientific Officer
Afroza Chowdhury, *MS*
Senior Scientific Officer
Md Shajedur Rahaman, *MS*
Scientific Officer
Limon Deb, *MS*
Scientific Officer
S M Mehedy Hasan Noman, *MS*
Scientific Officer
Saida Akter Jui, *MS*
Scientific Officer

*PhD deputation

Agricultural Statistics Division

Md Ismail Hossain, *PhD*
Chief Scientific Officer and Head
Niaz Md Farhat Rahman, *MS*
Senior Scientific Officer
Md Abdul Qayum, *M. Phil*
Senior Scientific Officer
Md Abdullah Aziz, *MS*
Senior Scientific Officer
Md Abdullah Al Mamun, *MSc*
Scientific Officer
Md Shahnur Alam, *Diploma in Ag.*
Scientific Assistant

ICT Cell

S M Mostafizur Rahman, *BSc (Engg.)*
System Analyst
Md Mahfuz Bin Wahab, *MS*

Programmer
Kabita, *MSc*
Assistant Programmer
Rokib Ahmed, *MSc*
Data Analyst
Nuraiya Kulsum, *BSS*
Senior Data Entry / Control Operator
Md Aminuzzaman, *BSc*
Computer Assistant
Md Akhter Hossain, *MA*
Computer Assistant

Farm Management Division
Md Sirajul Islam, *MS*
Chief Scientific Officer and Head
Dr Md Mamunur Rahman, *PhD**
Senior Scientific Officer
Dr Mohammad Rezaul Manir, *PhD**
Senior Scientific Officer
Md Mamunur Rashid, *MS***
Senior Scientific Officer
Setara Begum, *MS*
Scientific Officer
Md Ayub Ali, Dip. in Agriculture
Farm Superintendent

* Joined on FMD, BRRI from regional station / higher study
** Deputation for higher Study

Farm Machinery and Postharvest Technology Division
Mohammed Abdur Rahman+, *PhD*
Chief Scientific Officer and Head
Md Durrul Huda, *PhD*
Chief Scientific Officer and Head
AKM Saiful Islam, *PhD*
Principal Scientific Officer
Md Golam Kibria Bhuiyan, *PhD*
Senior Scientific Officer
Md Anwar Hossen, *PhD*
Senior Scientific Officer
Mohammad Kamruzzaman Milon, *PhD*
Senior Scientific officer
Subrata Paul, *M. Engg.*
Senior Scientific officer
Md Ashraful Alam, *PhD***
Senior Scientific Officer
Md Kamruzzaman Pintu, *MS*
Senior Scientific officer
Sharmin Islam, *MS*
Agriculture Engineer
Haimonti Paul, *MS*
Agriculture Engineer
Md Monirul Islam, *MS*
Scientific Officer
Md Mizanur Rahman, *MS*
Scientific Officer
Md Mahir Shahriyar, *MS*
Scientific Officer
Arafat Ullah Khan, *MS**
Scientific Officer

Workshop Machinery and Maintenance Division
Biraj Kumar Biswas, *PhD*
Principle Scientific Officer and head
Md Golam Kibria Bhuiyan, *PhD*
Senior Scientific Officer and head
Bidhan Chandra Nath, *MS**
Senior Scientific Officer
Mohammad Afzal Hossain, *PhD*
Senior Scientific Officer
Hafizur Rahaman, *MS*
Scientific Officer
Md. Modud Ahmed, *MS**
Agriculture Engineer

*On deputation for higher study

Adaptive Research Division
Md Humayun Kabir, *PhD*
Chief Scientific Officer and Head
Md Atiqul Islam, *PhD*
Chief Scientific Officer (CC)
Md Rafiqul Islam, *PhD*
Principal Scientific Officer
Md Humayun Kabir, *PhD*
Senior Scientific Officer
Md Mamunur Rahman, *PhD***
Senior Scientific Officer
Shamsunnaher, *PhD*
Senior Scientific Officer
Afruz Zahan, *MS*
Senior Scientific Officer
Md Romel Biswash, *MS*
Scientific Officer
Mir Mehedi Hasan, *MS*
Scientific Officer
Md Niaz Morshed, *MS**
Scientific Officer
Khandakar Khalid Ahmed, *MS*
Scientific Officer

* Joined from BRRI RS, Sonagazi
** Transferred to Farm Division

Training Division
Md Shahadat Hossain, *PhD*
Chief Scientific Oficer and Head (C.C.)
Shahnaz Parveen, *PhD*
Senior Scientific Oficer

BRRI RS, Barishal
Md Alamgir Hossain, *PhD*
Chief Scientific Oficer and Head
Quazi Shireen Akhter Jahan, *PhD*
Principal Scientific Officer
Muhammad Sajidur Rahman, *PhD*
Principal Scientific Officer

Priya Lal Biswas, *PhD*
Senior Scientific Oficer
Mir Md Moniruzzaman Kabir, *MS*
Senior Scientific Oficer
Md. Abu Syed, *PhD*
Senior Scientific Oficer
Md. Hasibur Rahaman Hera, *MS*
Scientific Oficer
Aishik Debnath
Scientific Oficer
Tomalika Saha, *MS*
Scientific Oficer
Abu Sayem, *MS*
Scientific Oficer
Md. Suhel Mia, *MS*
Scientific Oficer
Md. Taharat Al Tauhid, *MS*
Scientific Oficer (TRB)
Mohammad Jahurol Haque Shamim, *Dip-in Ag.*
Assistant Farm Manager

BRRI RS, Bhanga
Mohammad Akhlasur Rahman, *PhD*
Principal Scientific Officer and Head
Md. Iftekhar Mahmud Akhand, *MS**
Senior Scientific Officer
Rajesh Barua, *MS**
Senior Scientific Officer
Tusher Chakrobarty, *MS*
Scientific Officer
Md Asadulla Al Galib, *MS*
Scientific Officer
Rowmika Jahan Promee, *MS*
Scientific Officer

BRRI RS, Cumilla
Aminul Islam, *PhD*
Chief Scientific Officer and Head
Md. Rafiqul Islam, *PhD*
Chief Scientific Officer
Mohammod Hossain, *PhD*
Principal Scientific Officer
Rakiba Sultana, *PhD*
Senior Scientific Officer
Md. Mamunur Rashid, *PhD*
Senior Scientific Officer
Faruk Hossain khan
Scientific Officer
AKM Shalahuddin
Scientific Officer
Tasnia Ferdous
Scientific Officer
Bijoya Saha
Scientific Officer
Israt Zahan
Scientific Officer (TRB)
Most. Nusrat Zahan
Scientific Officer (TRB)

BRRI RS, Habiganj
Md Mozammel Hoque, *PhD*
Senior Scientific Officer and Head
Md Rafiqul Islam, *PhD*
Senior Scientific Officer
Md Abu Syed, *PhD*
Senior Scientific Officer
Tuhin Halder, *MS*
Scientific Officer
Avijit Biswas, *MS*
Scientific Officer
Sanjida Akter, *MS*
Scientific Officer
Md Abu Nayeem, *BScAg (Hons)*
Scientific Officer
Md Shahin Alam, *MS*
Scientific Officer
Most Mahamuda Khatun, *BScAg (Hons)*
Scientific Officer

BRRI RS, Rajshahi
Md Fazlul Islam, *PhD*
Principal Scientific Officer and Head
Md Shafiqul Alam, *B Sc Ag (Hons)*
Senior Scientific Officer
Md Harun-Ar-Rashid, *PhD*
Senior Scientific Officer
ABM Anwar Uddin, *PhD*
Senior Scientific Officer
Md Rafiqul Islam[1], *PhD*
Senior Scientific Officer
Md Abu Syed*[2], *PhD*
Senior Scientific Officer
Anjuman Ara, *MS*
Senior Scientific Officer
Fahamida Akter[3], *MS*
Scientific Officer

1 Joined BRRI RS, Rajshahi on 3 Mar 2022
2 Joined BRRI RS, Rajshahi on 22 Nov 2021 and transferred to BRRI RS Habiganj on 3 Feb 2022
3 Deputation for PhD programme on 6 Feb 2022

BRRI RS, Rangpur
Md Rokebul Hasan, *PhD*
Senior Scientific Officer and Head
Shila Pramanik, *MS*
*Senior Scientific Officer**
Anowara Akhter, *MS*
*Senior Scientific Officer **
Lipi Ara Khatun, *MS*
*Scientific Officer**
Tapon Kumar Roy, *MS*
Scientific Officer
Md Khalid Hasan Tarek, *MS*
*Scientific Officer**

Md Solaiman Hossain, *MS*
*Scientific Officer**
Wazifa Afrin, *MS*
*Scientific Officer**
Md Anisar Rahman, *MS*
Scientific Officer (TRB)

*Joined BRRI RS Rangpur

BRRI RS, Satkhira
Tahmid Hossain Ansari, *PhD**
Chief Scientific Officer and Head
S.M. Mofijul Islam, *PhD***
Senior Scientific Officer
Md Imran Ullah Sarkar, *MS****
Senior Scientific Officer
Md. Asif Rahman, *MS*
Scientific Officer
Md Amanut Ullah Razu, *PhD*
Scientific Officer
Tamal Patra Shuvo, *MS*****
Scientific Officer
Md. Nahidul Islam Nahid, *MS*****
Scientific Officer
Tahmina Akter, *MS*****
Scientific Officer
Afroza Awal Shoily
Scientific Officer, TRB

*Joined on 15 February, 2022
**Transferred on 14 February, 2022
***Transferred on 15 December, 2021
****Joined on 05 December, 2021

BRRI RS, Sonagazi
Biswajit Karmakar, *PhD*
Principal Scientific Officer and Head
Md Nayeem Ahmed, *MS*
Senior Scientific Officer
Md Adil, *MS*
Senior Scientific Officer
Md Niaz Morshed, *MS*
Scientific Officer
Md Rashid Shahriar Ripon, *MS*
Scientific Officer
Md Raihan Uddin, *MS*
Scientific Officer
Md Asib Biswas, *MS*
Scientific Officer
Md Ariful Islam Khalid, *MS*
Scientific Officer
Md Al-Imran Hasan, *MS*
Scientific Officer
Tanzila Ferdous, *MS*
Scientific Officer
Sania Tamanna, *B.Sc. (Ag.)*
Scientific Officer
Md Zahirul Haque
Farm Manager

* On deputation for higher Studies
** Transferred to BRRI Gazipur

BRRI RS, Kushtia
Md Mahbubur Rahman Dewan, *MS*
Senior Scientific Officer and Head
Md Eftekhar Uddin, *MS*
Scientific Officer
Mohammad Rezoan Bin Hafiz Pranto, *MS*[1]
Scientific Officer
Md Masud Rana *MS*[3*]
Scientific Officer
Kh Dil Afroze, *MS*[3*]
Scientific Officer
Nahida Akter, *MS*[3*]
Scientific Officer

1Transferred to Head Office on 17-10-2021, 2 joining on 22-11-2021, 3* joining on 05-12-2022

BRRI RS, Sirajganj
Md Adil Badshah, *PhD*
*Principal Scientific Officer and and Head**
Md Saidee Rahman, *MS*
Scientific Officer
S M M Shahriar Tonmoy, *MS*
Scientific Officer
Samia Lutfa Hasan, *MS*
*Scientific Officer***
Nymphaea Parveen, *MS*
*Scientific Officer***
Tanzila Ferdous, *MS*
*Scientific Officer ***
Md. Sajal Miah, *Dip. in Ag*
*Assistant Farm Manager ****
Md. Oli Ahmed Arif, *Dip. in Ag.*
*Scientific Assistant*****

*Deputed from BRRI HQ as Head in Charge
**Newly appointed
***Transfered from BRRI RS
****Transfered to BRRI RS

BRRI RS, Gopalganj
Md Khairul Alam Bhuiyan, *PhD**
Principal Scientific Officer & Head
Mohammad Zahidul Islam, *PhD*
Senior Scientific Officer & Head
*Md Saidee Rahman, MS**
Scientific Officer & Head

*Transferred

---

* Abroad for higher studies
+ On deputation outside BRRI
*+ On deputation for higher studies
** Transferred
*** Joined BRRI
++ Resigned from BRRI

Weather information

Weather is the state of the atmosphere, describing for example the degree to which it is hot or cold, wet or dry, calm or stormy, clear or cloudy. We present here the available weather parameters *viz* maximum and minimum temperature (^0C), rainfall (mm), evaporation (mm), humidity (mostly 9 am and 2pm), sunshine hours (hours/day) and solar radiation ($Cal/cm^2/day$) during the experimental year (July 2019 – June 2020) as recorded from BRRI headquarter and seven regional stations Rangpur, Barishal, Habiganj, Bhanga, Rajshahi, Sonagazi and Cumilla by Plant Physiology Division.

Temperature. Monthly average maximum temperature was quite high during April and August in most of the stations. It was the highest in August at Cumilla (35.9)^0C followed by Habiganj (34.7^0C), Gazipur (33.78^0C) and Rangpur (32.6^0C). On the other hand, highest monthly average maximum temperature was recorded in April at Rajshahi (34.73^0C) followed by Bhanga (34.17^0C) and Barishal (32.98^0C), while it was in September at Sonagazi (32.4^0C). Mean minimum temperature was the lowest in January for all the stations. The lowest temperature (11.2^0C) was recorded during January in Rangpur (Fig. 1).

Rainfall and pan evaporation. During the reporting period, the highest rainfall was occurred in July followed by June, May, September, August, April and October. Other months had little rainfall except in February when there was no rainfall. Total rainfall was the highest at Habiganj (2172 mm) during the reported year. It was the lowest in Rajshahi (1200 mm). Irrespective of station, the highest pan evaporation was recorded in April but it was the lowest in January (Fig. 2).

Solar radiation and solar hours. The highest solar hour/day was recorded in March due to clear sky in all stations. On the contrary, it was the lowest in July due to cloudy sky in most of the stations. The solar radiation is directly proportional to the solar hour. So, the highest solar radiation was recorded in the month march for all the station except Rangpur where it was in August. The lowest solar radiation was found in January in all the stations (Fig. 3).

Relative humidity. Relative humidity was higher in June to September and then it decreased. It was found the lowest during February to March. Relative humidity was higher at morning but decreased gradually till noon. (Fig. 4).

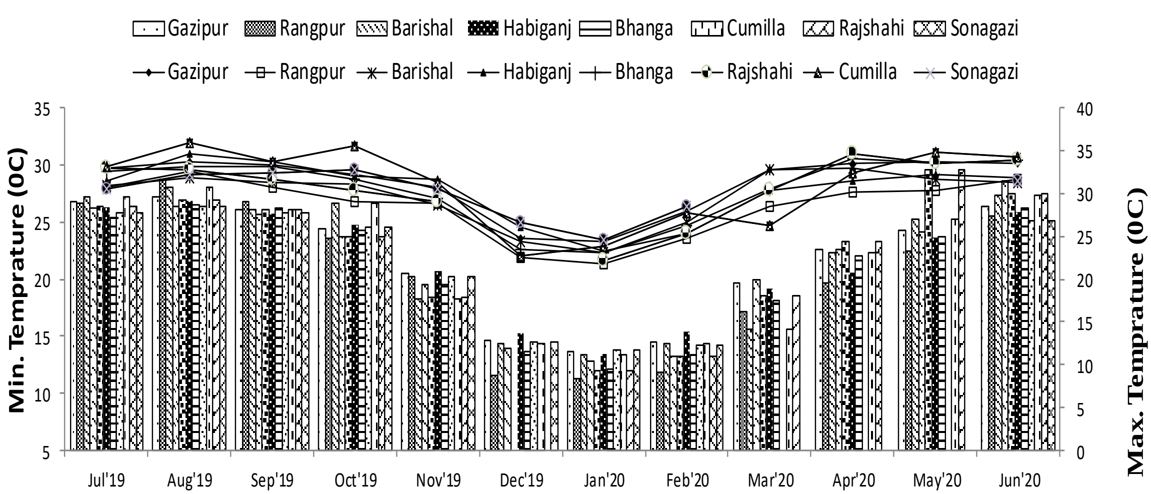


Fig. 1. Maximum and minimum temperature of eight different stations of BRRI during the period of July 2019 to June 2020. Bar and line graph show minimum and maximum temperature respectively.

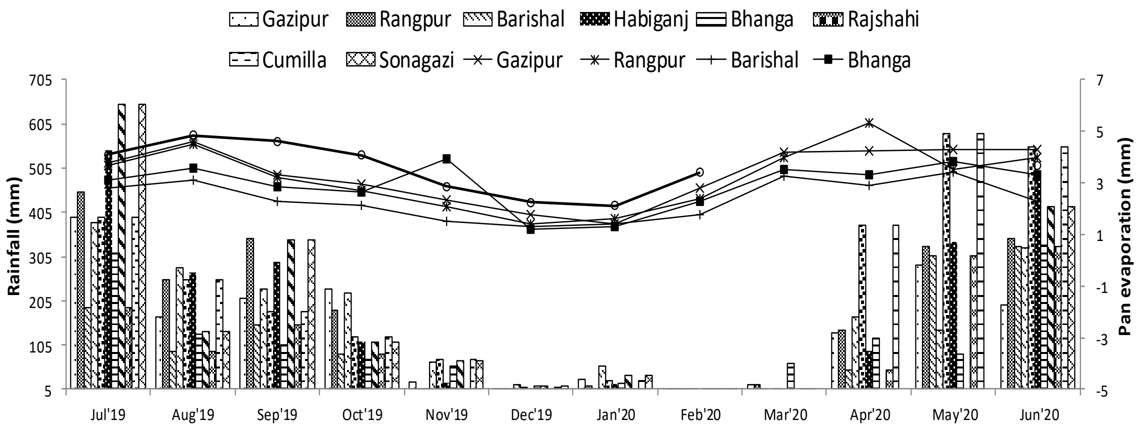


Fig. 2. Rainfall at eight stations and pan evaporation at five stations of BRRI during the period of July 2019 to June 2020. Bar and line graph show rainfall and pan evaporation respectively.

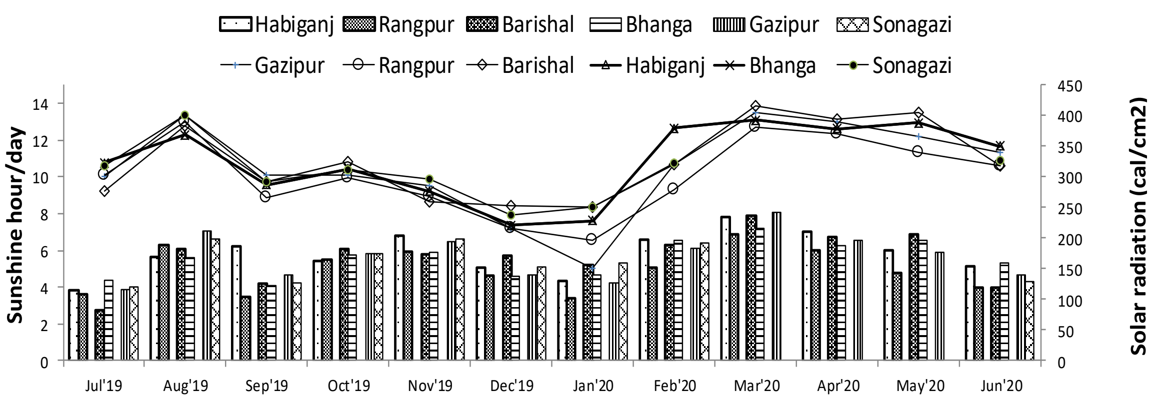


Fig. 3. Sunshine hour and solar radiation of six different stations of BRRI during the period of July 2019 to June 2020. Bar and line graph show sunshine hour and solar radiation respectively.

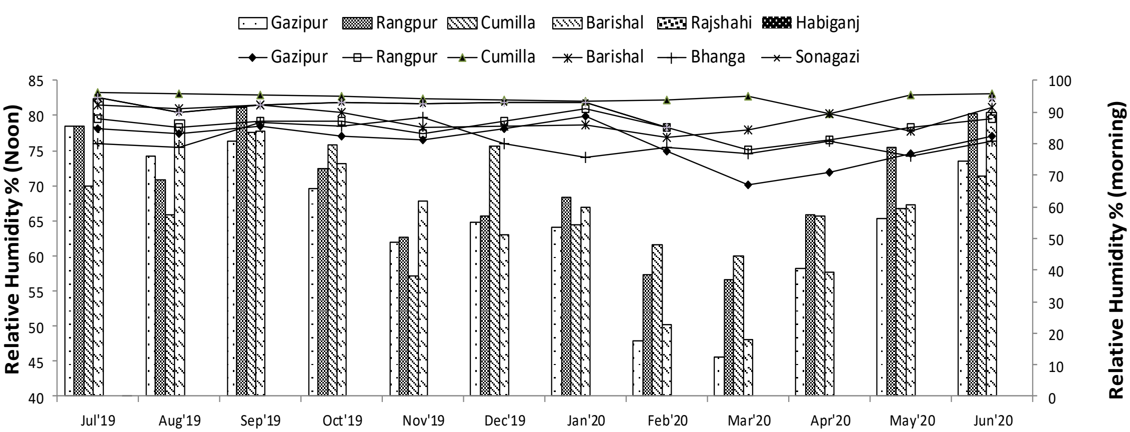


Fig. 4. Relative humidity at morning of six stations and at noon of five stations of BRRI during the period of July 2018 to June 2019. Bar and line graph show relative humidity at noon and morning respectively.

Abbreviation and acronyms

AEZ	=	agroecological zone
ALART	=	advanced line adaptive research trial
ARIMA	=	auto regressive integrated moving average
As	=	arsenic
AT	=	active tillering
AWD	=	alternate wetting and drying
AYT	=	advanced yield trial
B. Aman	=	broadcast Aman
BADC	=	Bangladesh Agricultural Development Corporation
B. Aus	=	broadcast Aus (upland rice)
Bak	=	bakanae
BARI	=	Bangladesh Agriculture Research Institute
BB	=	bacterial blight
B	=	Blast
BC	=	back cross
BCR	=	benefit-cost-ratio
BI	=	blast
BLB	=	bacterial leaf blight
BINA	=	Bangladesh Institute of Nuclear Agriculture
BMDA	=	Barind Multi Purpose Development Authority
BPH	=	brown plant hopper
BR	=	Bangladesh rice
BS	=	breeder seed
BRRI	=	Bangladesh Rice Research Institute
BWDB	=	Bangladesh Water Development Board
BShB	=	bacterial sheath blight
CAB	=	Commonwealth Agriculture Bureau
ck	=	check
cm	=	centimetre
CDB	=	Carabid beetle
CMS	=	cytoplasmic male sterile
CV	=	common variance, co-efficient of variation
DAE	=	Department of Agricultural Extension (Bangladesh)
DAP	=	drought animal power
DAS	=	days after seeding
DAT	=	days after transplanting
DH	=	dead heart
DHB	=	dark-headed borer
DMRT	=	Duncan’s multiple range test
DNA	=	deoxyribonucleic acid
DNI	=	Direct normal irradiance
DHI	=	Diffuse horizontal irradiance
DTF	=	days to flowering
DWSR	=	Direct wet seeded rice
DWR	=	deepwater rice
ET	=	evapotranspiration
FS	=	foundation seed

FMPHT	=	Farm Machinery and Postharvest Technology
GABA	=	gamma amino buteric acid
GH	=	grasshopper
GM	=	gall midge
GMB	=	green mirid bug
GLH	=	green leafhopper
GoB	=	Government of Bangladesh
GRS	=	Genetic Resources and Seed
GSR	=	green super rice
GQN	=	Grain Quality and Nutrition
HA	=	Habiganj Aman
HAT	=	hours after treatment
HB	=	Habiganj Boro
HNRP	=	Hill Nerica Rice Productivity
ht	=	height
IIRON	=	International Irrigated Rice Observational Nursery
INGER	=	International Network for Genetic Evaluation of Rice
INM	=	integrated nutrient management
IPM	=	integrated pest management
IPNS	=	integrated plant nutrition system
IRRI	=	International Rice Research Institute (Philippines)
IRSSTN	=	International Rice Soil Stress Tolerance Nursery
IURON	=	International Upland Rice Observational Nursery
LCC	=	leaf colour chart
LBB	=	lady bird beetle
LHC	=	long-horned cricket
Lit/ha	=	litre per hectare
LR	=	leaf roller
LSc	=	leaf scald
LSD	=	least significant difference
LV	=	local variety
LIV	=	local improved variety
MAS	=	marker assisted selection
MER	=	micronutrient enriched rice
ML	=	monogenic line
MLT	=	multi-location trial
MMT	=	million metric tons
MR	=	moderately resistant
MT	=	maximum tillering
MV	=	modern variety
meq	=	milli equivalent
NGO	=	non-government organization
NIL	=	near isogenic line
NIR	=	net irrigation requirement
NSB	=	National Seed Board (Bangladesh)
OC	=	oil cake
OHLH	=	orange headed leafhopper
OT	=	observational trial
OYT	=	observational yield trial
PAcp	=	phenotypic acceptance

PI	=	panicle initiation
PQR	=	premium quality rice
PVART	=	proposed variety adaptive research trial
PVS	=	participatory varietal selection
PVT	=	proposed variety trial
PYT	=	preliminary yield trial
QTL	=	quantitative trait loci
RCB design	=	randomized complete block design
RF	=	rainfall
RH	=	rice hispa
RLF	=	rice leaf folder
RLR	=	rice leaf roller
RPT	=	rice production training
RS	=	Regional station
RTV	=	rice tungro virus
RWM	=	rice whorl maggot
RWS	=	relative water supply
RYT	=	regional yield trial
SAAO	=	Sub Assistant Agricultural Officer
SB	=	stem borer
SCA	=	Seed Certification Agency (Bangladesh)
SD	=	standard deviation
SES	=	standard evaluation system
ShB	=	sheath blight
ShR	=	sheath rot
SPDP	=	seed production and dissemination trial
SPIRA	=	Strengthening Physical Infrastructure and Research Activities
SR	=	solar radiation, stem rot
STB	=	soil test based
STPD	=	staphylinid
SYT	=	secondary yield trial
T. Aman	=	transplanted Aman
T. Aus	=	transplanted Aus
TGW	=	1000-grain weight
TLS	=	truthfully labelled seed
TOC	=	Training and operation cell
TRB	=	Transforming Rice Breeding
TSP	=	triple super phosphate
USG	=	urea super granule
WMM	=	Workshop Machinery and Maintenance
WBPH	=	white-backed plant hopper
WS	=	wet season
WSR	=	wet-seeded rice
WTR	=	weed tolerant rice
wt	=	weight
YSB	=	yellow stem borer

Plant Breeding Division

SUMMARY

For the development of rice varieties under different ecosystems 587 crosses were made and 533 crosses were confirmed during 2021-22. In pedigree nursery, 32,295 individual plants were selected from F_2 to F_6 generations based on phenotypic performances of segregating progenies of each cross and 37 fixed lines were bulked. A total of 5,64,725 individual plants were advanced from F_{2-6} generation following single seed decent (SSD) method under rapid generation advanced (RGA) condition. From line-stage testing (LST), 19,024 genotypes were selected based on yield and other agronomic performances. A total of 1,229 genotypes from observational yield trial (OYT) and 593 advanced breeding lines were selected from yield trials (PYT, SYT, AYT, RYT and PVT). A total of 33 germplasm from different biotic and abiotic screening nurseries were selected to use as parents in the breeding programme.

National Seed Board (NSB) of Bangladesh has released two promising genotypes *viz* BR8938-19-4-3-1-1-P2-HR3 and IR99285-1-1-1-P2 as BRRI dhan101 and BRRI dhan102, respectively for cultivation throughout the country in Boro season on 18 January 2022. BRRI dhan101 produced 0.33 t/ha higher yield than the popular check variety BRRI dhan58 (7.39 t/ha) with 142 days growth duration. The variety BRRI dhan101 showed strong resistance to BB (BB score-1) under artificial inoculation with virulent BB pathogens. QTL fingerprinting with functional SNP markers for the BB resistance detected three dominant BB resistant genes *Xa4, Xa7* and *Xa21* in this variety. The average yield of zinc enriched variety BRRI dhan102 was 8.11 t/ha with 150 days growth duration and zinc content of the milled rice was 25.5 mg/kg which was higher than that of BRRI dhan29 (18.2 mg/kg).

VARIETY DEVELOPMENT

Development of upland rice (B. Aus). Efforts were made to develop upland rice varieties with multiple traits viz quick seedling emergence, vigorous growth, short growth duration (90-100 days); tolerance to lodging and drought and pre-harvest sprouting tolerance; medium bold to medium slender grains and good eating quality. In 2021-22, seven crosses were made using 11 parents. Out of 20, eight crosses were confirmed as true F_1. A total of 9,360 progenies obtained from 14 crosses of F_5 generation were advanced through field RGA (Rapid generation advance). Out of 2,830 lines, a total of 207 breeding lines comprising 21 crosses were selected from LST lines based on identical flowering, grain type traits and phenotypic acceptability under field condition. Twenty nine entries were selected considering growth duration, yield, uniformity of morpho-agronomic traits and superiority in one or more traits over the standard checks from 176 advanced breeding lines in OYT. Three genotypes such as BR11274-B-35-1-36, BR11274-B-11-1-16 and BR11262-B-109-3-47 were selected from five tested entries on the basis of yield and short growth duration in PYT. Five genotypes viz BR10756-2B-8-72, BR10759-2B-11-3, BR10418-32-1-58, BR10417-15-2-11 and BR10409-15-2-8 were selected from eight tested entries in SYT.

Improvement of jhum rice under upland rice programme was implemented to develop high yielding rice variety with low (10-19%) to high (>25%) grain amylose content and drought tolerance along with good eating quality for jhum cultivation acceptable to tribal population of Chattogram hill districts. Seven crosses were made involving10 parents including four local Jhum cultivars, two exotic varieties, single BRRI variety and three advanced breeding lines having low to intermediate level amylose content. Six crosses out of 15 were confirmed as true F_1. Seventeen F_2 population were grown for generation advance through field RGA (Rapid generation advance). A total of 18,970 progenies obtained from 17 crosses of F_3 generation were advanced through field RGA. Fourteen, eight and eight entries from 31 entries in OYT#1, 18 entries in OYT#2 and nine entries in OYT#3 were selected, respectively. Six out of 15 entries and four out of nine entries were selected in preliminary yield trial (PYT#1 and PYT#2), respectively. Five out of eight entries were selected in SYT. Farmers chose chinese rice variety (Luyin 46) AYT (Advanced yield trial) in hills of three upazilas of two hill districts i.e. Khagrachari and Bandarban having about half t/ha yield advantage over the local cultivar Mongthongno (**Table 1**) along with medium slender grain, dense panicle, lodging and drought tolerance, high amylose content with light aroma.

Table 1. Yield, agronomic performance and physico-chemical properties of the genotypes in AYT, development of Jhum rice, B. Aus 2021-22.

Genotype	GD (day)	Yield (t/ha)	Amylose content (%)	Protein content (%)	Head rice recovery (%)	Size & Shape	ER	IR
Chinese rice	114	2.2	26.0	7.0	23	MS	1.5	3.7
Koshihikari	106	0.9	17.8	8.2	28	SR	1.8	3.1
Japanese black rice	126	1.7	10.9	10.3	50	LB	1.2	4.2
Mongthongno	107	1.6	22.8	8.1	51	LB	1.2	4.3
BRRI dhan83 (ck)	111	2.6	26.6	7.7	46	MB	1.4	4.5
Gunda (Local check)	119	1.9	23.1	7.1	58	MB	1.4	3.6
LSD	2.8	0.5						
Heritability	0.94	0.9						

ER-Elongation ratio IR-Imbibition ratio

Investigators: M A Hossain and N Jahan

Development of transplanted Aus rice (T. Aus). The project was aimed to develop short duration (105-110 days), high yield potential genotypes having tolerance to lodging and heat (high temperature) at the reproductive phase, pre-harvest sprouting and good grain quality. In total, 20 crosses were made using 35 parents and 5,348 F_1 seeds were obtained; 29 crosses were confirmed as true F_1; 18270 progenies of 37 crosses in T. Aus season were advanced through modified field rapid generation advance (FRGA) technique. Out of 12,491 lines of 39 crosses, 792 uniform lines were identified from LST based on uniformity in heading, plant height, and acceptable grain type in the field condition. Finally, 713 fixed lines were selected from 792 lines on the basis of trait genotyping with 12-SNP indica panel. Ninety-three genotypes were selected from 384 entries from observational yield trial (OYT), ten advanced lines out of 37 from PYT were selected for T. Aus growing areas of Bangladesh on the basis of homogeneity with respect to plant height, phenotypic acceptability at vegetative and maturity stages and physicochemical properties. With respect to performance in ALART, one genotype BR8781-16-1-3-P2 was recommended for PVT for non-saline tidal condition of Bangladesh (**Table 2**). The promising genotype BR9006-40-2-3-1 was evaluated along with the check variety BRRI dhan48 under PVT in ten locations of T. Aus growing areas of Bangladesh.

Improvement of rice for shallow flooded and deep water environment. The major objectives of the this project were to develop high yielding (4.0-5.0 t/ha) rice varieties for deep (>1.0 m), shallow flooded area (up to 1.0 m depth), shallow deep area (30 cm water) and medium deep area (50-60 cm water) along with submergence, facultative elongation and hypoxia tolerance. Seventeen crosses were made by using 20 parents and produced 1,413 F_1 seeds. In total 25 F_1 crosses were confirmed through QC SNP panel analysis. A total of 3,748 progenies of 19 F_2 crosses, 3,541 progenies of 20 F_3 crosses, 2001 progenies of 18 F_4 crosses were advanced through RGA. In yield trials, 15 genotypes were selected out of 30 genotypes. In OYT the genotype BR10211-22-9-2_PS4 produced the highest yield (2.6 t/ha) which is significantly higher than the check variety BRRI dhan91 (1.4 t/ha) whereas in PYT the genotype

Table 2. Agronomic performance of the advanced lines under advanced line adaptive research trial (ALART), T. Aus 2021-22.

Designation	GD	PH	Yield (t/ha)							
			L1	L2	L3	L4	L5	L6	L7	Avg.
BR8784-4-1-2-P2	123	119	3.03	4.58	4.23	5.46	4.47	4.65	4.02	4.35
BR8781-16-1-3-P2	121	114	3.84	**5.53**	5.00	5.43	4.72	5.51	3.94	**4.85**
BRRI dhan27 (Ck)	118	137	3.21	4.02	3.88	4.79	3.77	4.12	4.09	3.98
BRRI dhan48 (Ck)	114	108	3.09	5.47	4.86	5.36	4.86	5.49	4.49	4.80
LSD(0.05)					**0.46**					**0.18**

*Mean of seven locations GD-Growth duration PH-Plant height

Locations : L1=Barguna (Nilganj, Amtali), L2= Barguna (Nilganj, Amtali), L3=Patuakhali (Kalapara), L4= Barguna (Taltoli),L5=Pirojpur (Kuakhali), L6= Mirsori (Chattogram), L7= BRRI Gazipur

Investigators: M Khatun, S K Debsharma and J Ferdousy

BR10260-7-19-2B (3.8 t/h) produced highest yield which was significantly higher than the check variety BRRI dhan91 (1.7 t/ha). In SYT, two tall advanced breeding lines (stagnant water, 50-90 cm) were evaluated. The breeding lines BR9377-21-3B (5.9 t/ha) and BR9396-6-2-2B (5.4 t/ha) with BRRI dhan91 (4.7 t/ha) performed better than Fulkori (2.6 t/ha) as checks. Six RYT breeding materials under direct seeded deep flooded (100-150 cm water depth) condition was evaluated. The genotypes BR10230-7-19-2B (2.5 t/ha), BR9892-6-2-2B (2.8 t/ha), BR9376-6-2-2B (2.9 t/ha), BR9392-6-2-1B (3.0 t/ha), BR-KM (Mun)-PL-5-7-3-B (2.9 t ha), BR-DL(Hbj)-PL-12-4-7-B (3.2 t/ha) performed better than the local check Fulkori (2.4 t/ha). ALART for shallow deep (50-100 cm) flooded areas were conducted in five locations, two advanced genotypes BRBR9390-6-2-1B (3.4 t/ha) and BR10260-5-15-21-6B (4.5 t/ha) produced better yield than the standard check BRRI dhan91 (2.35 t/ha). The genotypes were characterized with moderate elongation and better yield than the check variety. Notably, BR9390-6-2-1B was found as strongly photoperiod sensitive, BR10260-5-15-21-6B and BRRI dhan91 were moderately photoperiod sensitive.

Performance of main and ratoon crops of F_1 and their parents in respect to perennial growth habit in rice was evaluated in B. Aman 2021-22. Development of a robust tall rice variety BRRI dhan91 having perennial growth has opened the door of breeding for better ratooning ability in inbred and hybrid rice. A basic study was conducted to evaluate the perennial growth habit or superior vegetative ratooning performance in modern rice. The objectives of the studies were to evaluate ratooning performance under standard ratoon system (10 cm stubbles remain after harvest) compared to main crops of perennial BRRI dhan91, non-perennial BRH11-9-11-4-5B (CN6) and their hybrid. Bio-chemical analysis showed that stem of BRRI dhan91 contained three times more starch than BRH11-9-11-4-5B indicating its more energy storage capacity for better ratooning ability. In this study, main crop did not die after harvest, new tillers originated from dormant buds of stubbles provided a second crop as taller as like main crop, yield was same as main crop with almost same growth duration.

Investigators: Sharmistha Ghosal, A S M Masuduzzaman, Z A Riyadh, N Jahan and K M Iftekharuddaula

Development of rainfed lowland rice (RLR). The project aims to develop genotypes superior to standard varieties and adaptable to rainfed lowland environment in T. Aman season. In T. Aman, 7,442 F_1 seeds were obtained from 37 single crosses and 23 crosses were confirmed as true hybrid using 10-SNP *indica* QC panel. A total of 7,506 individual progenies of 32 crosses from F_3-F_5 generations were harvested through RGA method in T. Aman season. In Boro 2021-22, 8,666 progenies were harvested from 27 crosses from F_2 and F_4 generations through RGA method. A total 507 genotypes were selected from 10,333 progenies of line stage testing (LST) trial. Figure 1 and 2 present the selection intensity and trait marker profile of the genotypes of LST. A total of 699 genotypes were evaluated in four observation yield trials (OYTs) in Gazipur, Cumilla and Rangpur. Among the tested genotypes 60 genotypes were selected for Advanced Yield Trial (AYT). Out of the preliminary yield trials (PYT) consisting seven tested genotypes, three were advanced for secondary yield trial (SYT) based on grain yield. Only one genotype was selected from five genotypes of regional yield trial (RYT). Three genotypes were selected for retrial in RYT.

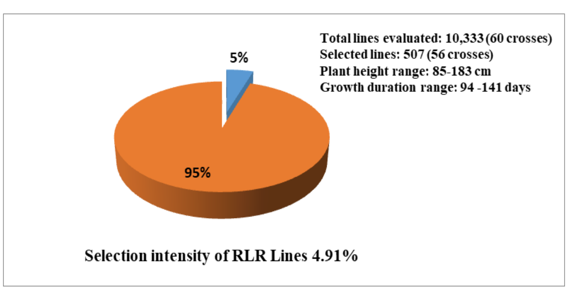


Fig. 1. Selection intensity in the genotypes of LST, RLR, T.

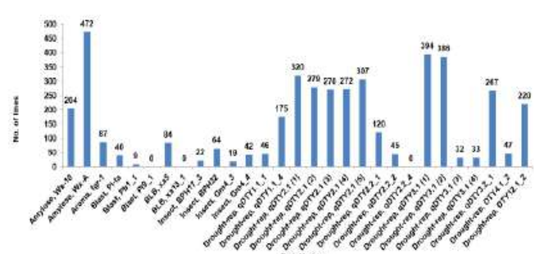


Fig. 2. Trait marker profile of the genotypes of LST, RLR, TA

Investigators: M A Kader, R R Majumder, U R Shaha and K Fatema

Development of high yielding superior variety (SHR). Three SYT trials were performed during T. Aman 2021-22. Secondary yield trial (SYT-Short Slender) under recommended management practices was performed to evaluate the yield potential of short slender grain type materials in comparison with BRRI dhan49. Three materials viz, BRH13-2-14-2-1B (5.5 t/ha), BRH17-23-8-2-7B (5.0 t/ha) and BRH13-7-9-3-2B (5.2 t/ha) were selected compared to BRRI dhan49 (4.9 t/ha). Secondary yield trial (SYT-Swarna and long slender type) under recommended management practices was performed to evaluate the yield potential of Swarna and long slender grain type materials. The breeding materials BRH9392-6-2-1-3-4 (5.7 /tha), BR9396-6-2-2B (5.4 t/ha), BR9392-10-20-1B (5.6 t/ha), BRH11-2-4-7B (5.5 t/ha) were selected for their better yield than the check variety BRRI dhan87 (5.3 t/ha). Secondary yield trial (SYT- Zirashail type) under recommended management practices was performed for evaluating yield potential of Zirashail grain type materials (early transplanting by mid-July) season in representative areas. The breeding materials BRH11-7-17-10B (5.2 t/ha), BRH13-9-5-3B (4.9 t/ha), BRH9-3-14-2B (4.9 t/ha) were selected compared to Zirashail (4.2 t/ha).

Development of rice varieties for favourable Boro environment. The aim of this project was to develop improved genotypes with high yield potential (≥8.0 t/ha), earliness (135-145 days) and accepted grain quality for favourable irrigated ecosystem in Bangladesh.

Twenty-four crosses were made using 24 promising lines/varieties as parents targeting to develop high yielding breeding lines enriched with favourable alleles of key target traits, viz. disease resistance (blast and BLB), insect resistance (BPH) and acceptable grain quality (amylose, chalkiness, palatability, zinc content, etc). Twenty-one crosses were confirmed as true F_1 through a hybridity test using QC SNP genotyping. In total 20,692 individual progenies from 72 cross combinations of F_2-F_5 generations were advanced in the RGA nurseries following single seed decent method of breeding. Out of 1,919 lines tested in LST, 415 uniform lines in terms of plant height, days to flowering, grain size and shape were selected based on the presence of the favourable alleles of key target genes for BB (*xa5*, *xa13* and *Xa21*), blast (*Pi9*, *Pita*, *Pita2* and *Pb1*) and BPH (*Bph17* and *BPH32*) resistance, cold tolerance (*qSCT1*, *qPSST3, qPSST6, qPSST7 and qPSST9), grain quality (Wx-a, Wx-10, chalk5, BADH2*) **(Fig. 3)**.

Thirty-three genotypes out of 558 fixed lines tested in four locations following sparse testing model of genomic selection in OYT were selected based on genomic BLUP for yield. Genomic BLUP values were estimated using genome-wide genotyping data and phenotypic values for yield of training population tested at MLT sites. Figure 4 shows the scattered plots of breeding lines tested at specific sites for standardized mean values (BLUES) and growth duration of the breeding lines indicating that a big chunk of medium duration (145 -155 days) having yield potential more than 7.0 t/ha have been isolated from the OYT. Seventy-nine breeding lines were tested in advanced yield trial (AYT) at three locations under three categories, AYT_Early, AYT_late and AYT_AGGRiNet. In AYT_Early, five genotypes out of 32 entries showing around 0.40-0.80 t/ha yield advantage with similar growth duration over the check variety BRRI dhan96 were selected (**Table 3**). From AYT_Late, two genotypes showing almost similar yield but 5-7 days shorter growth duration compared to the check variety BRRI dhan89 were selected (**Table 4**). Three genotypes produced 1.02-1.45 t/ha yield advantage with 3-5 days shorter growth duration compared to the check variety BRRI dhan81 and the genotype IR18A1398 showed the highest yield 8.52 t/ha with similar growth duration to BRRI dhan89 (7.46 t/ha), were selected from 17 tested entries in AYT_AGGRiNET (**Table 5**).

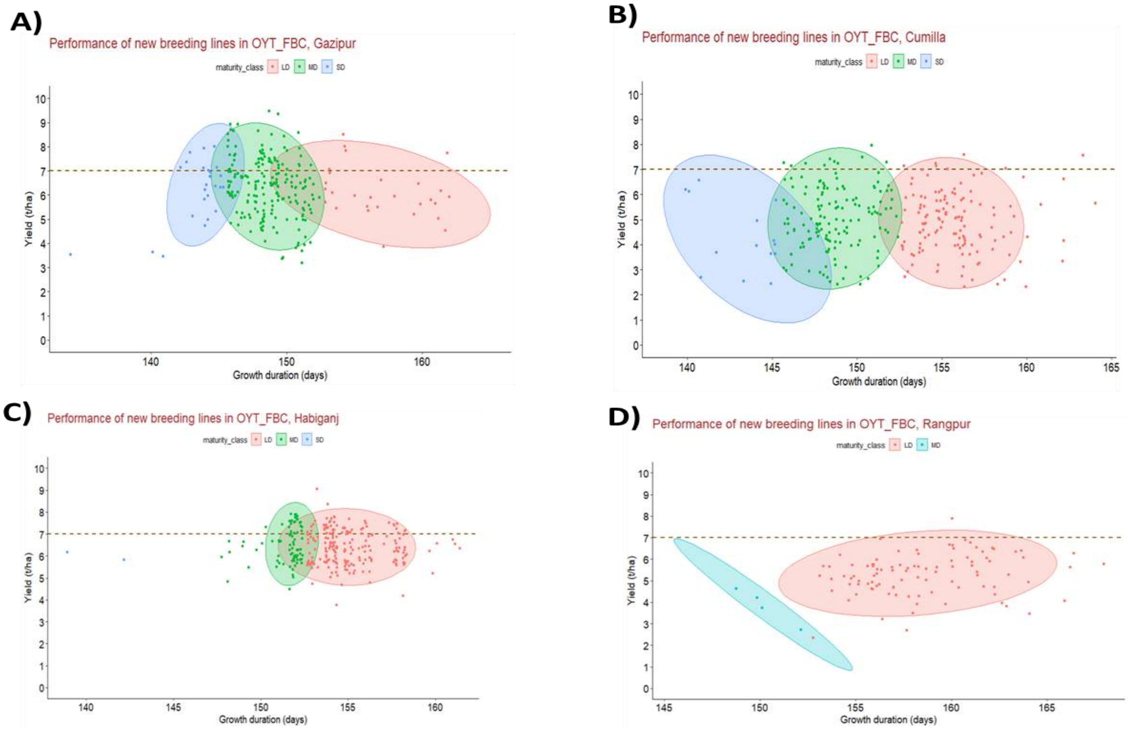


Fig. 3. Performance of 558 advanced breeding lines under OYT_FBC trial evaluated in Gazipur (A), Cumilla (B), Habiganj(C), and Rangpur (D). The genotypes were classified based on days to maturity. It ranged from 135 to 145 days for short duration (SD), 136 to 152 days for medium duration (MD), 153 to 161 days for long duration (LD).

Table 3. Yield performances of the selected breeding lines from AYT#Early conducted at different locations, favourable boro rice, Boro 2021-22.

Designation	Growth duration (day)	Yield (t/ha)				
		Barishal	Cumilla	Gazipur	Habiganj	Average
AYT#Early						
BR11637-5R-140	147	6.22	7.03	6.39	7.97	6.90
BR11894-5R-376	149	6.34	7.96	5.41	6.36	6.52
BR11900-5R-24	150	5.91	7.50	5.63	7.01	6.55
BR11903-5R-56	145	7.02	7.75	5.60	5.85	6.56
BRRI dhan28	145	6.10	6.13	4.44	6.20	6.01
BRRI dhan96	143	6.07	6.62	NA	6.67	6.08
LSD	6.94	0.73	0.96	0.96	1.26	0.90
H2b	0.79	0.69	0.75	0.64	0.38	0.28

Table 4. Yield performances of the selected breeding lines from AYT#late conducted at different locations, favourable Boro rice, Boro 2021-22

Designation	Growth duration (day)	Yield (t/ha)				
		Barishal	Cumilla	Gazipur	Habiganj	Average
AYT#Late						
BR11894-5R-260	152	6.80	6.51	6.04	6.28	6.41
BR11660-5R-6	150	6.45	5.99	5.78	6.80	6.25
BRRI dhan81	155	6.08	6.36	4.37	5.77	5.64
BRRI dhan89	159	6.25	6.75	5.17	6.76	6.23
LSD	8.09	0.25	0.85	0.92	0.82	1.08
H2b	0.89	0.98	0.64	0.79	0.42	0.20

Table 5. Yield performances of the selected breeding lines from AYT#AGGRiNet conducted at different locations, favourable Boro rice, Boro 2021-22.

Designation	Growth duration (day)	Yield (t/ha)			
		Gazipur	Rajshahi	Rangpur	Average
AYT#AGGRiNet					
IR17A1275	142	7.38	6.13	6.48	6.66
IR17A1694	146	6.27	6.40	7.77	6.81
IR17A1735	143	5.68	7.22	6.95	6.62
IR18A1398	153	NA	8.67	8.40	8.52
IR18A1907	154	7.12	8.92	6.45	7.50
IR18A2119	150	5.28	7.63	8.77	7.23
BRRI dhan81	147	5.25	5.49	5.33	5.36
BRRI dhan89	155	7.72	6.84	7.82	7.46
LSD	6.04	0.90	0.98	1.67	1.25
H2b	0.79	0.91	0.92	0.62	0.23

Out of 45 advanced breeding lines tested at nine research stations including HQ in regional yield trial (RYT) under short, medium and long maturity classes, two breeding lines showed 141 days and 146 days growth duration with 0.34 t/ha and 0.79 t/ha higher yield, respectively over BRRI dhan96 (yield 6.03 t/ha growth duration 142 days) (**Table 6**); two breeding lines showing 7.0-7.1 t/ha yield with 148 days growth duration while both the check varieties BRRI dhan81 and BRRI dhan96 yielded 6.0 t/ha in RYT (MD) (**Table 7**). In RYT (LD) the advanced lines BR11318-5R-148 and BR11318-5R-84 produced similar yield to the check variety BRRI dhan89 (7.0 t/ha). Among two varieties BR11318-5R-148 showed four days shorter growth duration than the check variety BRRI dhan89 (**Table 8**), was selected for further advancement. Besides, two entries from RYT (AGGRiNET) of IRRI bred breeding lines showed similar yield but five days shorter growth duration compared to the check variety BRRI dhan89 (6.8 t/ha) (**Table 9**) which were selected for further advancement.

Table 6. Agronomic performances of the selected genotypes out of six tested in RYT (SD), Development of Favourable Boro rice during Boro 2021-22.

Designation	PH	DM	Yield BLUE (t/ha)									
	(cm)	(day)	L1	L2	L3	L4	L5	L6	L7	L8	L9	Avg.
IR17A1694	102	146	5.6	8.1	6.7	7.1	6.8	5.4	7.6	6.3	6.5	6.8
IR17A1723	89	141	6.4	5.5	5.7	5.3	6.4	5.7	5.7	6.0	6.8	6.4
BRRI dhan81	98	144	5.0	6.1	6.2	6.0	5.8	6.8	6.1	5.1	6.5	6.0
BRRI dhan96	94	142	7.2	5.7	-	-	-	5.8	6.4	4.8	6.3	6.0
LSD	7.72	5.14	0.69	0.90	0.39	0.71	0.41	0.37	0.29	0.78	0.31	1.10
H^2b	0.82	0.84	0.98	0.87	0.84	0.71	0.94	0.97	0.97	0.78	0.73	0.43

L1=Barishal, L2=Bhanga, L3=Cumilla, L4=Gazipur, L5=Habiganj, L6=Kushtia, L7=Rajshahi, L8=Rangpur, L9=Sonagazi, Avg.= Average

Table 7. Agronomic performances of the selected genotypes out of 15 tested in RYT (MD, development of favourable Boro rice during Boro 2021-22.

Designation	PH	DM	Yield BLUE (t/ha)									
	(cm)	(day)	L1	L2	L3	L4	L5	L6	L7	L8	L9	Avg.
BR11318-5R-63	107	149	5.8	8.6	7.1	7.0	7.2	7.4	7.6	6.9	6.4	7.1
BR11337-5R-72	102	149	6.2	7.9	7.2	6.7	7.6	7.2	7.9	5.3	6.8	7.0
SVIN109	104	148	6.5	7.7	7.3	7.1	8.4	7.6	6.4	6.3	6.6	7.0
BRRI dhan81	100	147	5.1	7.7	6.2	4.6	6.6	5.7	6.1	5.1	6.6	6.0
BRRI dhan96	93	148	5.9	7.4	6.4	6.5	7.3	7.2	6.4	5.7	6.4	6.6
LSD	3.90	4.61	0.39	0.92	0.52	0.82	0.47	0.59	0.35	0.51	0.39	0.55
H2b	0.97	0.70	0.86	0.41	0.69	0.76	0.87	0.93	0.96	0.89	0.53	0.78

*PH=Average plant height, DM= Average days to maturity, BLUE=Best linear unbiased estimation
L1=Barishal, L2=Bhanga, L3=Cumilla, L4=Gazipur, L5=Habiganj, L6=Kushtia, L7=Rajshahi, L8=Rangpur, L9=Sonagazi, Avg.= Average

Table 8. Agronomic performances of the selected genotypes out of 11 tested in RYT (LD), development of favourable Boro rice during Boro 2021-22.

Designation	PH (cm)	DM (days)	BLUE Yield (t/ha)									
			L1	L2	L3	L4	L5	L6	L7	L8	L9	Avg.
BR11318-5R-148	109	156	6.7	6.7	7.7	6.3	6.6	6.9	7.2	6.5	8.0	7.0
BR11318-5R-84	115	160	6.2	8.4	6.4	6.3	7.2	7.9	8.4	5.8	7.1	7.1
BRRI dhan89	111	160	6.1	6.6	6.6	6.1	7.2	7.8	7.1	6.8	8.3	7.0
LSD	3.86	5.10	0.53	0.61	0.67	1.10	0.45	0.35	0.37	0.47	0.49	0.57
H2b	0.80	0.89	0.71	0.88	0.79	0.03	0.83	0.92	0.97	0.92	0.82	0.73

L1=Barishal, L2=Bhanga, L3=Cumilla, L4=Gazipur, L5=Habiganj, L6=Kushtia, L7=Rajshahi, L8=Rangpur, L9=Sonagazi, Avg.= Average

Table 9. Agronomic performances of the selected genotypes out of 13 tested in RYT (AGGRiNet), development of favourable Boro rice during Boro 2021-22.

Designation	PH (cm)	DM (day)	BLUE yield (t/ha)									
			L1	L2	L3	L4	L5	L6	L7	L8	L9	Avg.
IR 12 A 173	109	153	6.4	5.3	7.4	7.8	6.7	7.5	6.8	6.0	7.2	6.8
IR17A1694	103	152	5.9	5.0	6.9	7.2	6.8	7.7	6.6	6.2	6.8	6.6
BRRI dhan89	111	157	6.8	5.3	6.8	7.0	6.4	7.4	7.6	6.3	8.2	**6.9**
BRRI dhan92	113	158	6.6	5.4	6.8	6.5	6.1	7.9	7.8	5.4	8.5	6.8
LSD	5.88	4.90	0.53	0.74	0.51		0.33	0.53	0.31	0.25	0.37	0.49
h2b	0.90	0.88	0.88	0.31	0.74	0.74	0.88	0.87	0.95	0.98	0.94	0.77

L1=Barishal, L2=Bhanga, L3=Cumilla, L4=Gazipur, L5=Habiganj, L6=Kushtia, L7=Rajshahi, L8=Rangpur, L9=Sonagazi, Avg.= Average

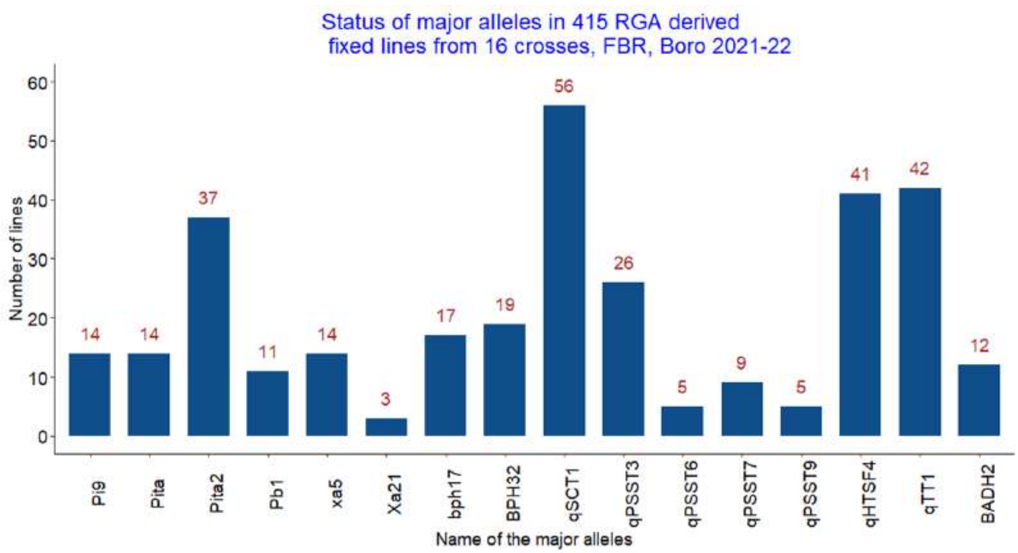


Fig. 4. Status of major alleles in selected LST population (415 lines from16 crosses), FBR, Boro 2021-22.

Development of cold tolerant rice. The major objective of the project was to develop high yielding and short duration (6.0-7.0 t/ha yield and 135-145 days growth duration for haor areas) and high yielding medium duration (6.5-7.5 t/ha yield with 145-150 days growth duration for Northern regions) rice varieties tolerant to cold stress at seedling and reproductive stage. Twenty-three crosses were made using 24 lines/varieties as parents targeting to develop high yielding breeding lines enriched with favourable alleles of key target traits, viz. disease resistance (blast and BLB), insect resistance (BPH) and acceptable grain quality (amylose, chalkiness, palatability, zinc content, etc). Twenty-four crosses were confirmed as true F1 through a hybridity test using QC SNP genotyping. From segregating RGA nurseries, in total 14,578 individual plants were advanced from 56 cross combinations of F_2-F_5 generations following SSD method of breeding. Out of 2,445 lines tested in LST, 278 uniform lines in terms of plant height, days to flowering, grain size and shape were selected based on the presence of the favourable alleles of key target genes **(Table 10 and Fig. 5)**. A set of 180 lines were identified with genes for cold tolerance (*qSCT1 or qPSST*), 79 for blast resistance (*Pi-ta, Pi-9* or *Pita2*), 46 for cold (either seedling or reproductive) and blast, 29 for BPH resistance (*Bph17* and *BPH32*), 923 lines for higher amylose specific markers.

Forty genotypes out of 456 breeding lines and 25 genotypes out of 778 breeding lines tested under natural cold stress (at booting stage) and non-stress conditions at two locations in OYT-1 and OYT-2, respectively were selected based on significantly higher yield than the check varieties of similar growth duration under non-stress condition and minimum yield reduction under cold stress condition for further yield trial. A total of 46 breeding lines were selected from 170 lines tested at four locations in three AYT class trials under two simulated cold-stress (October seeding) and non-stress control environments. From AYT_cold, 19 genotypes out of 43 tested entries showing around 0.70-1.30 t/ha yield advantage with shorter growth duration compared to the check varieties BRRI dhan28, BRRI dhan96 and BRRI dhan67, 11 short to medium duration (146 -154 days) genotypes showing 0.4 -1.44 t/ha higher yield compared to the check variety BRRI dhan96 (146 d) in AYT_Haor set-1, and 12 breeding lines with 146-151 days growth duration and four genotypes with 153-157 days growth duration showing 0.7-1.9 t/ha and 1.6 - 2.8 t/ha higher yield over BRRI dhan28 and BRRI dhan89, respectively were selected for further evaluation from AYT_Haor set-2. From RYT-CTR, three genotypes out of six breeding lines/varieties tested at 13 locations including 10 haor sites under Kishoreganj, Sunamganj, and Habiganj districts showed better performance in terms of yield and cold tolerance at reproductive stage. In this trial BR11894-R-R-R-R-169 yielded up to 3.04 t/ha under severe cold stress (<20^0C) for consecutive three weeks during PI to heading stage, while others including moderately tolerant BRRI dhan67 produced no grain.

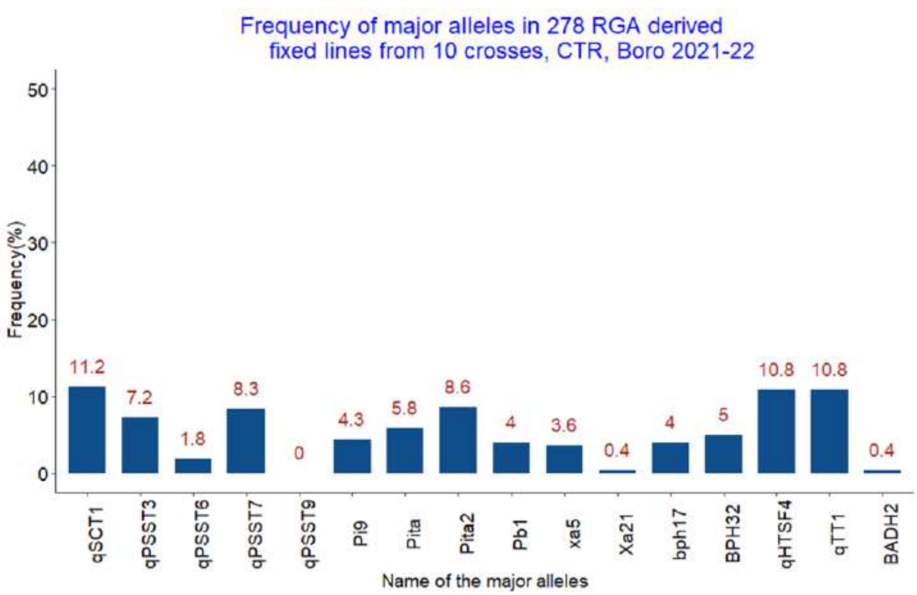


Fig. 5. Status of major alleles in selected LST population (278 lines from 10 crosses), CTR, Boro 2021-22.

Table 10. Allele/gene combination in selected LST population, FBR, Boro 2021-22.

Gene combination	Trait	No. of line
Pi9 +Pita+Pita2+Pb1+qSCT1	Blast, Cold (Seedling)	8
Pi9+Pita+Pita2+Pb1	Blast	13
Pi9+Pita+Pita2	Blast	34
Pi9+Pita2	Blast	37
bph17+BPH32	BPH	61
bph17+BPH32+xa5+Pb1+qSCT	BPH, BLB, blast, cold (Seedling)	12

Development of salt tolerant rice (STR): The objective of this project is to develop high yielding salt tolerant rice cultivars based on product profile. Salinity is one of the major constraints for the rainfed lowland and Boro rice ecosystem in the southern coastal zone of Bangladesh. In T. Aman season, 29 crosses were made using 31 well characterized elite parents. A total of 14 F_1s were confirmed as true hybrids through F_1 verification by quality check (QC) genotyping with purity SNP panel during T. Aman season. In T. Aman season, 1,06,268 segregating progenies derived from 103 crosses were advanced in F_2-F_6 generations using FRGA technique. Yield trials were carried out in Gazipur, and Assasuni, Debnagar, Debhata, Kaliganj and BRRI RS Farm, Satkhira in T. Aman season. In LST, out of 6,199 breeding lines of 30 crosses, 682 lines were selected on the basis of strong culm with good plant ideotype, acceptable grain type and uniformity at heading in field condition (Fig.6). A total of 658 LST lines were genotyped using trait-specific SNP panel (**Fig. 7**) to identify promising breeding lines with trait of interest (ToI) **(Fig.8**).

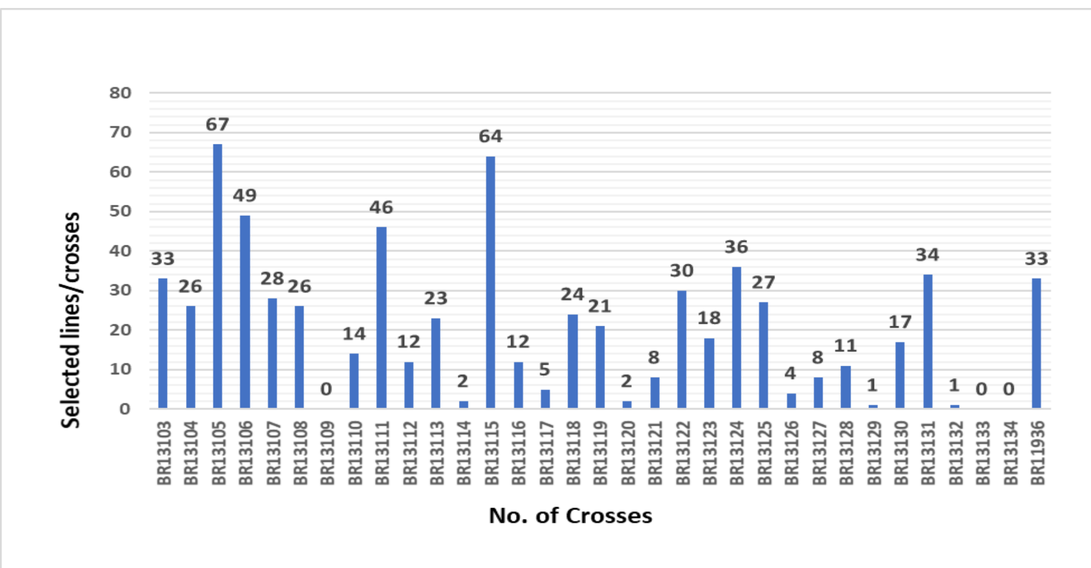


Fig. 6. Number of selelcted lines of LST population, T. Aman 2021-22.

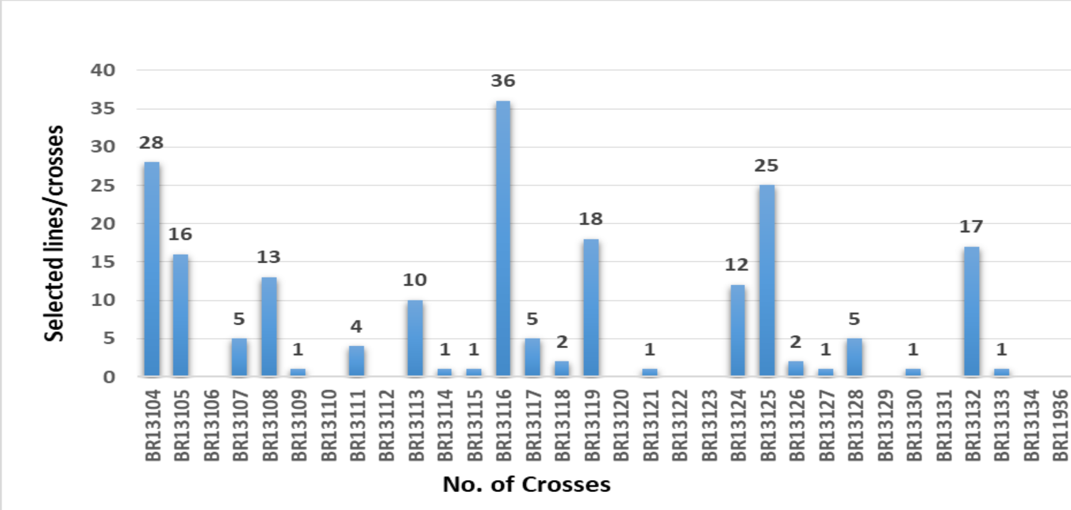


Fig. 7. Number of LST lines per cross genotyped using trait-specific SNP panel, T. Aman 2021-22.

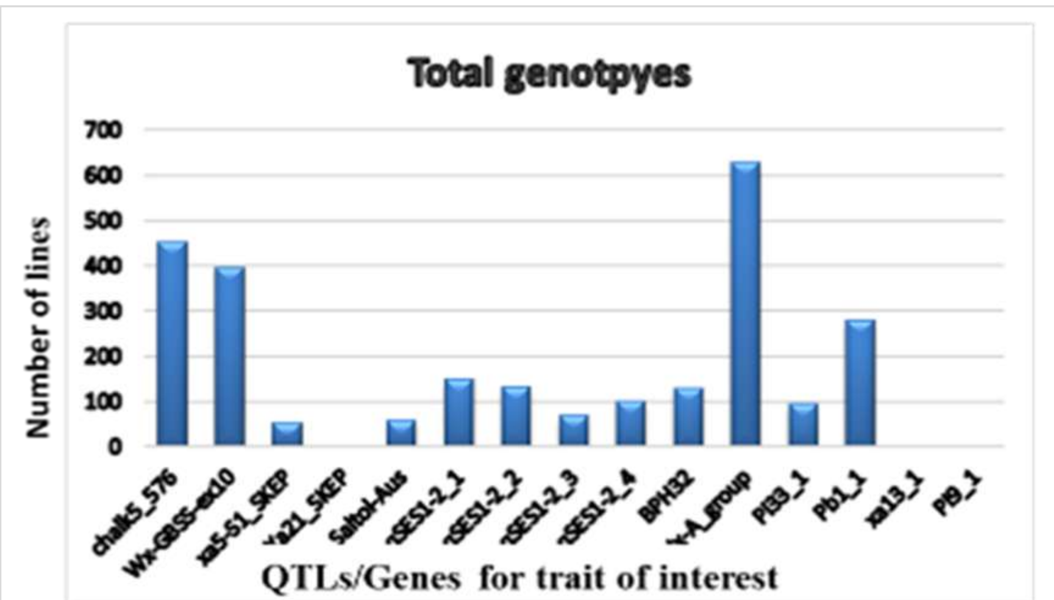


Fig. 8. Selected LST genotypes with QTL/genes for trait of interest, T. Aman 2021-22.

Out of 722 genotypes, 240 genotypes were selected from OYT. Three PYTs (PYT#1 to PYT#3) were conducted using 232 breeding lines. One hundred nine genotypes were selected from these trials depending on grain yield, salinity tolerance and phenotypic acceptability. Sixteen genotypes, out of 42 were selected from SYT/AYT. In RYT#2, a total eight of genotypes were evaluated in ten locations and three genotypes such as BR11712-4R-218, BR11716-4R-102, and BR11723-4R-172 were selected based on grain yield, (**Table 11**). The mean grain yield of selected lines ranged from 5.28 t/ha (BR11712-4R-218) to 5.53 t/ha (BR11716-4R-102) which were higher than the check varieties. These three genotypes such as BR11712-4R-218, BR11716-4R-102 and BR11723-4R-172 were selected for conducting ALART (**Table 11**).

Table 11. Performance of genotypes in RYT#2 STR, salinity breeding, T. Aman 2021-22.

Designation	GD (day)	PH (cm)	Yield (t/ha)										
			Gazi	Com	Deb	Gopal	Kustia	Raj	Rang	Sat	Sona. Chandina	Sona. farm	Mean
BR11712-4R-218	119	110	6.70	5.82	4.92	6.38	5.41	5.74	4.38	6.09	4.06	3.31	5.28
BR11712-4R-227	121	109	5.67	5.66	4.45	6.68	5.30	5.40	4.07	5.14	3.17	3.56	4.91
BR11715-4R-186	119	110	5.09	6.17	4.86	6.64	5.14	5.09	4.65	5.88	3.90	3.39	5.08
BR11716-4R-102	119	107	6.00	6.34	4.89	7.08	5.35	5.84	4.36	6.70	4.42	4.37	5.53
BR11716-4R-105	118	116	4.76	6.31	4.25	6.00	5.83	4.16	3.19	5.71	3.47	5.71	4.94
BR11716-4R-129	121	110	5.79	6.09	4.86	6.80	4.81	5.04	5.33	5.77	3.94	3.93	5.24
BR11723-4R-172	118	109	7.05	6.26	4.35	6.80	5.07	5.65	4.88	5.06	4.33	3.44	5.29
BR11723-4R-27	119	107	5.70	6.38	4.67	6.39	4.96	5.37	4.71	5.68	4.57	4.15	5.26
BRRI dhan73	121	126	5.87	5.78	4.49	5.91	4.87	4.55	3.20	4.61	5.24	2.91	4.74
BRRI dhan87	124	121	6.34	6.10	5.66	6.37	6.02	5.72	3.74	6.18	2.03	1.74	4.99
LSD (5%)	2.31	3.92	0.96	0.37	0.40	0.37	0.42	0.46	0.73	0.78	0.95	1.06	0.39

Gazi= Gazipur, Com= Cumilla, Ded= Debhata, Gopal = Gopalganj, Raj= Rajshahi, Rang = Rangpur, Sat= Satkhira, Sona chandina = Sonagazi chandina, Sona.far = Sonagai farm

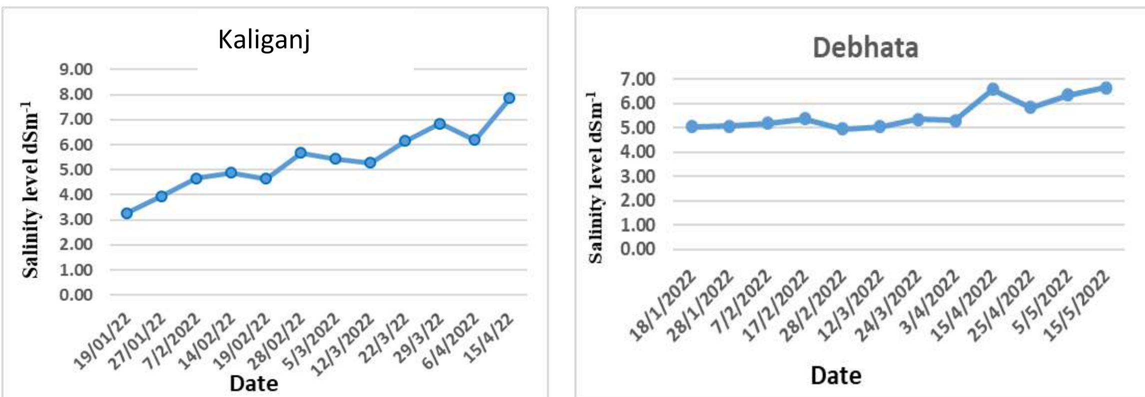


Fig. 9. Salinity dynamics of different experimental fields in coastal saline areas in Boro 2021-22.

In Boro Season, 40 crosses were made using 64 elite parents. A total of 32 F_1s were confirmed as true hybrids through F_1 verification by quality check (QC) genotyping with purity SNP panel. In total 1,13,098 segregating progenies from 113 crosses (F_2-F_5 generation) were harvested from FRGA nursery and grown in the subsequent generation. In LST trial, 320 lines out of 5170 lines were selected on the basis of desirable plant type, grain quality and uniformity at flowering under field condition. A total of 54 genotypes were selected out of 422 from OYT based on growth duration, grain yield, and homogeneity in different morpho-agronomic traits. Out of 112 genotypes, 30 genotypes were selected from two PYTs. Twenty genotypes were selected from three AYT's. Two genotypes from RYT#1 and three genotypes from RTY#2 were selected. The highest level of salinity (EC) was found at Kaliganj being ranged from 3 dS/m to 7.15 dS/m in Boro 2021-22 (**Fig. 9**).

Investigators: M Akhlasur Rahman, Hasina Khatun, M Asif Rahman, R Farzana Disha, Avijt Biswas, A.A Shoily and T H Ansari

Development of premium quality rice (PQR)

T. Aman. Efforts were made to develop aromatic and non-aromatic fine quality rice with national and international standards (Kalizira/ Chinigura /Kataribhog /Radhunipagol/Jasmine type), anti-oxidant enriched (black and red) rice and photosensitive rice for domestic use and export. In T. Aman 2021-22, a total of 109 crosses (52 single crosses and 10 backcrosses for PQR, 34 single crosses for anti-oxidant enriched rice and 22 single crosses and one backcross for photosensitive rice) were made and 70 crosses (51 for PQR, eight for anti-oxidant enriched rice and 11 for photosensitive rice) were confirmed as true hybrid using quality control SNP panel analysis. A total of 14,800 progenies (11,038 progenies of 24 F_2 crosses, 1,681 progenies of 12 F_3 crosses, and 2,081 progenies of 14 F_4 crosses) were advanced through RGA under PQR. A total of 5,638 progenies (1,564 progenies of four F_2 crosses, 1,448 progenies from five F_3 crosses, 484 progenies from 10 F_4 crosses and 1,300 progenies from 15 F_5 crosses and 842 progenies from three F_6 crosses) were advanced through RGA under Antioxidant programme. A total of 1,633 progenies (945 progenies of five F_2 crosses, 177 progenies from five F_3 crosses, 484 progenies from five F_4 crosses and 27 progenies from three F_6 crosses) were advanced through RGA under photosensitive programme. Under PQR programme 62 genotypes were selected out of 158 from different yield trials based on growth duration, yield, homogeneity and morpho-agronomic traits. From Observational Yield Trial (OYT) 26 genotypes were selected out of 66 genotypes. From preliminary yield trial (PYT), 23 genotypes were selected out of 64 genotypes. Seven genotypes were selected out of 16 genotypes from secondary yield trial (SYT). In OYT#1, the genotype BR10820-2-3-3-5-3 produced the highest yield (6.5 t/ha) which was non-aromatic whereas the second highest yielder genotype having 5.7 t/ha yield is an aromatic line with 136 days growth duration. In OYT#2, the aromatic genotype BR9178-7-2-4-4 produced the highest yield of 7.0 t/ha with growth duration 130 days. In PYT#1 the genotype BR11224-7-9-4-3 produced the highest yield (6.5 t/ha) which was a non-aromatic genotype having long slender type grain whereas the aromatic genotype BR10062-8-3-2-1-P2 produced 4.4 t/ha yield with growth duration 107 days. In PYT#2, the aromatic genotype BR11811-9-2-2 produced 6.6 t/ha yield but grain was bold while the genotype BR8493-12-7-4-P1 produced 5.6 t/ha yield with grain type almost same with BRRI dhan90**.** In SYT, the aromatic genotype BR10824-5-6-4-1 having BRRI dhan34 type grain produced 4.3 t/ha with a growth duration of 141 days. In AYT, the aromatic genotype BR9126-15-3-4-1 having BRRI dhan34 type grain which produced 5.7 t/ha with growth duration 128 days. Another aromatic genotype BR10813-75-20-10-2 produced 4.0 t/ha with 125 days growth duration with Kalizira grain type. The aromatic genotype BR8493-3-5-1-P1 having BRRI dhan90 type grain produced 6.2 t/ha yield during seed purification stage which were recommended to evaluate in ALART as *polaw* rice whereas a non-aromatic genotype producing 6.5 t/h yield was also recommended to evaluate in ALART as table rice. The growth duration of these two genotypes are 139 days and 135 days, respectively. Under Antioxidant enriched rice breeding programme, 1,075 fixed lines were selected from LST in T. Aman 2021, which were evaluated under OYT in Boro 2021-22. From OYT 152 advanced lines were selected. The yields of the selected lines ranged from 4.0 t/ha to 6.9 t/ha. Most of the selected lower yielder genotypes had very long slender or Katari type grain and possessed aroma. The genotype BR12839-4R-93 produced 6.9 t/ha yield followed by the genotype BR12839-4R-72-1 (6.5 t/ha). Under photosensitive rice programme, 36 genotypes were selected out of 111 from different yield trials. From OYT, 28 genotypes were selected from 86 genotypes based on growth duration, yield, homogeneity and morpho-agronomic traits. From PYT, eight genotypes were selected out of 14 genotypes. Seven genotypes were selected out of 11 genotypes from SYT. In OYT, the genotype BR8845-21-1-10-3-4 produced significantly higher yield (6.5 t/ha) and this was followed by the genotype BR8845-21-1-10-3-5 (6.0 t/ha) whereas the yield of the check varieties was BR22 (4.7 t/ha) and BR23 (4.9 t/ha). Both of the genotypes had similar growth duration with the check varieties. The genotype TL Aus-Gaz10-40-5-11 produced 5.4 t/ha yield which also possesses aroma. In PYT, the genotype BR8845-21-1-10-6-1 produced significantly higher yield (5.4 t/ha) than the check varieties BR22 (4.7 t/ha) and BR23 (4.9 t/ha) possessed aroma having shorter growth duration, which has been transferred to trial under premium quality rice for the next season. In SYT, the genotype TL Aus Kushtia-3 (PR-2)-2 produced significantly higher yield (6.0 t/ha) with bold grain followed by the genotype BR8845-21-1-5-10-3-P4 (5.7 t/ha) with aroma. The heritability obtained for growth duration was ranging from 86% to 96% and grain yield was ranging from 80 % to 88% indicating acceptable level of precision in these experiments.

Investigators: Sharmistha Ghosal, M M Yasmin, Z A Riyadh and K M Iftekharuddaula

Boro: The project aims to develop aromatic and non-aromatic fine quality rice with international (Basmati/Banglamati/SoruBalam type) standards in Boro season for domestic use and export quality. Totally 1,820 F_1 seeds were obtained from 29 crosses. Twenty-six F_1 crosses were confirmed out of 20 crosses as true hybrid. In total 13,210 progenies of 29 crosses from F_2, F_4 and F_5 generations were advanced through RGA method. A total of 623 genotypes were selected from 6,546 progenies of LST trial. A total of 199 genotypes were evaluated in three OYTs in Gazipur, Rajshahi and Rangpur. Figures 10 and 11 present selection intensity and trait marker profile of the genotypes of LST. Among the tested genotypes, 63 genotypes were selected and forwarded in Advanced Yield Trial (AYT). In PYT, none of the genotypes were selected out of seven tested genotypes. From two SYT's, 27 genotypes were evaluated and 12 genotypes were advanced in RYT. In RYT, none of the genotypes was selected to forward in ALART out of two genotypes. None of the genotypes was recommended to advance from ALART by the Adaptive Research Division.

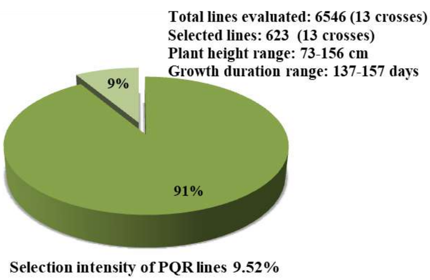


Fig.10. Selection intensity in the genotypes of LST, PQR, Boro 2021-22.

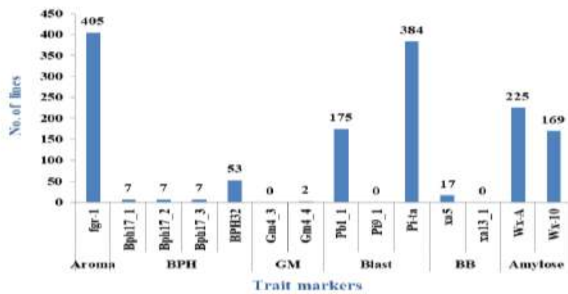


Fig.11. Trait marker profile of the genotypes of LST, PQR, Boro 2021-22.

Investigators: R R Majumder, K Fatema, U R Shaha and M A Kader.

Development of Zinc Enriched Rice (ZER). The project aims to develop high yielding rice varieties with improved nutritional quality with high zinc (Zn≥24 mg/kg) in polished grain. The project also prioritizes development of stress tolerant zinc enriched rice varieties in a combination of submergence + zinc, drought + zinc, salinity + zinc and cold + zinc enriched rice with improved grain yield. The experiments were conducted in both T. Aman and Boro seasons. In T. Aman season, 59 single crosses were made that produced 9906 seeds. A total of 48 crosses were selected and confirmed as true F_1s. In pedigree selection, 1,512 plants were selected from F_2 population of 18 crosses and 2,504 progenies and 69 fixed lines were isolated from 87 crosses from F_2-F_6 generations. From two OYT's, 56 genotypes were selected from 169 genotypes. A total of 11 genotypes were selected from 48 genotypes of two PYT's based on yield performances. Only three promising genotypes were selected out of 23 genotypes of three SYT's. None of the genotypes was selected from RYT. None of the entries was recommended for promoting from ALART by ARD. In Boro season, 20 single crosses were made that produced 1,424 seeds. A total of 58 crosses were confirmed as true F_1s. A total of 29,250 progenies were harvested from F_2 and F_3 generation at the time of maturity. After that seed materials were preserved and processed with proper labels. Following pedigree selection method, 1,310 progenies and 471 fixed lines of 60 crosses were isolated from F_4 and F_6 generation. From OYT, 64 genotypes were selected from 184 genotypes. A total of 15 genotypes were selected out of 53 genotypes from PYT based on yield performances. Three promising genotypes were selected out of seven genotypes from SYT. Zinc enriched

IR99285-1-1-1-P2 was approved to release as BRRI dhan102 for cultivation throughout the country for Boro season by National Seed Board (NSB) of Bangladesh in its 106th meeting held on 18 January 2022. The average yield of BRRI dhan102 was 8.11 t/ha with 150 days growth duration and zinc content of the milled rice of the variety was 25.5 mg/kg which was higher than that of BRRI dhan29 (18.2 mg/kg) (**Table 12**). BRRI dhan102 is expected to be very popular in the areas where BRRI dhan29 is cultivated and plays a major role in increasing overall rice production of Bangladesh.

Table 12. Performance of BRRI dhan102 in proposed variety trial, Boro 2020-21.

Designation	Plant height (cm)	Growth duration (day) *	Grain yield (t/ha) *	Grain characteristics						
				Head rice yield (%)	L-B ratio	Size and shape	Elongation ratio	Protein (%)	Amy (%)	Zinc content (mg/kg)
BRRI dhan102 (BR99285-1-1-1-P2)	101	150	8.11	62	3.1	LS	1.3	7.5	28.0	25.5
BRRI dhan29(Ck)	96	152	7.84	61	3.0	MB	1.4	7.0	26.9	18.2

*Mean of ten locations (BRRI HQ, Gazipur; BRRI RS Rangpur, BRRI RS Faridpur, BINA-Mymensingh; Jashore, Feni, Cumilla, Bogura, Dinajpur, Barishal)

Fig.12. Pictorial view of BRRI dhan102.

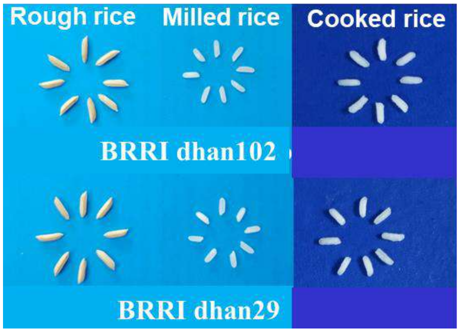


Fig.13. Grains of BRRI dhan102.

Investigators: M A Kader, R R Majumder, S M T Islam, U R Shaha and K Fatema.

Development of disease resistant rice. Efforts were made for developing varieties resistant to bacterial blight (BB), rice tungro virus (RTV) and blast diseases. The experiments were conducted in both T. Aman and Boro seasons. Seven crosses for BB and nine for blast in T. Aman and 12 crosses for BB and 18 for blast were made in Boro season. Sixteen crosses for BB and five for blast in T. Aman and seven crosses for BB and nine for blast in Boro season were confirmed as true F_1. A total of 17,900 progenies for BB and 13,250 progenies for blast were advanced from F_{2-6} generation through Green-house RGA and FRGA. Out of 6,700 lines, 1,150 lines were selected from LST in Boro season based on uniformity in heading, plant height and grain type. Seventeen genotypes for BB were selected from observational yield trial (OYT) in T. Aman season whereas 60 entries out of 750 for BB during Boro season showed better yield potential and agronomic performance over the check varieties and tolerance to BB. From AYT, three advanced lines were promoted based on growth duration, grain yield and BB score compared to the check varieties in T. Aman season and 21 genotypes out of 87 for BB were selected in Boro season. From MLT, three genotypes for T. Aman season and six for Boro were selected compared to yield, growth duration, BB resistance and better grain quality characters and three BB resistant genotypes performed better but yield was not >10% higher than the check variety. Therefore, the high yielding background of

BB resistant promising lines will be used as genetic resource to develop high yielding disease resistant varieties. The promising BB resistant line BR8938-19-4-3-1-1-P2-HR3 was released as BRRI dhan101. The average yield of this variety was 7.72 ton per hectare. Growth duration of it was 142 days, which was four days earlier than the popular variety BRRI dhan58. Its grain contains 25.0% amylose and 9.8% protein (**Table 13 and Fig.14**). The variety showed strong resistance to BB (BB score-1) under artificial inoculation with virulent BB pathogens. QTL fingerprinting with functional SNP markers for the BB resistance detected three dominant BB resistant genes *Xa4, Xa7* and *Xa21* in this variety.

Table 13. Yield, agronomic performance and physico-chemical properties of the proposed variety BRRI dhan101 (BR8938-19-4-3-1-1-P2-HR3), Boro 2020-21.

Designation	Yield (t/ha)	GD (day)	Amylose (%)	Protein (%)	Head rice yield (%)	Size & shape	ER	IB
BRRI dhan101 (BR8938-19-4-3-1-1-P2-HR3)	7.72	142	25.0	9.8	60.0	LS	1.4	3.0
BRRI dhan58 (Ck)	7.39	146	26.0	7.0	61.3	MB	1.3	3.0

ER-Elongation Ratio IR-Imbibition Ratio

Fig.14. Pictorial view of BRRI dhan101.

Investigators: M Khatun, S K Debsharma, J Ferdousy, M A I Khan and M A Latif

Development of Insect Resistant Rice. The main thrust of the project was to develop varieties resistant to gall midge (GM), brown plant hopper (BPH) and white backed plant hopper (WBPH). The experiments were conducted in both T. Aman and Boro seasons. In the T. Aman season, 12 crosses for forward breeding, three crosses for line augmentation and three crosses for QTL deployment were made and 22 crosses were confirmed as true hybrids using quality check (QC) genotyping with purity SNP panel. In total 62530 segregating progenies from 67 crosses of F_2-F_5 generations were advanced through field rapid generation Advanced (FRGA) technique. Out of 3569 $F_{5:6}$ of LST lines derived from 16 different crosses, 204 genotypes were selected based on strong plant architecture, grain type and uniformity in heading under field condition as well as the presence of the favourable alleles of key target genes for BPH (*bph9*, *bph17_1*, *bph17_2, bph17_3 and bph32*), Gm (*Gm4_3* and *Gm4_4*) and grain quality *(Wx-A and Wx-10*). The selected four and 149 LST genotypes had *bph17* and *bph32* favourable alleles, respectively. The favourable alleles for gall midge resistant genes, *Gm4_3* and *Gm4_4* were present in 32 lines. However, two genotypes had both *bph17* and *bph32* as well as one genotype had *bph17*, *bph32* with *GM4* SNP favourable alleles (**Table 14**). The yield trials (OYT and AYT) were conducted at three locations of BRRI HQ, Gazipur, BRRI RS, Cumilla and Rangpur. Ninety-three genotypes were selected from 432 breeding lines in OYT. Nine selected OYT genotypes had both *bph9* and *bph17, and* four had *bph17* with *Gm4* SNP favourable alleles. Eighteen genotypes were selected from 92 lines in AYT. Nine selected AYT genotypes had both *bph17* and *bph32* SNP favourable alleles. Table 15 showed the performance and favourable alleles of selected OYT and AYT genotypes. Two promising lines such as BR9880-40-1-3-34 and BR9880-27-4-1-18 were evaluated in ALART that showed moderate resistance to BPH (SES Score 5.0). None of the entries was recommended from ALART for PVT due to non-competitive performance compared to the standard checks BRRI dhan87 and BRRI dhan93. In Boro season, 16 crosses for forward breeding, three F_1 and three BC_1F_1 crosses for line augmentation were made, and 23 crosses were confirmed as true hybrids through F_1 verification using quality check (QC) genotyping with purity SNP panel. A total of 85,124 individual plants were advanced from 84 crosses in F_2-F_5 generations by FRGA technique. In LST, 257 lines having strong plant architecture, grain quality, uniformity in heading under field condition and the presence of the favourable alleles of key target genes for BPH (*bph9, bph17_1*, *bph17_2*, *bph17_3 and bph32*), Gm (*Gm4_3* and *Gm4_4*) and grain quality *(Wx-A and Wx-10*) were selected from 2,350 $F_{5:6}$ breeding lines that are the descendants of 12 crosses. A set of 64 lines were identified with genes for *bph17* (*bph17_1*, *bph17_2*, *bph17_3*), 122 for *bph32*, three for *bph9* and 18 for *Gm4 (Gm4_3, Gm4_4)* specific markers. Fifty-three genotypes out of 542 were selected from OYT that were tested in three locations. Fifteen lines were selected from 87 lines in PYT. Out of 60 genotypes, 10 were selected from AYT for further evaluation. Seven genotypes were evaluated in RYT and two entries showed 0.40 t/ha yield advantage with similar growth duration over the check variety BRRI dhan58. In total 65 parental lines were maintained in insect resistant maintenance breeding programme.

Table 14. Gene combinations of breeding lines selected from LST, IRR, T. Aman 2021-22.

Designation	Gene combination
BR13090-4R-22	*bph32, Gm4_3, Gm4_4, Wx-A_group*
BR13094-4R-221	*bph32, Gm4_3, Gm4_4, Wx-GBSS-ex10, Wx-A_group,*
BR13094-4R-259	*bph17_1, bph17_2, bph17_3, Wx-A_group*
BR13097-4R-76	*bph32, Gm4_3, Gm4_4, Wx-GBSS-ex10, Wx-A_group,*
BR13097-4R-105	*bph32, Gm4_3, Gm4_4*
BR13097-4R-124	*bph32, Gm4_3, Gm4_4*
BR13097-4R-151	*bph32, Gm4_3, Gm4_4*
BR13097-4R-268	*bph32, Gm4_3, Gm4_4*
BR13100-4R-149	*bph17_1, bph17_2, bph17_3, bph32*
BR13100-4R-180	*bph32, Gm4_3, Gm4_4, Wx-A_group*
BR13100-4R-181	*bph17_1, bph17_2, bph17_3, Gm4_3, Gm4_4, Wx-GBSS-ex10, Wx-A_group,*
BR13100-4R-216	*bph32, Gm4_3, Gm4_4,*
BR13100-4R-255	*bph17_1, bph17_2, bph17_3, bph32, Gm4_3, Gm4_4,*

Table 15. Grain yield, agronomic performance and favourable alleles for trait of interest of selected genotypes from OYT and AYT lines, IRR, T. Aman 2021-22.

	Duration (day)	PH (cm)	Yield (t/ha)				Trait of interest (ToI)
			Gaz	Ran	Cum	BLUE	
				OYT			
BR 12193-5 R-63	136	113	5.1	4.8	5.8	5.2	*bph9, bph17_1, bph17_2, bph17_3, Gm4_3, Gm4_4, Wx-A_group*
BR 12193-5 R-66	125	116	3.0	3.7	5.5	4.1	*bph9, bph17_1, bph17_2, bph17_3, Gm4_3, Gm4_4, Wx-A_group*
BR 12193-5 R-219	119	99	4.0	4.7	6.1	4.9	*bph9, bph17_1, bph17_2, bph17_3, Gm4_3, Gm4_4, Wx-A_group*
BR 12193-5 R-148	128	99	3.4	3.9	NA	4.1	*bph9, bph17_1, bph17_2, bph17_2, Gm4_3, Gm4_4, Wx-A_group*
BR 12193-5 R-17	121	109	4.1	NA	NA	4.4	*bph9, bph17_1, bph17_2, bph17_3, Gm4_3, Gm4_4, Wx-A_group, Wx-GBSS-ex10*
BR 12193-5 R-54	126	93	4.6	2.5	5.1	4.1	*bph9, bph17_1, bph17_2, bph17_3, Wx-A_group, Wx-GBSS-ex10*
BR 12193-5 R-88	127	132	3.1	3.8	6.3	4.4	*bph9, bph17_1, bph17_2, bph17_3, Wx-A_group*
BR 12193-5 R-93	130	120	3.1	4.4	6.2	4.6	*bph9, bph17_1, bph17_2, bph17_3, Wx-A_group*
BR 12193-5 R-225	122	119	5.8	3.0	5.9	4.9	*bph9, bph17_1, bph17_2, bph17_3, Wx-A_group*
BR 12193-5 R-23	115	113	4.3	4.0	NA	4.6	*bph17_1, bph17_2, bph17_3, Gm4_3, Gm4_4, Wx-A_group, Wx-GBSS-ex10*
BR 12181-5 R-158	132	108	3.2	3.6	6.0	4.3	*bph17_1, bph17_2, bph17_3, Gm4_3, Gm4_4, Wx-A_group, Wx-GBSS-ex10*
BR 12208-5 R-332	113	109	6.0	4.3	5.8	5.3	*bph17_1, bph17_2, bph17_3, Gm4_3, Gm4_4, Wx-A_group, Wx-GBSS-ex10*
BR 12208-5 R-227	116	108	5.3	5.5	5.7	5.5	*bph17_1, bph17_2, bph17_3, Gm4_3, Gm4_4, Wx-A_group*
				AYT			
BR 11044-4 R -33	121	113	3.8	4.1	5.2	4.4	*bph17_1, bph17_2,bph17_3, bph32, Gm4_3, Gm4_4, Wx-A_group*
BR 11035-4 R -101	120	119	3.9	5.2	5.9	5.0	*bph17_1, bph17_2, bph17_3, bph32, Gm4_3, Gm4_4, Wx-A_group*
BR 11052-4 R -251	121	129	4.6	4.3	5.7	4.9	*bph17_1, bph17_2, bph17_3, bph32, Gm4_3, Gm4_4, Wx-A_group*
SVIN308	122	111	4.6	4.6	5.5	4.9	*bph17_1, bph17_2, bph17_3, bph32, Gm4_3, Gm4_4, Wx-A_group*
BR 11035-4 R -190	119	124	5.3	4.7	5.2	5.1	*bph17_1, bph17_2, bph17_3, bph32, Wx-A_group*
BR 11052-4 R -273	114	119	4.6	4.4	4.3	4.4	*bph17_1, bph17_2, bph17_3, bph32, Wx-A_group*
BR 11035-4 R -1	120	118	3.9	4.4	6.0	4.7	*bph17_1, bph17_2, bph17_3, bph32, Wx-A_group*
BR 11052-4 R -234	116	109	4.9	4.4	5.7	5.0	*bph17_1, bph17_2, bph17_3, bph32, Wx-A_group*
IRBPHN-SVIN013-18	118	121	3.3	7.1	5.6	5.3	*bph17_1, bph17_2, bph17_3, bph32,*

Investigators: Md Ruhul Amin Sarker, Hasina Khatun, Ribed Farzana Disha and M Akhlasur Rahman

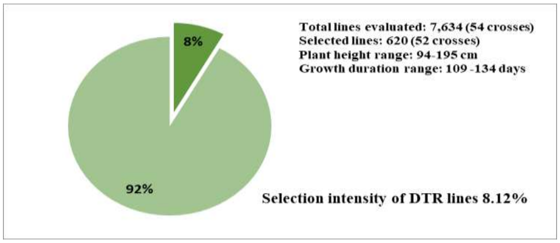
Development of submergence and water stagnation tolerant rice varieties. The project aims for the development of high yielding rice varieties tolerant to submergence (flash flooding) and medium stagnant water (MSW) stresses. Totally 4885 F_1 seeds were obtained from 33 single and two back crosses. Thirty-four single F_1 crosses were selected and confirmed through QC SNP panel analysis. Panicles of 4,350 from 15 F_2 crosses, 2,510 from nine F_3, 2,324 from ten F_4 progenies, 3,080 from nine F_5 progenies, and 5072 from 22 F_6 progenies were harvested at the time of maturity, processed with proper labels and preserved. The ranges of mortality percentage of different RGA generations were around 15%. From LST population, 2,230 lines from nine crosses were genotyped with trait markers using custom SNP panel among which 178 lines were selected based on uniformity and traits markers like *Sub1, Wx-A group, Wx-A_NB, xa13, Xa21* etc. In yield trial, 573 genotypes were tested out of which 122 genotypes were selected based on phenotypic acceptance, growth duration, survivability and higher yield performance. From OYT#1, thirty genotypes out of 148 genotypes, from OYT#2, thirteen genotypes out of 43 genotypes, from OYT#3 (INGER_IRSTN_FP), four genotypes out of 10, from OYT#4 (AGGRi Network trial), 35 genotypes out of 265, from PYT#1_Early, eight genotypes out of 21, from PYT#2_Late, eight genotypes out of 18 genotypes, from AYT#1_Early, nine genotypes out of 28 genotypes, from AYT#2_Late, eleven genotypes out of 29 were selected. Three lines were evaluated in ALART from which one line was recommended to evaluate in PVT. In OYT#1, the genotype BR10211-22-9-2-1 with 89% survivability produced the highest yield 6.7 t/ha under stress condition. In OYT#2 the genotype BR12162-5R-350 showed higher yield (6.6 t/ha) under controlled stress with 95% survivability. In OYT#3, the genotype SV1170_WS21-FP-5 produced highest yield (5.8 t/ha) under rainfed condition. In OYT#4, the highest yield was 7.2 t/ha given by the genotype IR18T1135 with survivability of 83% followed by the genotype IR19A1914 (7.1 t/ha) with survivability of 73%. In PYT#1, the genotype BR11690-5R-98 produced the highest yield (6.1 t/ha) with survivability of 98% and growth duration of 137 days under 18 days of controlled submergence stress condition. In PYT#2, the genotype BR11686-5R-179 produced the highest yield (5.9 t/ha) with 130 days growth duration in flood prone farmers' field with 100% survivability. In AYT#1 the genotype IR16F1033 produced the highest yield 7.0 t/ha followed by the genotype IR103782-B-B-1-1 (6.1 t/ha) under controlled stress condition. In AYT#2, the genotype BR10212-7-5-1 produced the highest yield 6.9 t/ha with 96% survivability followed by the genotype BR11185-5R-569-3 (5.8 t/ha) with 80% survivability. Table 16 shows that in ALART#1 the genotype IR16F1148 produced significantly higher yield (5.0 t/ha) over both the submergence tolerant check BINA dhan11 (4.06 t/ha) and the susceptible check BRRI dhan71 (4.02 t/ha) with similar growth duration. The genotype also has almost similar growth duration with check varieties. This line was recommended to evaluate in PVT. The ALART#2 trial was recommended for re-trial in tidal submergence ecosystem. The heritability obtained for grain yield under stress of all trials conducted was ranging from 55 % to 99%, whereas that for non-stress trials was ranging from 50 % to 93%, indicating acceptable level of precision in these experiments.

Investigators: Sharmistha Ghosal, Z A Riyadh, A Rahman, R Hassan and K M Iftekharuddaula

Development of drought tolerant rice (DTR). The project aims to develop high yielding drought tolerant rice varieties under rainfed lowland rice ecosystem in T. Aman season. In, T. Aman 2021-22, 1,916 F_1 seeds were obtained from 14 crosses using 22 parents and 19 crosses were confirmed as true hybrids using 10 SNP *indica* QC panel. A total of 2,398 individual panicles from 20 crosses of F_4 and F_5 were harvested through RGA. The materials were advanced in Boro 2021-22, a total of 4,543 progenies were harvested from 19 crosses of F_3 generations through RGA method. From LST, 620 lines were selected from 7,634 progenies of 45 crosses. Figures 15 and 16 present selection intensity and trait marker profile of the genotypes of LST. A total of 717 genotypes were evaluated in three OYTs in Gazipur, Rajshahi and Rangpur. Among the tested genotypes. 23 were selected and forwarded in AYT. In OYT, 12 genotypes were selected from 181 genotypes based on yield performances. Two genotypes were selected from RYT for advancing in ALART.

Table 16. Grain yield performance of genotypes in advanced line adaptive research trial (ALART), development of submergence tolerant rice, T. Aman 2021-22.

	Under rainfed condition			Yield under submergence stress condition								
Designation	Plant height (cm)	Growth duration (days)	Yield (t/ha) at Gazipur	Gazipur Water Tank	Rangpur Water Tank	Rangpur Sadar	Lalmonirhat Sadar	Aditmari Lalmonirhat	Gaibandha	Kurigram	Chittagong	Mean
IR16F1148	120	124	**5.31**	5.66	5.44	5.64	4.95	5.05	4.04	3.84	5.57	**5.02**
BRRI dhan71 (Sus. Ck)	118	117	**4.37**	0.00	5.2	5.18	4.15	4.72	3.65	1.43	3.43	**3.47**
Binadhan11 (Tol.Ck)	111	120	**3.99**	4.76	4.7	5.15	4.45	4.26	3.91	3.02	3.0	**4.16**
$LSD_{0.05}$	5.28	1.17	0.60	0.68								**0.24**
CV (%)	2.76	0.56	8.5	9.52								



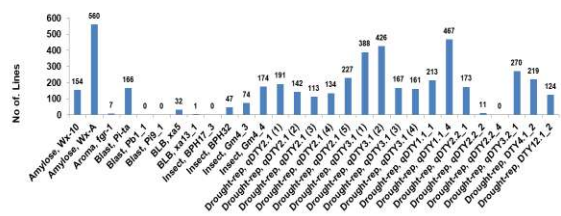


Fig. 15. Selection intensity in the genotypes of LST, DTR, T. Aman 2021-22.

Fig. 16. Trait marker profile of the genotypes of LST, DTR, T. Aman 2021-22.

Investigators: M A Kader, R R Majumder, M E Haq, U R Shaha and K Fatema

Development of water saving and aerobic rice varieties. The objective of the project was to develop short duration water-use-efficient rice genotypes with 10% more yield than the check varieties under transplanted alternate wetting and drying (AWD) and aerobic conditions. A total of 18 crosses were made using 23 parents and 1,670 F_1 seeds were obtained, and 13 single crosses were selected and confirmed through QC SNP panel analysis. Panicles of 292 F_3 from four crosses were advanced through FRGA. From advanced yield trial (AYT) conducted under AWD condition, seven genotypes were selected from 12 genotypes tested. In OYT, 53 genotypes were selected from 140 genotypes. In AYT, the genotype BR11206-5B-351 produced the highest yield (6.6 t/ha) under AWD condition however it was not significantly higher than the check variety BRRI dhan89 (6.2 t/ha). In OYT, yield of the genotype IR18R1109 (7.5 t/ha), IR18R1179 (7.3 t/ha) and IR18R1176 (7.3 t/ha) were significantly higher than the check variety BRRI dhan81 (5.5 t/ha) with similar growth duration. The heritability obtained for grain yield under stress condition was ranging from 74 % to 99% indicating acceptable level of precision in these experiments.

Investigator: Sharmistha Ghosal, Z A Riyadh and K M Iftekharuddaula

Deployment and validation of high beta-carotene rice and high iron as well as zinc rice varieties (Healthier Rice). The main objective of the project was to develop high yielding transgenic rice varieties with enhanced provitamin-A, iron and zinc content in polished rice grain. A total of 2,280 F_1 seeds were obtained from six crosses in T. Aman 2021-22 to develop high iron and zinc enriched rice (HIZR). For developing provitamin-A enriched rice, 123 homozygous plants were selected from six backcrosses from BC_3F_1 generations through marker assisted selection (MAS) method. Twelve genotypes from contained trial (CT) were selected based on the yield performances from 24 transgenic lines of provitamin-A enriched GR2E BRRI dhan49 and GR2E BRRI dhan62.

In Boro 2021-22, 782 BC_1F_1 seeds were obtained from six backcrosses to develop high iron and zinc enriched rice. In total 349 plants were selected from BC_3F_1 generation for developing provitamin-A enriched golden rice through MAS selection method. Ten genotypes from CT were selected based on the yield performances from 70 transgenic lines of provitamin-A enriched GR2E BRRI dhan28. Among 11 genotypes, three genotypes were selected from three events IRS1030-039, IRS1030-031, IRS1027-059 from the confined field trial (CFT) conducted at Gazipur, Rajshahi, Barishal, Satkhira and Habiganj districts of Bangladesh under Healthier Rice project.

Investigators: M A Kader, R R Majumder, U R Shaha and K Fatema.

International network for genetic evaluation of rice (INGER): This project focused on sharing and use of germplasm and breeding lines through international platform for the acceleration of genetic improvement of rice varieties. Totally 28 genotypes out of 116 from six INGER nursery sets of T. Aman 2021-22 and five genotypes out of 62 from two INGER nursery sets of Boro 2021-22 seasons were selected to be used in different breeding programmes for direct use in the breeding pipeline or as parents.

National Coordinator: K M Iftekharuddaula, **Key Cooperator**: Sharmistha Ghosal

Biotechnology Division

SUMMARY

A total of 31 experiments were conducted during the year 2021-22. A doubled haploid line BR (Bio)8961-AC26-16 was approved by National Technical Committee of Bangladesh as BRRI dhan103 for T. Aman season. Thirteen doubled haploid lines derived from a cross between BRRI dhan29 and Kanaklata for developing low glycemic index (GI) rice variety were grown as PYT in T. Aman 2021. Among them, five lines were selected. In total 126 calli were obtained from four different crosses for premium quality rice variety and 94 green plants were regenerated. Among them seeds were harvested from 19 regenerated double haploid plants of BRRI dhan90/Kataribhog cross. Besides 842 F_1 seeds were harvested from ten crosses for future anther culture programme. Seven plants were selected for backcross progeny (BC_2F_3) of BRRI dhan50*^{2} /(Bashful/BRRI dhan50 (DH_1)). During Aus 2021 a total of 261 F_1 seeds were harvested from ten crosses for high yielding Aus varieties. During Boro 2021-22, 3 and 19 lines for antioxidant enriched black rice were selected from PYT and OT respectively. Twelve lines were also selected during T. Aman 2021. One line was selected from three doubled haploid lines in T. Aman 2021 for the development of intermediate amylose rice. These lines were also evaluated by Plant Breeding Division in hilly areas. During Boro 2021-22, five antioxidant enriched black rice were developed using anther culture were evaluated as PYT and four lines were selected for RYT. Forty antioxidant enriched black rice developed by using both seed and anther culture were evaluated as OT in T. Aman 2021 and 12 lines were selected for further evaluation. Twenty-one lines were selected for PYT from sixty-nine antioxidant enriched black rice lines developed by using both seed and anther culture in Boro 2021-22. Eighty-four plants were selected from 38 lines of four different wide crosses. Besides, nine backcrosses were done with previously embryo rescued plants to reduce hybrid sterility and nine plants (BC_2F_2) were selected. One QTL (q7.1 TSH) on chromosome 7 was identified for taller seedling height from a F_2 population of BR11 x Sadamota (acc. no. 1576). One hundred and seven F_5 progenies were selected based on aroma, growth duration and plant height from the cross between BRRI dhan87 and Kalijira for the development of high yielding aromatic rice. All tested aromatic lines were confirmed by using functional marker of fragrance gene *BADH2*. Two hundred and forty-nine F_1 seeds were harvested for both blast and bacterial blight resistant rice. BRRI dhan29 was transformed with salt tolerant genes (*GlyI and GlyII).* Seventeen fixed lines were harvested from T_5 plants. Transgenic plant containing mangrove salt tolerant gene, *AeMDHAR* was crossed with BRRI dhan28 and three BC_2F_3 plants are now growing in transgenic net house for further evaluation. Drought and heat tolerant *TaCRT* gene was isolated from wheat to develop drought tolerant rice by *Agrobacterium* mediated transformation. During T. Aman 21, seven lines were selected from 20 fixed lines of EMS treated somaclonal variants of BR11. A total of 7000 M4 lines of Kaoun (*Setaria italica*) have been developed to observe loss of C4 functions under low concentration (20 ppm) CO_2 for 72 hours. DNA of seven aromatic and two non-aromatic rice were amplified with a functional marker of *BADH2* gene and sequenced. Multiple alignment of seven aromatic and two non-aromatic rice was done with functional *BADH2* gene. Eight bp deletion was observed in aromatic rice Kalijira, Radhunipagol, BR5, BRRI dhan34 and in BRRI dhan70.

DEVELOPMENT OF DOUBLE HAPLOID RICE THROUGH ANTHER CULTURE

High yielding rice variety for Aman season

The proposed line BR (Bio)8961-AC26-16 was approved by National technical committee of Bangladesh as BRRI dhan103 for T. Aman season. The variety produced 17.71% higher yield than BRRI dhan87 with similar growth duration. The average yield of proposed BRRI dhan103 is 6.2 ton/ha.

Low glycemic index (GI) rice variety

Six and seven doubled haploid lines were grown as two PYT in T. Aman 2021. Among them two and three lines were selected respectively depending on the growth duration and yield compared with the check variety (Tables 1and 2). During Boro 2021-22, two doubled haploid lines derived from a cross between BRRI dhan29 and Kanaklata were evaluated as a regional yield trial (RYT). None of them was selected.

Table 1. Agronomic characteristics of selected anther culture derived materials. PYT-1, T. Aman 2021.

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)10381-AC11-1-1	129	125	5.41
BR(Bio)10381-AC11-5-1	122	108	4.82
BR(Bio)10381-AC11-6-1	140	125	5.26
BR(Bio)10381-AC11-7-1	139	127	6.07
BR(Bio)10381-AC11-8-1	102	106	5.10
BR(Bio)10381-AC11-9-1	136	125	5.03
BRRI dhan71(ck)	138	118	5.71
CV			4.61
LSD			0.43

Table 2. Agronomic characteristics of selected anther culture derived materials. PYT-2, T. Aman 2021.

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)	Remark
BR(Bio)13031-AC1-2	109	119	5.62	
BR(Bio)13031-AC1-3	107	109	3.22	
BR(Bio)13031-AC1-4	104	105	3.39	
BR(Bio)13031-AC1-5	108	109	4.73	
BR(Bio)10381-AC34-1	108	112	3.21	
BR(Bio)10381-AC30-2	104	118	6.32	
BR(Bio)10381-AC11-1	109	114	5.82	
BRRI dhan71(ck)	129	112	5.58	
BRRI dhan87 (ck)	134	126	3.602	lodging
CV			12.48	
LSD			0.96	

Bold = Selected

Investigators: Jannatul Ferdous, Shahanaz Sultana and Md Enamul Hoque

Development of salt tolerant rice variety through anther culture

Two doubled haploid fixed lines from BRRI dhan28/BRRI dhan61 cross were evaluated along with the checks BRRI dhan28, BRRI dhan96 and BRRI dhan86 during Boro 2021-22 as SYT (Table 3). Among them no lines were selected due to lower yield than the check varieties. On the other hand 7,171 hybrid anthers from 13 crosses were plated on N6 media. In total 17 calli were obtained from different crosses and no green plants were regenerated yet. Ten crosses were done and 470 F_1 seeds were collected during Boro 2021-22 for further anther culture.

Table 3. List of double haploid (DH) lines evaluated as SYT during Boro 2021-22.

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)11310-AC2-1	91	142	5.94
BR(Bio)11310-AC2-2	93	144	5.80
BRRI dhan28	96	143	6.60
BRRI dhan96	95	142	7.11
BRRI dhan86	96	142	6.89
CV			7.12
SD			0.68

*Parentage: BRRI dhn28/ BRRI dhan61

Investigators: Nilufar Yasmin Shaikh and Ripon Kumar Roy

Development of premium quality rice variety through anther culture

During T. Aman 2021, a total of 4,969 and 7,776 hybrid anthers from nine crosses were plated on N6 and M10 media. In a total of 126 calli were obtained from different crosses and 94 green plants were regenerated from BRRI dhan90/Kataribhog, BRRI dhan90/Kalijira, BRRI dhan90/BRRI dhan34, and BRRI dhan90/Tulshimala crosses (Table 4). Among them seeds were harvested from 19 regenerated doubled haploid plants of BRRI dhan90/Kataribhog cross. Ten crosses were done for future anther culture programme. In total 842 F_1 seeds were harvested for future anther culture programme. During T. Aman 2021, two OT was conducted with double haploid plants from BRRI dhan38/Bashful and BRRI dhan50/Bashful cross. None of them was selected due to lodging. Backcross progeny ($BC2F_3$) of BRRI dhan50/Bashful(DH1)//*^{2} BRRI dhan50 were grown in T. Aman 2021 as pedigree. Seven plants were selected for further evaluation.

Development of Aus variety through anther culture

Ten crosses were made. A total of 261 F_1 seeds were harvested for future anther culture programme.

Investigators: Shampa Das Joya, Shahanaz Sultana, Jannatul Ferdous and Md Enamul Hoque

Table 4. Number of anthers plated, calli obtained and plants regenerated in T. Aman 2021.

Cross	No. of Anther plated		No. of calli obtained	No. of plant regenerated
	N6	M10		
BRRI dhan70/ Tulshimala (Acc. 1870)	857	1055	7	
BRRI dhan87/ Tulshimala (Acc. 1870)	509	254	-	
BRRI dhan90/ Kataribhog	487	676	94	91
BRRI dhan87/ Kalizira (B)	950	1475	-	
BRRI dhan90/ Kalizira (B)	442	975	10	1
BRRI dhan90/ BRRI dhan34	942	1645	7	1
Kalizira/ Shakkorkhana	72	320	5	
BRRI dhan87/ Radhunipagol (Acc. 6711)	507	1036		
BRRI dhan90/ Tulshimala (Acc. 1870)	203	340	3	1
Total	4969	7776	126	94

Fig. 1. Regenerated plants from BRRI dhan90/Kataribhog by Anther culture.

Investigators: Nilufar Yasmin Shaikh, Jannatul Ferdous and Md Enamul Hoque

Development of antioxidant enriched black rice variety through anther culture

During Boro 2021-22, five antioxidant enriched black rice were developed using anther culture were evaluated as PYT. Four lines were selected for RYT (Table 5). Forty antioxidant enriched black rice developed by using both seed and anther culture were evaluated as OT in T Aman 2021. Twelve lines were selected for further evaluation. Sixty-nine antioxidant enriched black rice lines developed by using both seed and anther culture were evaluated as two OT in Boro 2021-22. Among them 21 lines were selected for PYT (Tables 6 and 7). Moreover 46 soma clonal (SC4) variants of antioxidant enriched black rice were evaluated as pedigree. Among them 32 soma clonal (SC4) variants of antioxidant enriched black rice were evaluated as pedigree.

Table 5. Agronomic characteristics of selected anther culture derived materials. PYT, Boro 2021-22.

Designation	Plant Height (cm)	Growth Duration (day)	Yield (t/ha)
BR(Bio)13028-AC24-1-2	120	141	6.42
BR(Bio)13028-AC24-2-3	101	142	5.97
BR(Bio)13028-AC24-2-4	106	143	6.82
BR(Bio)13028-AC24-3-3	113	142	6.03
BR(Bio)13028-AC11-3-1	104	140	4.27
BRRI dhan86	97	142	6.39
BRRI dhan96	97	141	7.04

Table 6. Agronomic characteristics of selected anther culture derived materials. OT, Boro 2021-22.

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)13028-AC24-4-4-2	106	142	8.48
BR(Bio)13028-AC11-2-1-1	135	143	7.17
BR(Bio)13028-AC15-3-1-2	107	143	6.88
BR(Bio)13028-AC24-3-2-4	101	141	7.31
BR(Bio)13028-AC24-4-2-2	104	148	6.86
BR(Bio)13028-AC24-4-3-3	110	143	7.45
BR(Bio)13028-AC24-4-4-2	110	142	6.99
BRRI dhan86 (Ck)	96	143	6.47

Table 7. Agronomic characteristics of selected anther culture derived materials. OT, Boro 2021-22.

Designation	Plant height (cm)	Growth duration (days)	Yield (t/ha)
BR28/Podi chelum-AC 4-1-2	123	141	5.24
BR28/Podi chelum-AC 6-2-6	105	143	5.17
BR28/Podi chelum-AC 6-3-2	131	143	5.05
BR28/Podikool-AC1-2-2	101	144	5.41
BR28/Podikool-AC1-2-3	103	141	6.27
BR28/Podikool-AC1-2-4	112	145	5.79
BR28/Podikool-AC1-2-6	110	143	4.86
BR28/Podikool-AC1-2-7	111	141	5.39
BR28/Podikool-AC2-2-2-1	126	141	5.27
BR28/Podikool-AC2-2-2-3	124	145	5.18
BR28/Lansan-AC 5-2-1	128	144	5.53
BR28/Lansan-AC13-2-2	98	141	5.11
Lansan-2-1	127	141	5.10
Lansan-2-2	108	146	5.22
BRRI dhan86(CK)	91	141	4.29
BRRI dhan96(CK)	94	141	7.03

Investigators: Jannatul Ferdous, Shahanaz Sultana and Md Enamul Hoque.

Development of doubled haploid rice variety for high yield

Four doubled haploids were grown as SYT in T. Aman 2021. None of them was selected for further evaluation because amylose content of these materials were less than 20%.

Investigators: Shahanaz Sultana**,** Jannatul Ferdous and Md Enamul Hoque.

Development of doubled haploid photoperiod sensitive rice variety through anther culture

A total of 6,067 anther were plated in two media. Two calli were obtained from the cross BRRI dhan87/BR22 and each BRRI dhan87/ BR23. BRRI dhan87/BRRI dhan46 produced single callus. Seven crosses were done in T. Aman 2021. A total of 273 F_1 seeds were harvested for anther culture in T Aman 2021

Investigators: Md Arafat Hossain, S M Hisam Al Rabbi, Shahanaz Sultana, Md Enamul Hoque

Development of doubled haploid rice variety through anther culture for intermediate amylose rice

Three doubled haploid lined were grown as SYT in T. Aman 2021. Among them one line was selected for further evaluation (Table 8). These materials were given to Plant Breeding division for evaluation under hilly areas.

DEVELOPMENT OF RICE VARIETY THROUGH SOMACLONAL VARIATION

Development of premium quality (Kalijira type) variety through somaclonal variation

Fourteen lines somaclonal variants (SCV_1) of Kalijira rice were grown in T. Aman 2021. One hundred and twenty-six plants were selected for further evaluation.

Investigators: Shahanaz Sultana, Jannatul Ferdous and Md Enamul Hoque

Development of rice variety through wide hybridization followed by embryo rescue

Thirty-eight lines from different generation of wide hybridization followed by embryo rescue programme were evaluated in T. Aman 2021 and Boro 2021-22 (Table 9). Among them, eighty-four plants were selected from BRRI dhan28/*O. nivara* (IRGC103821), BRRI dhan28/*O. glaberrima* (IRGC105190), BRRI dhan87/*O. glaberrima* (IRGC105190), BRRI dhan48/*O. glaberrima* (IRGC105190) for generation advancement. Besides those, five backcrosses were done with previously embryo rescued plants to reduce hybrid sterility. Seeds were harvested from those and evaluated in T. Aman 2021. Among them nine plants (BC_2F_2) were selected for generation advancement.

Table 8. Agronomic and physic-chemical characteristics of selected anther culture derived materials, SYT-1, T. Aman 2021.

Designation	PH	GD	Yield (t/ha)	Amy (%)	Pro (%)	Shape and size
BR (Bio)10376–AC4-1-3	105	110	3.59	20.7	9.5	LS
BR (Bio)10376–AC9-1-3	107	108	3.61	20.4	9.0	LS
BR (Bio)10376–AC11-3-1	108	111	5.01	20.9	9.0	LS
BRRI dhan71	131	115	4.36	24.3	9.3	LB

Investigators: Jannatul Ferdous, Shahanaz Sultana, and Md Enamul Hoque

Table 9. Number of plants selected from embryo rescued rice lines during T. Aman 2021.

Cross	Generation	No. of lines evaluated	No. of plants selected
BRRI dhan28/*O. nivara* (IRGC103821)	BC1F2 - BC1F6	13	54
BRRI dhan28/*O. glaberrima* (IRGC105190)	F5	11	15
BRRI dhan87/*O. glaberrima* (IRGC105190)	F5	1	2
BRRI dhan48/*O. glaberrima* (IRGC105190)	F5	13	13
Total		38	84

Investigator: Nilufar Yasmin Shaikh and Ripon Kumar Roy

SELECTION BREEDING OF RICE THROUGH MARKER ASSISTED SELECTION

Identification of QTLs for taller seedling height

Genotyping was done using 55 polymorphic primers with 184 F_2 individuals developed from a cross between BR11 x Sadamota (acc. no. 1576). One QTL (q7.1 TSH) on chromosome 7 was identified for taller seedling height in rice (Figs. 2 and 3).

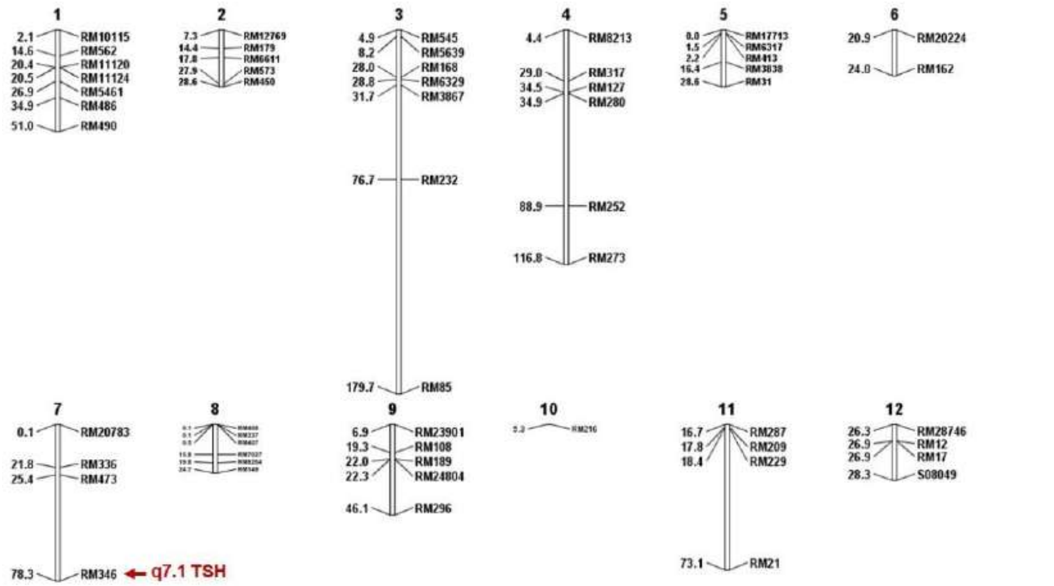
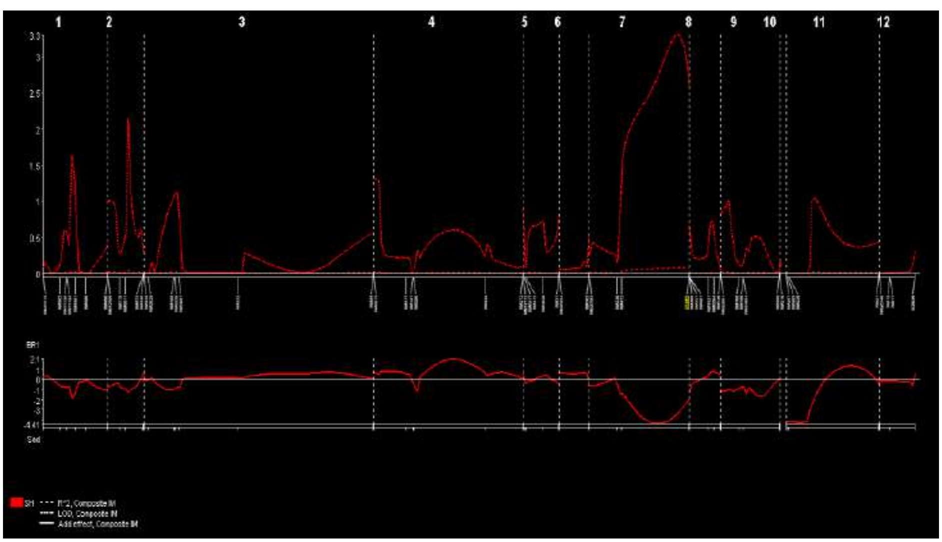


Fig. 2. A genetic linkage map of the 12 chromosomes of rice constructed based on selected individuals of F2 population of a cross between BR11/Sadamota. The map was constructed using 55 SSR markers.



Significant threshold level of LOD=3

Fig. 3. Chromosomal location of QTL q7.1 TSH for taller seedling height by CIM.

Investigators: Nilufar Yasmin Shaikh, Jannatul Ferdous, Md Arafat Hossain, S M Hisham Al-Rabbi and Md Enamul Hoque.

Marker assisted selection for fragrance in F_5 Population of BRRI dhan87 and Kalijira.

Seventy two pedigree lines developed from a cross between BRRI dhan87 and Kalijira were evaluated. Among them 107 plants were selected on the basis of aroma, growth duration and plant height. All the tested aromatic lines were confirmed by using functional marker of fragrance gene *BADH2* (Fig. 4). The primers combination of ESP and IFAP amplified the fragrance specific allele at 257 bp. On the other hand, the primers combination of INSP and EAP amplified the expected non-fragrance-specific allele (355 bp).

Marker assisted selection for aromatic and submergence tolerance rice genotype

Hybridization between BRRI dhan90/Kalijira and BRRI dhan52/Kalijira were done. Ninety-three and 185 F_1 seeds were harvested from BRRI dhan90/Kalijira and BRRI dhan52/Kalijira

Investigators: Jannatul Ferdous, Shahanaz Sultana and Md Enamul Hoque.

Development of multiple disease resistant (blast and bacterial blight) rice varieties using marker assisted selection

For both BB and blast resistant four crosses such as BR (Bio)11447-1-28-14-3/IR64Pi9 (L), BR (Bio)11447-1-28-14-3/IR64Pi9 (E), BR (Bio)11447-3-10-7-1/IR64Pi9 (L), BR (Bio)11447-3-10-7-1/IR64Pi9 (E) were made. A total of 28, 103, 90 and 28 F_1 seeds were harvested from four crosses respectively

Investigators: Jannatul Ferdous, Shahanaz Sultana, Md Enamul Hoque, Ashik Ikbal Khan.

Association mapping for rice photosensitivity

An association mapping panel of 147 was raised in two replications in short-day condition. Heading dates were scored for each.

Investigators: S M Hisam Al Rabbi, Md Arafat Hossain, Ripon Kumar Roy, Munnujan Khanam

Production of Transgenic Plants that are Resistant to Different Biotic and Abiotic Stresses

Development of salt tolerant transgenic rice

BRRI dhan29 was transformed with salt tolerant genes (*GlyI and GlyII*). After transformation with *GlyI and GlyII* genes, plants were confirmed by GlyI and GlyII primers and sequencing. Seed from 17 T_5 plants were harvested. Now these are growing in transgenic net house for further evaluation.

Investigators: Shahanaz Sultana, Jannatul Ferdous, Shampa Das Joya and Md Enamul Hoque

Introgression of salt tolerant mangrove gene

Transgenic plant containing mangrove salt tolerant gene *AeMDHAR* was crossed with BRRI dhan28 for the introgression of salt tolerant gene *AeMDHAR* . *AeMDHAR* salt tolerant gene (from mangrove plant) containing transgenic was crossed with BRRI dhan28 to introgress *AeMDHAR salt* tolerant gene. Three BC_2F_3 plants of BRRI dhan28 are now in in transgenic net house for further evaluation and confirm ation by gene specific primer.

Investigators: Shahanaz Sultana, Jannatul Ferdous, Shampa Das Joya and Md Enamul Hoque.

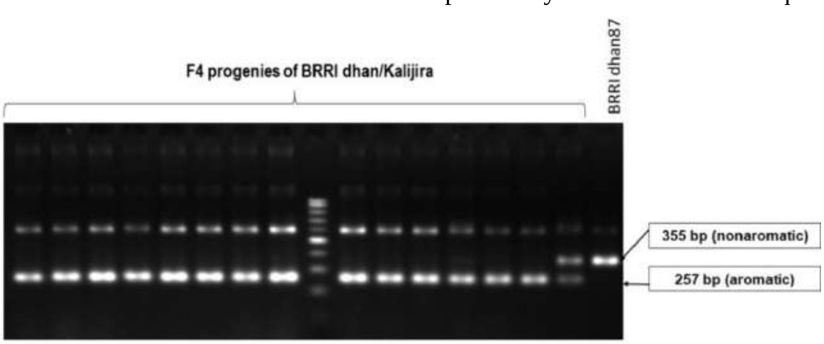


Fig. 4. Confirmation of F_4 progenies of BRRI dhan87/Kalijira with functional marker of *BADH2* gene.

Investigators: Jannatul Ferdous, S M Hisham Al-Rabbi and Md Enamul Hoque.

Development of salt tolerant transgenic rice with *PVA1*

A construct was made at Biotechnology Division of BRRI by using vacuolar ATPase (*PVA1*) from a wild rice. *Porteresia coarctata* to develop salt toleranted transgenic rice variety. Twenty-one day Old calii of BRRI dhan86 were used transform with *PcPVA1 through Agrobacterium.* Calli were co-cultured with *PVA1*

Investigators: Shahanaz Sultana, Jannatul Ferdous, Shampa Das Joya and Md Enamul Hoque.

Development of high yielding aromatic rice lines through genome editing

For deactivation of Function of *BADH2* gene, two primers were designed for construct preparation. Vector pRGEB31 was used in this experiment. DNA was extracted from pRGEB31. Both primer and vector pRGEB31 were digested with *Bsa1* and ligated for construct preparation

Investigators: Shahanaz Sultana, Jannatul Ferdous, S M Hisam Al Rabbi, Shampa Das Joya, Md Enamul Hoque, Hirendro Nath Barman

Isolation and cloning of stress tolerant gene from Wheat

cDNA was synthesized from RNA of wheat to isolate and clone heat and drought tolerant gene. *TaCRT* gene was isolated from wheat (Fig. 5) and send for sequencing

Investigators: Jannatul Ferdous, Shahanaz Sultana, Md. Enamul Hoque and Hisam Al Rabbi, Md Sentu Rahman, Sadia Jafrin

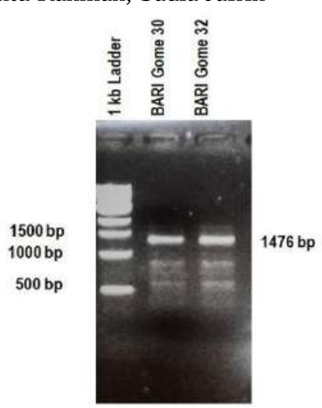


Fig. 5. Targeted T*aCRT* gene isolated from wheat.

Development of rice variety through mutation breeding

Development of variants using EMS of BRH-11-9-11-4-5B having reduced sterility

In total 500 BRH-11-9-11-4-5B seeds were treated with 20 mM EMS solution for six hrs to create variation. Six M_2 lines along with check were transplanted in Boro 2021-22 and 31 plants were selected for further evaluation

Investigators: Shahanaz Sultana, Md Enamul Hoque, Jannatul Ferdous.

Development of Kilijira type rice variety through mutation by NMU

Seed from 215 M_2 Kilizira lines were transplanted in T. Aman 2021. Seeds from 91 M_3 plants were harvested during T. Aman2021 for further evaluation.

Investigators: Shahanaz Sultana, Md Enamul Hoque, Jannatul Ferdous

Development of high yielding sheath blight resistant rice variety

During T. Aman 2021, 500 seeds of BRRI dhan87 were treated by 20 mM EMS solution for six hrs to create variation. Twenty-two M_2 plants were selected for further evaluation

Investigators: : Md Arafat Hossain, Md S M Hisam Al Rabbi, Shahanaz Sultana, Jannatul Ferdous, Md Enamul Hoque, Shamima Akter

Development of somaclonal variants of BR11 using EMS treaded rice seed

During Aus 2021, twenty fixed lines of EMS treated somaclonal variants of BR11 were grown as OT-1 with check variety BRRI dhan48. None of them was selected. During T. Aman 20 21, one OT as OT-4 was conducted with 20 fixed lines of EMS treated somaclonal variants of BR11 with the check variety BR11 and among them seven lines were selected for further evaluation. Besides, during T. Aman 2021, 116 pedigree lines were evaluated as pedigree. Fifty fixed lines were selected for further evaluation.

Table 10. Agronomic Characteristics of selected lines, OT. T Aman 2021.

Designation	PH	GD	Yield t/ha
T6-BR11-14-1-46-2	112	107	2.16
T6-BR11-16-1-47-1			-
T5-BR11-19-3-5-1	115	107	2.96
T5-BR11-15-1-51-2	115	107	6.64
T5-BR11-19-4-52-1	116	107	-
T5-BR11-19-4-52-2	128	139	2.73
T5-BR11-19-5-53-1	136	143	4.61
T5-BR11-19-5-53-2	130	143	4.65
T5-BR11-19-6-54-1	109	109	5.70
T4-BR11-32-1-62-2	114	109	3.78
T4-BR11-37-1-65-1	117	109	3.74
T4-BR11-81-1-80-4	130	139	4.28
T4-BR11-81-1-80-5	126	139	5.14
T4-BR11-82-1-82-2	122	140	6.35
T4-BR11-96-1-93-2	137	141	5.72
T4-BR11-96-3-95-1	128	141	5.86
T4-BR11-97-1-99-1	124	140	6.36
T4-BR11-97-1-99-3	131	143	5.65
T4-BR11-99-101-1	116	124	4.93
T4-BR11-99-107-2	137	139	3.86
BR11 (Ck)	122	143	4.58
BRRI dhan87(Ck)	137	124	4.57

Fig. 6. Panicles of somaclonal variants of BR11.

Investigators: Shahanaz Sultana, Jannatul Ferdous and Md Enamul Hoque

INNOVATIVE RESEARCH

Identification of major regulators for C4 rice

Generation advancement for high-throughput screened for loss of C4 functions. A total of 7,000 M4 lines Kaoun (*Setaria italica*) have been developed for further study. These lines are gradually raised, subjected to CO2 stress in low concentration (20 ppm) CO2 chamber for 72 hours and high-throughput screened for loss of C4 functions.

Investigators: S M Hisam Al Rabbi, Shahanaz Sultana, Munnujan Khanam, Sazzadur Rahman, Md Enamul Hoque

BASIC RESEARCH

Study on Kernel Elongation of Rice

Fifty-seven selected genotypes were grown in T. Aman 2021 from single plant to make genetic purity. Purified seed from single hill were harvested

Investigators: Shahanaz Sultana, Jannatul Ferdous, Shampa Das Joya, Md Enamul Hoque, Habibul Bari Sojib

Variation of *BADH2* gene sequences in rice genotypes

DNA of seven aromatic and two non-aromatic rice were amplified with a functional marker of *BADH2* gene and sequenced. Multiple alignment of seven aromatic and two non-aromatic rice was done with functional *BADH2* gene. Eight bp deletion was observed in aromatic rice Kalijira, Radhunipagol, BR5, BRRI dhan34 and in BRRI dhan70, which is similar with Pakistani Basmati rice (Fig. 6). Interestingly, 8 bp deletion was not observed in Raniselut and Tulshimala indicating deletion of *BADH2* gene in some other location of the gene.

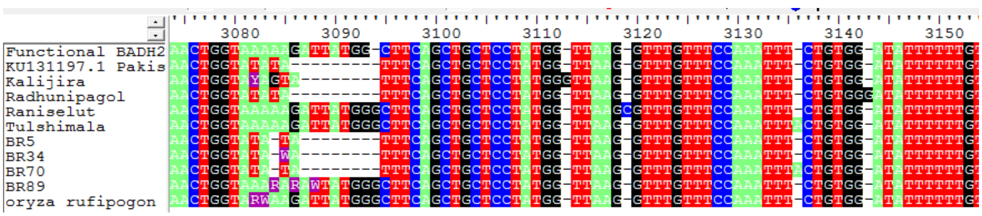


Fig. 6. Muliple alignment of *BADH2* gene sequence of aromatic and nonaromatic rice with reference sequence of functional *BADH2*.

Investigators: Jannatul Ferdous, Shahanaz Sultana, Md Enamul Hoque

Genetic Resources and Seed Division

SUMMARY

In total, 126 rice germplasm of which three in Aus, 20 *Jhum* rice, 38 in T. Aman and 65 in Boro seasons were collected from different districts of Bangladesh. One hundred and thirty-six germplasm accessions of which 28 germplasm in T. Aus 2020-21, 50 in T. Aman 2021-22 and 58 in Boro 2021-22 were morphologically characterized using 'Rice Germplasm Descriptors and Evaluation Form' of Genetic Resources and Seed Division (GRSD).

Rejuvenation of 2,848 accessions was completed of which 734 in T. Aus 2020-21, 1,440 in T. Aman 2021-22 and 674 in Boro 2021-22 seasons. A total of 2,119 accessions of which 700 in Aus 2020-21 and 1,419 in T. Aman 2021-22 were processed and stored in short-term storage. Similarly, 454 accessions of which 207 in Aus 2020-21 and 247 in T. Aman 2021-22 were processed and stored in medium and 287 accessions of which 78 in Aus 2020-21 and 209 in T. Aman 2021-22 seasons were processed and stored in long-term storages respectively. Apart from this, 41 new germplasm were registered as new accessions (from accession number 8,655 to 8,695) in BRRI Genebank. Besides, 2,399 samples of rice germplasm and BRRI developed varieties were supplied to 47 different users.

One hundred and sixteen BRRI developed and recommended rice varieties were maintained along with nucleus seed. Besides, nucleus seed stocks of 63 varieties were produced for the source of breeder seed. In total, 218.72 tons of breeder seed with tags of which 143.44 tons of 20 Boro varieties, 16.36 tons of ten Aus varieties and 58.92 tons of 35 T. Aman varieties were produced. At the same time, 198.994 tons of breeder seed of which 131.341 tons of 20 Boro varieties, 16.215 tons of ten Aus varieties and 51.438 tons of 34 T. Aman varieties were distributed among 718 partners (GO, NGO and PS) of BRRI 'Rice Seed Network'. Breeder and foundation seed producing plots and farms were also visited to observe the varietal purity and performance of respective seed.

RICE GERMPLASM CONSERVATION AND MANAGEMENT

Germplasm collection and acquisition. Three collection missions were made during the reporting year and 126 rice germplasm of which three in Aus, 20 *Jhum* rice, 38 in T. Aman and 65 in Boro seasons were collected from different districts of Bangladesh including hilly areas (Fig. 1).

PI: Mohammad Khalequzzaman and Mir Sharf Uddin Ahmed.

Fig. 1. Pictorial views of collecting rice germplasm from hilly areas of Bangladesh.

Germplasm rejuvenation for storage. Rice germplasm were rejuvenated to increase the seed for safe storage in the Genebank. The experiment was carried out under transplanted conditions using double rows of 5.4 m long per accession with 20 × 20 cm spacing between rows and plants respectively. Fertilizers were applied @ 60:20:40 kg NPK/ha in T. Aus and T. Aman and @ 80:20:40 kg NPK/ha in Boro seasons.

A total of 2,848 germplasm of which 734 accessions (between Acc. 6201 to 8600) in T. Aus 2020-21; 1,440 accessions (between Acc. 4001 to 6000) in T. Aman 2021-22 and 674 accessions (between Acc. 4601 to 8650) in Boro 2021-22 were rejuvenated in field for getting fresh seed and on average 500 g of seeds per accession were produced.

PI: Armin Bhuiya (T. Aus), Tonmoy Chakrabarty (T. Aman) and Md Humayun Kabir Baktiar (Boro).

Morphological characterization of germplasm. Three experiments were conducted to characterize 136 rice germplasm (accessions as well as new collections) of which 28 in T. Aus 2020-21, 50 in T. Aman 2021-22 and 58 in Boro 2021-22 through 52 agro-morphological traits (both 21 quantitative and 31 qualitative characters) using the Rice Germplasm Descriptors and Evaluation Form (2018), GRSD, BRRI, Gazipur. The experiments were conducted using a single row of 5.4 m long for each entry/accession with 25 × 20 cm spacing in T. Aman and 20 × 20 cm spacing in Boro between rows and plants respectively. Fertilizers were applied @ 60:20:40 kg NPK/ha in T. Aus and T. Aman and @ 80:20:40 kg NPK/ha in Boro seasons. Appropriate control measures were taken for insect, pests, diseases and weeds when necessary.

In T. Aus 2020-21, a total of 28 germplasm along with new collections were characterized. Among them, feight had short (<116 days), 13 had medium (116-131) and seven had long (>131) growth duration (Table 1). On the other hand, five germplasm had short (<90 days), 19 had medium (90-110) and four had long (>110) duration to the 50% flowering. In case of plant height, out of 28, eight germplasm were found with the shortest (<90 cm) and four with the longest (>130) height. Similarly, ten germplasm had very lowest (<4.08 mm) and seven possessed with the highest (>4.88 mm) culm diameter. Chakma Chikon and 576 possessed the lowest (3.50) and the highest (10) effective tiller number respectively. NBR9005-53-1-1 and PY84 possessed the lowest (2.70) and the highest (5.02) grain length breadth ratio respectively.

PI: Armin Bhuiya

In T. Aman 2021-22, all 50 NC germplasm were characterized. Among them, 10 had short (≤117 days), 12 had medium (118-125), 23 had moderate (126-133) and five had long (≥134) growth duration (Table 2). In case of plant height, out of 50, 12 germplasm were found with short (≤98 cm) and eight with long (≥135). Similarly for TGW, ten germplasm had very low (≤15 g) and two with high (≥28 g) grain weight at 14% moisture. Eleven germplasm had low (≤15 g/hill) and three possessed high yields (≥36 g) per hill. The shortest growth duration (110 days) was observed in FulKuri, Indian, BR10538-2-1-2-3-2. The shortest plant height (81.8 cm) was observed in the Indian and the longest (152.6 cm) in Kala Biruin. Debmoni had the highest (32 g) and Kala Biruin had the lowest (10 g) thousand grain weight (TGW). The highest yield per hill (42.18 g) was observed in BR10005-25-8-4-7-20. PI: Tonmoy Chakrabarty.

In Boro 2021-22, among the 58 germplasm accessions, one germplasm had short (<140 days), 33 had medium (140-150 days) and 24 had long (>150 days) growth duration (Table3). Similarly, nine germplasm were found with short (<110 cm), 44 medium (110-130 cm) and five with long (>130 cm) plant height. In case of panicle length, 14 germplasm had long (26-30 cm) panicle. For TGW, one germplasm had very low (≤15 g), 21 had high (24-27g) and four had very high (>27 g) TGW. For yield, 18 germplasm had higher (>20 g) yield per hill. The shortest growth duration (139 days) was observed in Habataki (Acc. 4190). The shortest plant height (70 cm) was observed in Habataki (Acc. 4190) and the longest (134 cm) in Muirol (Acc. 4014). GachiBoro (Acc. 4204) had the lowest (15.0 g) and Saita (Acc. 1794) had the highest (29.66 g) TGW. The highest yield per hill (28.42 g) was observed in GuchiBoro (Acc. 1796).

PI: Nashirum Monir.

Table 1. Some important features of characterized germplasm in T. Aus 2020-21.

Growth duration (day)		Plant height (cm)		Culm diameter (mm)		Total no. of tiller		No. of effective tiller		Grain LB ratio		Brown rice LB ratio		50% flowering (day)	
Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries
<116	8	<90	8	<4.08	10	<5	1	<5	2	<3.0	15	<2.0	1	<90	5
116-131	13	90-130	16	4.08-4.88	11	5-10	19	5-9	19	3.0-4.0	10	2.0-3.0	22	90-110	19
>131	7	>130	4	>4.88	7	>10	8	>9	7	>4.0	3	>3.0	5	>110	4

Shortes (102)	NC/25 (PY84)	Shortest (59.80)	NC/25 (PY84)	Shortest (3.28)	NC/25 (PY84)	Lowest (3.80)	NC/1 (Chakma Chikon)	Lowest (3.50)	NC/1 (Chakma Chikon)	Lowest (2.70)	NC/6 (NBR 9005-53-1-1)	Lowest (1.66)	Acc. 4954 (BIR PALA-2)	Lowest (74)	NC/25 (PY84)
Longest (145)	NC/16 (SundoriBinni)	Longest (160.10)	Acc. 4944 (CN (Indian))	Longest (5.66)	NC/20 (My Wachha)	Highest (11.30)	NC/26 (576)	Highest (10)	NC/26 (576)	Highest (5.02)	NC/25 (PY84)	Highest (4.18)	NC/25 (PY84)	Highest (118)	NC/16 (SundoriBinni)
Mean	124.36		105.25		4.38		8.27		7.37		3.18		2.63		98.21
Std. Dev.	11.33		23.13		0.68		2.07		1.87		0.57		0.52		10.33
CV	9.11		21.97		15.55		25.08		25.44		17.91		19.95		10.52
LSD	4.20		8.57		0.25		0.77		0.69		0.21		0.19		3.83

Table 2. Some important features of characterized germplasm in T. Aman 2021-22.

Growth duration (day)		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		No. of tiller		Filled grain/panicle		1000-grain weight (g)		Yield/hill (g)	
Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries
≤117	10	≤82	8	≤98	12	≤21	1	≤10	17	≤73	6	≤15	10	≤15	11
118-125	12	83-91	5	99-116	6	22-25	22	11-13	23	74-105	23	16-21	21	16-25	24
126-133	23	92-100	31	117-134	24	26-29	24	14-16	9	106-137	17	22-27	17	26-35	12
≥134	5	≥101	6	≥135	8	≥30	3	≥17	1	≥138	4	≥28	2	≥36	3
Shortest (110)	FulKuri, Indian, BR10538-2-1-2-3-2	Shortest (74)	BR-H15-24-7-B, BR14-9-13-16-B	Shortest (81.80)	Indian	Shortest (19.73)	Indian	Lowest (8.00)	Debmoni, Borodigha, FulKuri	Lowest (41.60)	Borodigha	Lowest (10.00)	Kala Biruin	Lowest (5.98)	Borodigha
Longest (141)	Black Rice	Longest (108)	Black Rice	Longest (152.60)	Kala Biruin	Longest (32.20)	Kala Biruin	Highest (17.00)	GandiShail	Highest (167.80)	PaniBiruin	Highest (32.00)	Debmoni	Highest (42.18)	BR10005-25-8-4-7-20
Mean	123.88		94.42	118.20		25.88		11.72		101.18		19.76		21.68	
S. Dev.	7.52		8.24	19.67		2.70		2.22		27.45		5.00		7.58	
CV	5.6		6.9	14.3		14.9		24.9		39.8		15.0		53.4	
LSD	2.08		2.28	5.45		0.75		0.62		7.61		1.39		2.10	

Table 3. Some important features of characterized germplasm in Boro 2020-21.

Growth duration (day)		Plant height (cm)		Panicle length (cm)		No. of tiller		No. of effective tiller		Grain LB ratio		1000-grain weight (g)		Yield/hill (g)	
Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries
<140	1	<110	9	≤20	1	<10	11	<6	1	<1.1	0	≤15	1	<10	1
140-150	33	110-130	44	21-25	43	10-15	47	6-10	54	1.1-2.0	0	16-19	5	10-20	39
>150	24	>130	5	26-30 >30	14	>15	0	>10	3	2.1-3.0 >3.0	49 9	20-23 24-27 >27	27 21 4	>20	18
Shortest (139)	Habataki (Acc. 4190)	Shortest (70)	Habataki (Acc. 4190)	Shortest (20)	TulsiBoro (Acc. 1968)	Lowest (6)	Habataki (Acc. 4190)	Lowest 5	Habataki (Acc. 4190)	Lowest (2.15)	LaliBoro (Acc. 4210)	Lowest (15)	GachiBoro (Acc. 4204)	Lowest (8.96)	Bash Boro (Acc. 1818)
Longest (160)	Iratom, LalDhan (Acc. 4201,4211)	Longest (134)	Muirol (Acc. 4014)	Longest (29)	Raj Bhog (Acc. 4216)	Highest (12)	Pankaij, Rata Topa, KhairaBoro (Acc. 1817, 4016, 4207)	Highest (11)	Pankaij, Rata Topa, KhairaBoro (Acc. 1817, 4016, 4207)	Highest (4.38)	Super Fast (Acc. 4367)	Highest (29.66)	Saita (Acc. 1794)	Highest (28.42)	GuchiBoro (Acc. 1796)
Mean	150.19		117.12		24.12		10.31		9.28		2.76		22.84		18.11
S. Dev.	4.92		16.70		2.09		1.08		1.09		0.38		2.95		4.91
CV	3.27		14.26		8.69		10.47		11.74		13.67		12.92		27.11
LSD	1.27		4.30		0.54		0.28		0.28		0.10		0.76		1.26

Germplasm processing, registration and storage. In total 2,860 germplasm were processed and conserved with respective accession number in different storages of BRRI Genebank during the reporting year. The germplasm were cleaned and dried with a seed moisture content of less than 9% for short-term storage.

In details, 2,119 accessions of which 700 in Aus 2020-21 and 1,419 in T. Aman 2021-22 were processed and stored in short-term storage.

Similarly, 454 accessions of which 207 in Aus 2020-21 and 247 in T. Aman 2021-22 were processed and stored in medium and 287 accessions of which 78 in Aus 2020-21 and 209 in T. Aman 2021-22 seasons were processed and stored in long-term storages respectively. Therefore, 985 accessions in Aus 2020-21 and 1,875 in T. Aman 2021-22 seasons were processed and stored. Apart from this, 41 new germplasm were registered as new accessions (from accession number 8,655 to 8,695) in BRRI Genebank during 2021-22.

Viability testing, periodic evaluation and routine monitoring of stored germplasm. The seed viability of the stored germplasm in short-term storage of BRRI Genebank was monitored from randomly selected germplasm in three seasons. One hundred and fifteen accessions in Aus, 175 in T. Aman and 110 in Boro seasons were checked and monitored randomly for viability (germination %) test in short-term storage. Among the randomly selected 400 stored germplasm, 191 had viability between 80-90% and 172 had above 90%. Viability was also monitored in mid and long-terms storage using five tester varieties namely Dharial (Acc. no. 649), Hashikalmi (Acc. 3575), Purbachi (Acc. 6207), Nizersail (Acc.1229) and Patnai-23 (Acc. 52.) to predict the viability of germplasm in respective storages. The viability was measured on six month interval usually on October and March of each year. The germination percentages of the five test samples/testers in the medium-term storages were found ranging from 79 to 92% in October 2021 and 82 to 94% in March 2022. Similarly, the germination percentages of the test samples/testers in the long-term storages were found ranging from 83 to 95% in October 2021 and 79 to 95% in March 2022. The germination percentages of the five test samples/testers indicating the probable viability condition of stored germplasm in respective storages.

The seed viability of the germplasm just before storage in the Genebank was also monitored. The germination tests of 410 germplasm just before short-term storage were carried out of which 110 were for Aus, 200 were for T. Aman and 100 were for Boro seasons. Among them, 226 had germination between 80-90% and 140 had above 90%. The germplasm that possessed less than 80% germination will be grown again in the following season for safe keeping.

Germplasm distribution and exchange. A total of 2,399 samples were supplied to 47 different users in the reporting year. Among the samples, 1,946 germplasm accessions were supplied for research purpose and 453 samples of BRRI developed rice varieties were supplied to the researchers, Department of Agricultural Extension (DAE) personnel and university students for research, demonstration as well as other purposes.

PI: Mohammad Khalequzzaman and Mir Sharf Uddin Ahmed.

SEED PRODUCTION AND VARIETY MAINTENANCE

Variety maintenance and nucleus seed production. One hundred and sixteen BRRI developed and recommended rice varieties including 16 locally improved varieties (LIVs) were maintained using panicle to row method, implementing time isolation and performing thorough roguing (Table 4). After harvest, both the intact panicles and nucleus seed of each variety were stored (20°C with 40% RH) for variety maintenance and distribution to researchers, DAE personnel and students respectively.

PI: Ebna Syod Md Harunur Rashid (T. Aman) and Mir Sharf Uddin Ahmed (Boro) for BRRI varieties and Tonmoy Chakrabarty (T. Aman) and Mir Sharf Uddin ahmed (Boro) for LIVs.

Table 4. List of BRRI developed and recommended rice varieties maintained during 2021-22.

Season	Type	Number	Variety
T. Aman	MV	55	IR64, BR4, BR5, BR10, BR11, BR21, BR22, BR23, BR24, BR25, BRRI dhan27, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan40, BRRI dhan41, BRRI dhan42, BRRI dhan43, BRRI dhan44, BRRI dhan46, BRRI dhan48, BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan76, BRRI dhan77, BRRI dhan78, BRRI dhan79, BRRI dhan80, BRRI dhan82, BRRI dhan83, BRRI dhan85, BRRI dhan87, BRRI dhan90, BRRI dhan91, BRRI dhan93, BRRI dhan94, BRRI dhan95, BRRI dhan98
	LIV	10	Nizersail, Latisail, Rajasail, Kalijira, Kataribhog, Basmati-D, Patnai23, Tilockkachari, DA29, DA31
Boro	MV	45	BR1, BR2, BR3, BR6, BR7, BR8, BR9, BR12, BR14, BR15, BR16, BR17, BR18, BR19, BR26, BRRI dhan28, BRRI dhan29, BRRI dhan35, BRRI dhan36, BRRI dhan45, BRRI dhan47, BRRI dhan50, BRRI dhan55, BRRI dhan58, BRRI dhan59, BRRI dhan60, BRRI dhan61, BRRI dhan63, BRRI dhan64, BRRI dhan65, BRRI dhan67, BRRI dhan68, BRRI dhan69, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan86, BRRI dhan88, BRRI dhan89, BRRI dhan92, BRRI dhan96, BRRI dhan97, BRRI dhan98, BRRI dhan99, Bangabandhu dhan100
	LIV	6	Hbj Boro II, Hbj Boro IV, Hbj Boro VI, Hbj Boro VIII, Purbachi, IR8
Total		116	

Nucleus seed stock production. Sixty-three BRRI developed rice varieties of which 42 in T. Aman and 21 in Boro were grown following panicle to row method to produce nucleus seed stocks for breeder seed (BS) production. The objective for nucleus seed production was to maintain genetic purity and homogeneity of morphological characteristics of a variety and subsequently breeder seed production.

'Panicle to row' method was used to maintain nucleus stocks, where intact panicles were sown instead of threshed seeds. If off-type plants were identified in a row then whole row was discarded or rogued out for variety maintenance. At maturity, panicles from 'true to type' plants of all the varieties were harvested and both intact panicles for BRRI HQ, Gazipur and nucleus seed stocks for BRRI regional stations were stored in controlled temperature (20°C with 40% RH).

Breeder seed production and distribution. GRS Division, Farm Management Division and nine regional stations of BRRI were engaged in breeder seed production as per national demand. The BS plots were visited to monitor the varietal purity and performances. Off-type plants were identified and rogued out in every growth stage. After harvesting of a variety, the seeds were separately threshed, dried, cleaned and stored in controlled temperature (20°C with about 40% RH) at BRRI HQ, Gazipur. The harvested seeds then offered as seed lot for getting 'tag' from Seed Certification Agency (SCA) which is required for distribution.

A total of 218.72 tons of breeder seed with tags of which 143.44 tons of 20 Boro varieties, 16.36 tons of ten Aus varieties and 58.92 tons of 35 T. Aman varieties were produced during 2021-22 (Tables 5, 6 and 7). At the same time, 198.994 tons of breeder seed of which 131.341 tons of 20 Boro varieties, 16.215 tons of ten Aus varieties and 51.438 tons of 34 T. Aman varieties were distributed among 718 partners (GO, NGO and PS) of BRRI 'Rice Seed Network'. Breeder and foundation seed producing plots and farms were also visited to observe the varietal purity and performance of respective seed.

PI: Md Adil Badshah (T. Aman) and Ebna Syod Md Harunur Rashid (Boro).

Table 5. Production and distribution of rice breeder seed for Boro 2021-22.

Variety	Production(with tag)		Distribution	
	Favourable variety (kg)	Stress tolerant variety (kg)	Favourable variety (kg)	Stress tolerant variety (kg)
BR14	160		130	
BR16	440		445	
BR26	1470		1470	
BRRI dhan28	29360		28121	
BRRI dhan29	19660		19734	
BRRI dhan36		160		120
BRRI dhan47		1140		951
BRRI dhan50	3910		3229	
BRRI dhan58	9010		7247	
BRRI dhan63	4620		3666	
BRRI dhan67		5900		5281
BRRI dhan74	7520		7547	
BRRI dhan81	5950		5507	
BRRI dhan84	10000		8086	
BRRI dhan88	2800		2854	
BRRI dhan89	23370		20907	
BRRI dhan92	17530		15621	
BRRI dhan96	120		130	
BRRI dhan97		220		190
Bangabandhu dhan100	100		105	
Total	**136,020**	**7,420**	**124,799**	**6,542**
Grand Total	**143,440**		**131,341**	

Table 6. Production and distribution of rice breeder seed for Aus 2021-22.

Variety	Production (with tag) (kg)	Distribution (kg)
BR14	30	0
BR26	110	110
BRRI dhan42	90	30
BRRI dhan 43	60	10
BRRI dhan 48	4510	4535
BRRI dhan 65	190	60
BRRI dhan 82	5130	5230
BRRI dhan 83	70	70
BRRI dhan85	80	80
BRRI dhan98	6090	6090
Total	**16,360**	**16,215**

Table 7. Production and distribution of rice breeder seed for T. Aman 2021-22.

Variety	Production (with tag)		Distribution	
	Favourable variety (kg)	Stress tolerant variety (kg)	Favourable variety (kg)	Stress tolerant variety (kg)
BR10	1250		1250	
BR11	3700		3700	
BR22	120		120	
BR23	3530		3225	
BRRI dhan30	780		730	
BRRI dhan32	300		290	
BRRI dhan33	510		500	
BRRI dhan34	3180		3150	
BRRI dhan39	210		210	
BRRI dhan41		30		30
BRRI dhan44	20		10	
BRRI dhan46	70		70	

Variety	Production (with tag)		Distribution	
	Favourable variety (kg)	Stress tolerant variety (kg)	Favourable variety (kg)	Stress tolerant variety (kg)
BRRI dhan49	15870		14382	
BRRI dhan51		2010		2000
BRRI dhan52		3870		3690
BRRI dhan56		120		88
BRRI dhan57		50		45
BRRI dhan62	190		197	
BRRI dhan66		40		0
BRRI dhan70	50		37	
BRRI dhan71		530		542
BRRI dhan72	1880		250	
BRRI dhan73		80		80
BRRI dhan75	2830		2877	
BRRI dhan76	2170		2161	
BRRI dhan77	800		801	
BRRI dhan78		60		60
BRRI dhan80	420		250	
BRRI dhan87	12460		8879	
BRRI dhan90	240		272	
BRRI dhan91		30		20
BRRI dhan93	440		430	
BRRI dhan94	420		420	
BRRI dhan95	510		522	
Nizersail	150		150	
Total	52,100	6,820	44,883	6,555
Grand total	58,920		51,438	

Sending SMS to SeedNet partners for breeder seed distribution. Text message (SMS) with variety name and allotted quantity of breeder seed were sent through mobile apps to 10, 8 and 170 partners before Boro 2021-22, Aus 2022 and T. Aman 2022 seasons, respectively for distributing breeder seed through BRRI 'Rice Seed Network'.

PI: Armin Bhuiya.

Monitoring seed production plots and farms. Breeder seed production plots of BRRI regional stations (RSs) at Cumilla, Sonagazi, Sirajganj, Kushtia, Rajshahi and Bhanga along with foundation seed production farm of BADC at Dinajpur, Chuadanga, Jhenaidah and Meherpur were visited. During the visit, no major insect-pest damage, varietal impurity (<1%) and no obnoxious weeds were observed. Isolation distances and crop conditions were satisfactory. The seed producers were advised for thorough roguing by themselves for one more time before harvesting.

PI: Mir Sharf Uddin Ahmed.

EXPLORATORY AND GENETIC STUDIES

Regional yield trial (RYT) of Balam rice germplasm. Balam (Acc. 516) and Jesso-Balam TAPL (Acc. 2472, 2473) along with BRRI dhan80 as the standard check variety were evaluated at BRRI HQ, Gazipur and BRRI RS, Barishal during T. Aman 2021-22. The highest panicle length (29.9 cm) and plant height (150.7 cm) were observed in Balam (Acc. 516). The highest grain yield from 6 sq. m plot was observed in Balam (Acc. 516) as 4.0 t ha^{-1}, which was significantly different from the check. Therefore, acc. 516 along with BRRI dhan80 will be evaluated at BRRI HQ, Gazipur and BRRI RS, Barishal in T. Aman 2022-23 as regional yield trial (RYT).

PI: Mir Sharf Uddin Ahmed.

Regional yield trial (RYT) of Sada Mota and Lal Mota rice germplasm. Sada Mota (Acc. 7888) and Lal Mota (Acc. 7889) along with BRRI dhan77 as standard check were evaluated at BRRI HQ, Gazipur and BRRI RS, Barishal during T. Aman 2021-22. The highest panicle length was found as

27.2 cm in BRRI dhan77, followed by 23.5 in Sada Mota (Acc. 7888) and 23.2 cm in Lal Mota (Acc. 7889) (Table 8). The highest grain yield from 6 sq. m plot was observed in BRRI dhan77 and Sada Mota (Acc. 7888) as 4.0 t ha^{-1}, followed by 3.4 t ha^{-1} in J Lal Mota (Acc. 7889). Therefore, acc. 7888 along with BRRI dhan77 will be evaluated at BRRI HQ, Gazipur and BRRI RS Barishal in T. Aman 2022-23 as RYT.

PI: Mir Sharf Uddin Ahmed.

Table 8. Agronomic performances of Sada and Lal Mota rice germplasm from RYT, T. Aman 2021-22.

Name	Acc. no.	Panicle length (cm)	Plant height (cm)	Growth duration	1000-garin weight (g)	Yield/ plot (g) at 14%	Yield/ hill (g)	Yield (ton/ha)
Sada Mota	7888	23.5	140.4	156	30.0	4322.2	35.0	4.0
Lal Mota	7889	23.2	144.1	153	31.2	3629.9	29.5	3.4
BRRI dhan77	--	27.2	129.9	139	23.7	4274.1	35.3	4.0
Mean		24.6	138.2	149	28.3	3629.9	29.5	3.4
Std. Dev.		2.2	7.4	9.3	4.0	4075.4	33.3	3.8
CV		9.1	5.3	6.2	14.3	386.6	3.3	0.4
LSD (0.05)		1.9	6.5	8.2	3.5	9.5	9.9	9.5

Secondary yield trial (SYT) of aromatic rice germplasm. The best yield performing eight aromatic rice germplasms (Chinigura, Chinisail, Chiniatop, Khatobabu, Subal lota, Kalijira, Dudhsail, Ranisalute and Radhunipagol) from the last three years' experiments along with BRRI dhan34 as standard check were evaluated at BRRI Gazipur as SYT. Table 9 presents the detailed yield performance of the germplasm for the studied parameter. The highest grain yield (2.5 t ha^{-1}) was observed in Chinisail, Subal Lata and BRRI dhan34, followed by 2.4 t ha^{-1} in Khatobabu and Ranisalute, 2.2 t ha^{-1} in Chinigura and Dudsail.

PI: Armin Bhuiya.

Table 9. Performance of nine aromatic rice germplasm for various yield contributing traits.

Acc. no.	Germplasm	GD (day)	Yield (t ha^{-1})
4867	Chinigura	119	2.2
7343	Chinisail	114	2.5
5093	Chiniatop	121	0.8
8675	Khatobabu	101	2.4
7680	Subal Lata	102	2.5
247	Kalijira	119	1.8
4840	Dudsail	127	2.2
5286	Ranisalute	134	2.4
6711	Radhunipagal	114	1.5
Check	BRRI dhan34	125	2.5

Legend: L=Ladder, 1=Kalijira (3) (Acc.247), 2=Kalajira (305), 3=Kaliajira (607), 4=Kalijira (2) (856), 5=Kalijira (3) (857), 6=Kalijira (858), 7=Kalajira (971), 8=Kalojira (2) (1129), 9=Kalojira (1130), 10=Kalojira (1303), 11=Kali Zira (1589), 12=Kaliajira (1937), 13=Kalijira Tapl-64 (2492), 14=Kalijira Tapl-65 (2493), 15=Kalijira Tapl-66 (2494), 16=Kalijira Tapl-67 (2495), 17=Kalijira Tapl-68 (2496), 18=Kalijira Tapl-70(2497),19=Kalijira Tapl-71 (2498), 20=Kalijira Tapl-72 (2499), 21=Kalijira Tapl-73 (2500), 22=Kalijira Tapl-74 (2501), 23=Kalijira (3200), 24=Kalijira (3429), 25=Kalijira (Short Gracn) (4357), 26=Kalikira (Hong Grain) (4358), 27=Kalijira (Short Gracn) (4359), 28=Kaliajira (4540), 29=Kalijira (4755), 30=Kalijira (4814), 31=Kalijira (Finer) (4815), 32=Kalijira (4820), 33=Kalijira (4832), 34=Kalijira (4862), 35=Kalijira (4872), 36=Kali Jira (7066), 37=Kali Jira (7073), 38=Kalojira (7290), 39=Kalijira (7505), 40=Kalijira (Lal) (7551), 41=Kalojira (7879), 42=Kali Jira (7945).

Fig. 2. DNA profile of 42 Kalijira accessions with SSR marker RM209.

DNA finger printing of Kalijira rice germplasm. Forty-eight Kalijira accessions were studied using 59 SSR markers for all 12 chromosomes. Among the 59 primers, three primers (RM273, RM223 and RM282) were used for evaluating aroma and four primers (RM170, RM190, RM253 and RM314) were used for evaluating amylose. Figure 2 presents the DNA profiles of 42 Kalijira accessions with SSR marker RM209.

PI: Armin Bhuiya.

Evaluation of photosensitive rice germplasm collected from northern districts. A total of 13 photosensitive germplasm along with three checks were grown late (transplanting 15 September) in T. Aman season to identify germplasm suitable for late transplanting after flood in northern region of Bangladesh (Bogura, Kurigram, Lalmonirhat, Gaibandha, Rangpur and Jamalpur). One Malshira, one Bindi Pakri accession and Indur Sail showed better performance on the basis of their morpho-agronomic traits among the tested entries (Table 10). Grain weights per hill of Malshira (Acc. 545), Bindi Pakri (Acc. 4810) and Indur Sail (Acc. 3661) germplasm were 22.97 g, 22.54 g and 20.16 g, respectively. Longer panicle length (27 to 28 cm), higher number of filled grain per panicle (98 to 122) and medium growth duration (122 to 127 days) were observed in selected three local germplasm and will be tested further in Rangpur region in the next T. Aman 2022.

PI: Ebna Syod Md. Harunur Rashid.

Table 10. Performance of ten photosensitive T. Aman rice germplasm from BRRI Genebank.

Name	Acc. no.	Effective Tiller per hill	Culm length (cm)	Panicle length (cm)	Days to maturity	TGW (g)	Filled grain/ panicle	Unfilled grain/ panicle	Grain weight / hill	Decort grain length (mm)	Decort grain breadth (mm)	L/B ratio
Mal Shira	545	11	101.2	27	127	19	122	17	22.97	5.52	2.02	2.73
Mal Shira	299	10	95	27.6	127	19	107	10	13.02	6.09	2.24	2.72
Mal Shira	360	11	93	24	127	22	80	17	13.96	6.08	2.25	2.70
Ganjia	287	10	98.8	28.8	139	16	75	20	12.44	5.17	1.87	2.76
Ganjia	520	11	102	27.6	134	17	98	18	13.38	5.69	1.93	2.95
Ganjia	531	10	101.6	27.6	134	16	103	13	14.94	5.58	2.19	2.19
Bindi Pakri	285	10	101.2	29.2	125	17	93	15	11.49	5.46	1.81	3.02
Bindi Pakri	4810	10	102.8	28	127	19	103	13	22.54	5.47	2.19	2.50
Indur Sail	3661	10	105.2	27	122	19	98	10	20.16	5.56	2.31	2.41
Joy Shail	5969	9	102	27.6	121	21	122	14	15.92	5.71	2.27	2.52
BR22 (ck)		10	83.2	26.6	140	21	101	10	17.92	5.65	2.32	2.44
BR23 (ck)		9	75.2	27.6	140	25	92	15	16.90	6.85	2.36	2.90
Nizersail(ck)		10	103.4	28.4	139	18	123	18	19.20	6.1	2.28	2.68
Mean		10.07	97.28	27.46	130.92	19.15	101.32	14.72	16.53	5.76	2.16	2.65
Std. Dev.		0.47	8.83	1.27	7.01	2.58	14.84	3.38	3.80	0.43	0.18	0.24
CV		4.71	9.08	4.61	5.35	13.45	14.65	22.96	17.03	7.41	8.57	8.92
LSD (0.05)		0.35	6.23	0.89	4.94	1.82	10.47	2.38	2.10			

Characterization of similar named Banshful group of rice germplasm. Twenty-eight similar named Banshful group of rice germplasm were characterized through 33 qualitative agro-morphological traits for developing core collections in T. Aman 2021-22 at BRRI HQ, Gazipur. The experiments were conducted using a single row of 5.4 m long for each entry with 20 × 20 cm spacing between rows and plants respectively in RCBD with three replications. Fertilizers were applied @ 60:20:40 kg NPK/ha. Appropriate control measures were taken for insect, pests, diseases and weeds when necessary. The frequency distributions of 31 main characters revealed that seven main characters had no variation and five main characters were most diversified and further divided into more than three sub characters. Moreover, 13 sub characters were most dominated (more than 72% of the total frequency) and 27 sub characters had the rare genotypes (less than 8% frequency).

Identification and selection of sticky rice from *Jhum* rice germplasm. Fifty-six *Jhum* rice germplasm were characterized to study the selection criteria in Aus 2020-21. The highest grain yield/hill (31.52 g) was observed in Katak Tara, followed by 28.11 g in BR 84-4-1-2-P2, 27.02 g in Guri Galon, 25.69 g in BR 8781-16-1-3-P2, 25.14 g in Galong and the lowest (7.8 g) in Parangi (Table 11).

PI: Armin Bhuiya.

Table 11. Mean performance of 28 Jhum germplasm for growth duration and yield.

Acc. no.	Variety	Growth duration (day)	Yield/hill (g) @14%M
4928	Koisramuri	123	17.18
4936	Katak Tara	124	31.52
4940	Kalo Soti	115	14.25
4944	CN (Indian)	132	17.55
4946	Lota Bhog	131	13.13
4948	Nuncha	134	12.37
4954	Bir Pala -2	115	8.93
4975	MTD 7029	132	23.92
5020	Aus Dhan	122	22.40
5021	IET -4049	127	11.42
N/C/1(809)	Chakma Chikon	124	9.14
N/C/2(445)	Parangi	115	8.41
N/C/3(450)	76 Dhan	130	9.81
N/C/4(452)	Parangi	121	7.80
N/C/5(480)	Parangi	120	22.59
N/C/6(400)	NBR 9005-53-1-1	120	24.90
N/C/7(401)	NBR 9006-40-2-3-1	121	20.46
N/C/8(402)	BR 84-4-1-2-P2	133	28.11
N/C/9(403)	BR 8781-16-1-3-P2	146	25.69
N/C/10(1)	Boushakhi Aus/20	131	21.93
N/C/11(2)	Guri Galon	130	27.02
N/C/16 (7)	Sundori Binni	146	24.03
N/C/17 (8	Bojha Dhan	141	12.45
N/C/18 (9)	Hamarong Dhan	139	20.25
N/C/19 (10)	Galong	143	25.14
N/C/20 (11)	My Wachha	115	22.84
N/C/25 (16)	PY84	102	14.29
N/C/26 (17)	576	121	16.13
	CV%	8	37.36
	LSD	4	2.54
	Max	146	31.52
	Min	102	7.80

Dormancy and storage ability of newly released BRRI rice varieties. Freshly harvested 13 new BRRI released rice varieties of T. Aman season (Fig. 3) were tested for germination to check the dormancy and storage ability. After sun-drying and grading, the seeds (<12% moisture) of all the varieties were stored at 20˚C in 50% RH. One hundred healthy seeds were set in each Petri dish in three replications. Germination data were collected starting from 20 December 2021 and continued with maintaining a 15 days interval from the initial date of storage.

No dormancy period was observed in any of the studied varieties (Fig. 3). Over all, the germination percent decreased over the time. But BRRI dhan77, BRRI dhan82, BRRI dhan85, BRRI dhan87, BRRI dhan91 and BRRI dhan94 continued with 100% germination rate up to interval 6. The experiment needs to continue for another six months with maintaining a 15 days interval for making conclusion.

PI: Tonmoy Chakrabarty.

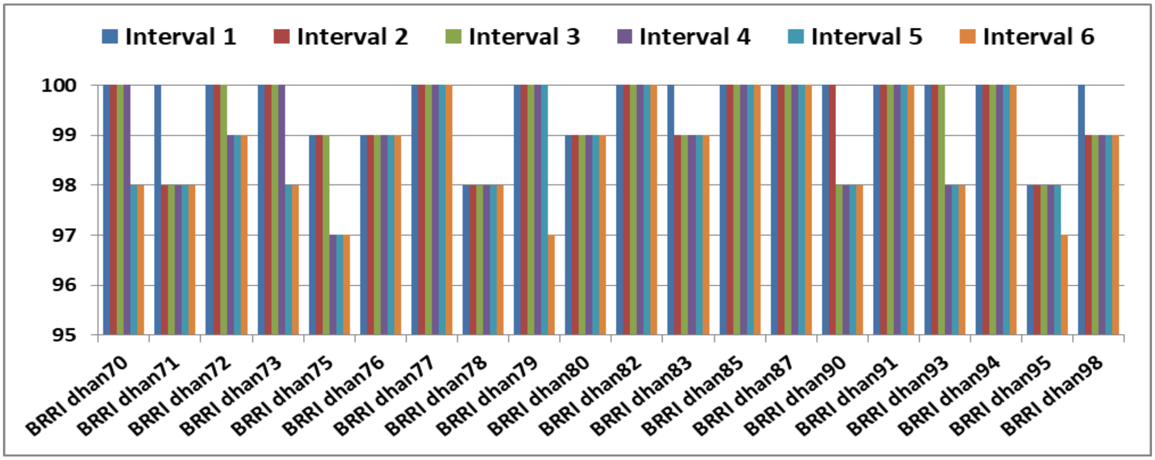
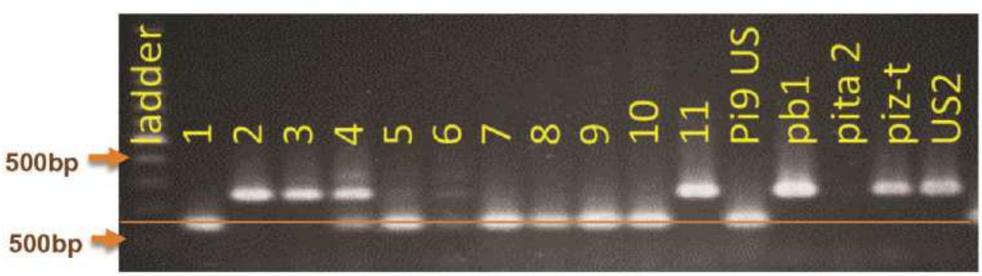


Fig. 3. Bar diagram of germination fluctuations of stored BRRI developed varieties.

Conformation of selected blast resistant materials using blast isolates and molecular markers.

A total of 303 rice germplasm were first screened against two blast isolates along with their morphological characterization and 117 genotypes were selected. Then, selected 117 genotypes were again screened against seven SDBIs (Standard differential blast isolates) and 11 genotypes were selected. Finally, DNA finger printings of selected 11 genotypes with linked markers were completed. The result revealed that nine genotypes contained *Piz*-t gene but genotype "Duria Sashpai" and "Lara" contained all of the target genes (*Pi9, Pb1* and *Piz*-t). Genotypes Beti Chikon, Voratain, Dingamoni and Holde Barud possessed *Pi9* and *Piz*-t genes, whereas genotypes Lal Jamai Babu, Bowaldar and Kambui possessed *Pb1* and *Piz*-t genes only (Fig. 4, 5 and 6).

PI: Md. Humayun Kabir Baktiar.



Legend: The numeric numper stpresents, 1= BetiChikon, 2= LalJamaiBabu, 3 = SadaJamaiBabu, 4 = PartikiDhan, 5 = Voratain, 6 = Bowaldar, 7 = DingaMoni, 8 = DuriaSashpai, 9 = HoldeBarud, 10 = Lara, 11= Kambui, Pi9 US = monogenic line IRBL9-W for Pi9 gene, Pb1= monogenic line Pb-1 (BD64) for Pb-1 gene, Pita-2 = monogenic line IRBLta2-Pi(LT) for pita-2 gene and Piz- t = monogenic line IRBLzt-T for Piz-t gene.

Fig. 4. DNA profile of selected 11 genotypes using Pi9 gene-specific marker NMSMPi9.

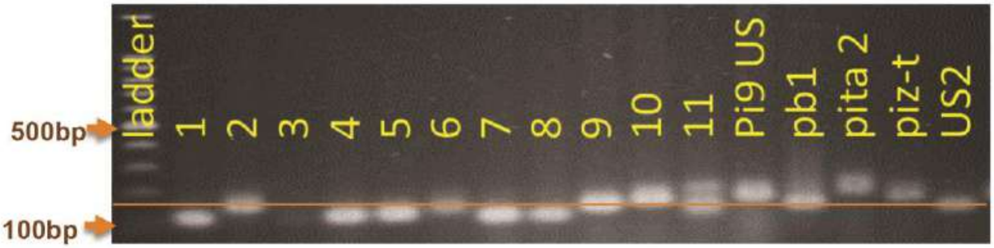
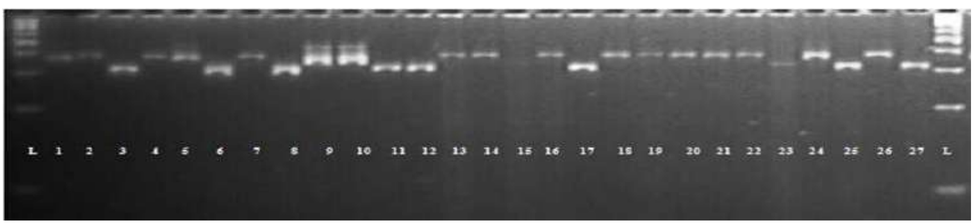


Fig. 5. DNA profile of selected 11 genotypes using Pb1 gene-specific marker RM206.

Fig. 6. DNA profile of selected 11 genotypes using Piz-t gene-specific marker RM1359.

DNA finger printing of latest BRRI varieties. A total of 27 BRRI varieties has been studied (Fig. 7) with about 50 polymorphic primers for all 12 chromosomes. Data processing are going on for analysis.



Legend: L:Ladder, 1:BRRI dhan74, 2:BRRI dhan75, 3:BRRI dhan76 : BRRI dhan77, 5: BRRI dhan78, 6: BRRI dhan79, 7: BRRI dhan80, 8:BRRI dhan81 , 9:BRRI dhan82, 10: BRRI dhan83, 11: BRRI dhan84, 12: BRRI dhan85, 13: BRRI dhan86, 14: BRRI dhan87, 15:BRRI dhan88, 16: BRRI dhan89, 17: BRRI dhan90, 18: BRRI dhan91, 19: BRRI dhan92, 20: BRRI dhan93, 21: BRRI dhan94, 22: BRRI dhan95, 23: BRRI dhan96, 24: BRRI dhan97, 25: BRRI dhan98, 26: BRRI dhan99, 27: Bangabandhu dhan100

Fig. 7. DNA profile of 27 BRRI varities with SSR marker RM 12.

Grain Quality and Nutrition Division

SUMMARY

A total of 359 breeding lines were analyzed and among them 88 had more than 70% milling outturn, 38 had more than 60% head rice recovery, 10 have shown translucent (Tr) grain, five had Extra and 175 had long grain, 103 had more than 3.0 L/B ratio, 155 had more than 25.0% amylose content, 11 had more than 10.0% protein content, four had more than 1.7 elongation ratio and 180 had between the range of (4.0-5.0) volume expansion ratio. Some of the promising lines were identified for higher milling and head rice recovery, size and shape, amylose content, protein content, elongation ratio and acceptable other physicochemical properties .On the other hand 8,532 transforming breeding lines were evaluated for physicochemical and cooking properties for superior quality. Based on the performance on grain quality, we recommended 36 lines and among them two lines for CTR, Haor (AYT#3,4), three lines for (SYT#1,2,3) Boro, 13 lines for FBR and CTR, four lines for IR (AYT) Boro, seven lines for IR (AYT) T. Aman and seven lines for FBR and CTR for further advancement.

Black pericarp rice has recently become popular among rice consumers for its diverse health benefits especially anti-cancer effect. Cyanidin-3-Glucosides (C3G), a prominent bioactive component of anthocyanins which is abundantly present in black pericarp rice. We investigated, how effectively it can be used to fortify Cyanidin-3-Glucosides (C3G) content in red and white pericarp polished rice or rice-based bakery products for more nutritional value. In the present study, we have characterized several black pericarp rice cultivars along with some red pericarp and white pericarp rice cultivars by physiochemically including mineral profiling, and quantified the C3G by UPLC and LCMS. C3G content was significantly reduced from raw rice to cooked rice condition. All the black pericarp rice cultivars synthesized C3G, while this content was not detected in red and white pericarp rice cultivars. However, when 25% of black pericarp rice were mixed with 75% red or white pericarp polished rice, C3G content was significantly retained in cooked rice conditions. Formulation of rice-based bakery food product using black pericarp rice powder was also remarkably retained the C3G content as compared to that of cooking. Black rice is harder in texture, difficult to digest and needs higher energy for cooking. Therefore, we tried to circumvent these challenges by fortifying 25% of black pericarp rice with white or red pericarp rice. Fortification of C3G enriched black rice (25%) with red or white pericarp rice (75%) might bring a better nutritional quality in both cooking and baking condition. This may lead a way to the effective management of the non-communicable disease such as cancer for common rice consuming population.

Eleven methods including nine HPLC and two GCMS methods were developed and validated using Shimadzu Prominence-i Modular HPLC and Shimadzu Nexis GC2030 equipped with MS-QP2020NX at GQN and BCL laboratory respectively. HPLC methods for detection and quantification of rice phytohormones including 3-Indoleacetic acid (IAA), Gibberellic Acid (GA_3) and Abscisic Acid (ABA), Water soluble rice vitamins such as Thiamine ($VitB_1$), Riboflavin ($VitB_2$), Niacin ($VitB_3$), Thyroxine (Vit B_6), Folic acid (Vit B_9) and Cyanocobalamin (Vit B_{12}). GCMS methods include detection and quantification of rice volatile aromatic compounds such as 2AP (2 Acetyl-1-Pyrroline) and rice fatty acid profiling (C14:0 Myristic acid, C14:1 Myristoleic acid, C16:0 Palmitic acid, C16:1 Palmitoleic acid, C18:0 Stearic acid, C18:1 Oleic acid, C18:2/Omega-6 Linoleic acid, C18:3/Omega-3 Linolenic acid, C20:0 Arachidic acid, C20:1 Eicosanoic acid, C22:0 Behenic acid).

Puffed, popped and flattened rice were produced from BRRI varieties to evaluate the quality products. Comparing few parameters (fully puffed rice, length and breadth increased percentage) with BR16 (Std), it is ascertained from the results that BRRI dhan99 and Bangabandhu dhan100 are better in producing whole puffed rice followed by BRRI dhan97 and BRRI dhan98. Considering physical parameters, BRRI dhan99 and Bangabandhu dhan100 show excellent performance for whole, partial broken, broken and unpopped

rice. Among the tested varieties, in terms of weight of whole, partial broken and broken flattened rice as well as percentage of length increased, BRRI dhan98 showed the best performance comparing with BR16.

GRAIN QUALITY CHARACTER

Determination of physicochemical and cooking properties of breeding lines

PI: M A S; **CI:** M A H, S S D, N F, H B S, S H and M R A

After yield, grain quality of rice is important parameter for researchers and consumers. Consumer acceptance of rice depends on its physicochemical quality. Physical parameters were measured by milling outrun, head rice yield and size and shape. Cooking quality were determined by cooking time, elongation ratio and volume expansion ratio. Chemical parameters were determined by amylose content, protein content and alkali spreading value. New HYR varieties that have better benefits than the existing ones will be more accepted if their characteristics are in accordance with consumers' preferences (Zen 2007). High quality rice, uniform shape, whiteness and translucency are major factors defining market value of rice (Fitzgerald et al. 2008). Rice is a very rich source of carbohydrate followed by protein. A total of 128 samples were provided from different divisions of BRRI and outside of BRRI to find out the desirable characteristics. In Bangladesh, long slender type translucent grains prefered by consumers as premium quality rice with higher price. But medium bold type grains are most suitable for milling. Total 359 samples were analyzed. Out of 287 samples, 88 had more than 70% milling outturn and 38 had more than 60% head rice recovery. Out of 235 samples, 10 have shown translucent (Tr) grain that means 0% chalkiness, 38 have shown less than 10% chalkiness, 70 have shown between the range of 10-20% chalkiness, 111 have shown more than 20% chalkiness and only six have shown opaque grain. Out of 356 samples, only five had Ex-long grain, 175 had long grain, 145 had medium grain and 31 had short grain. Among these samples 103 had more than 3.0 L/B ratio, whereas 250 had between the range of (2.0-3.0) L/B ratio. Out of 280 samples, only one sample had more than 30.0 g 1000-grain TGW., 38 had between the ranges of 25-30 g 1000-grain wt., 140 had between the ranges of 21-25 g TGW., 99 had between the ranges of 15-20 g TGW. and only two had less than 15 g 1000-grain wt. (Table 1). Amylose is the most important trait for eating quality, which indicates the texture of cooked rice and also volume expansion. Out of 359 samples, 155 had more than 25% amylose, 178 had between the range of 20-25% amylose, 25 had between the range of 10-20% amylose and only one had less than 10% amylose. Nutritional quality is measured by protein content. Out of 287 samples, 11 had more than 10% protein, 96 had between the range of 9-10% protein, 120 had between the range of 8-8.9% protein, 55 had between the range of 7-7.9% protein and only five had less than 7% protein. Less than 7% protein content in brown rice, which is not normally recommended for variety release. Grain with high gelatinization temperature is not desirable. Out of 287 samples, 39 had more than 20 minutes. cooking time, 117 had between the range of 18-20 minutes. cooking time, 129 had between the range of 15-17 min. cooking time and only two had less than 15 minutes. cooking time. The samples, having more than 20 min. cooking time may give comparatively hard cooked rice. Among 287 samples, only four had between the range of 1.7-2 elongation ratio, 188 had between the range of 1.4-1.6 elongation ratio and 95 had less than 1.4 elongation ratio. Higher elongation ratio is desirable factor. High volume expansion of cooking is still considered to be a good quality for the working class people who do not care whether the expansion is lengthwise or crosswise. Among these samples, no one had more than 5.0 volume expansion ratio, 180 had between the range of 4-5 volume expansion ratio and 107 had between the range of 3.0-3.9 volume expansion ratio. Out of 113 samples, two had intermediate aroma, six had low aroma but 105 had no aroma (Table-2).

Some of the promising samples were identified for higher milling and head rice recovery, amylose content, protein content, elongation ratio and other acceptable physicochemical properties (Table-3).

Table 1. Physical properties of rice samples.

Range	Properties and sample number
Milling Outturn (%) (Total sample 287)	
>70.0	88
68.0-70.0	151
<68.0	48
Head rice recovery (%) (Total sample 287)	
>60.0	38
50.0-60.0	135
<50.0	114
Chalkiness (%) (Total sample 235)	
0 (Chalk)	10
<10.0	38
10.0-20.0	70
>20.0	111
100 (Chalk)	6
Length (mm) (Total sample 356)	
>7.4	5
6.1-7.4	175
5.0-6.0	145
<5.0	31
L/B ratio (Total sample 356)	
>3.0	103
2.1-3.0	250
<2.0	3
Size & Shape (Total sample 356)	
>6.0 mm ; >3.0	107
>6.0 mm ; 2.1-3.0	74
5.0-6.0 mm ; >3.0	27
5.0-6.0 mm ; 2.1-3.0	117
<5.0 mm ; 2.1-3.0	28
<5.0 mm ; <2.0	3
1000-grain wt. (g) (Total sample 280)	
>30.0	1
25.0-30.0	38
21.0-25.0	140
15.0-20.0	99
<15	2

Table 2. Chemical and cooking properties of rice samples.

Range	Properties and sample number
Alkali spreading value (Total sample 287)	
6-7	38
4.1-5.9	130
<4	119
Amylose content (%) (Total sample 359)	
>25.0	155
20.0-25.0	178
10.0-20.0	25
<10.0	1
Protein content (%) (Total sample 287)	
>10.0	11
9.0-10.0	96
8.0-8.9	120

7.0-7.9	55
<7.0	5
Cooking time (min.) (Total sample 287)	
>20.0	39
18.0-20.0	117
15.0-17.0	129
<15.0	2
Elongation ratio (Total sample 287)	
>2.0	-
1.7-2.0	4
1.4-1.6	188
<1.4	95
Volume expansion ratio (Total sample 287)	
>5.0	-
4.0-5.0	180
3.0-3.9	107
<3.0	-
Aroma (Total sample 113)	
+++	-
++	2
+	6
-	105

Table 3. Physicochemical properties of promising samples.

AC #	Variety/Line	Milling outturn (%)	Head rice recovery (%)	Size & Shape	1000 grain wt. (g)	Amylose (%)	Protein (%)	ER	IR
16371	BRH14-9-13-16B	71	58	LS	14.4	26.4	10	1.4	4.3
16444	BR10247-14-18-4	71	51	LS	20.9	20.8	9.9	1.5	4.3
16552	BRH17-23-8-2-7B	69	53	LS	16.6	25.9	9	1.5	4.3
16566	BR(Path)12452-SL-53	70	63	MS	20.3	25.5	8.7	1.5	3.9
16810	BR12248-5R-37	69	49	LS	22.7	24.4	8.1	1.4	4.5
16827	BR12266-5R-22	69	50	LS	23	26.6	8.8	1.4	4.3
16907	Ranqui	69	55	LS	22.2	27.7	8.1	1.4	4.5
16908	Gunda	69	55	MB	22	26.5	8.2	1.6	4
16910	Bish Number	70	59	MB	24.4	26.8	8	1.6	4.8
16912	YAAS-V5	70	59	MB	21.7	27.2	7.3	1.6	4.3

Determination of Physicochemical and Cooking properties of Transforming Rice Breeding lines

PI: S S D CI: M A S

Grain quality is an important component for consumer's preference and profitability. For the transforming rice breeding project on rice grain quality screening, a total of 8532 (LST- Line Stage Trial 3817, OYT-Observational Yield Trial 2228 and PYT-Preliminary Yield Trial 2487) were received, processed and evaluated.

Three thousand eight hundred seventeen (3817) LST and OYT materials were analyzed for size, shape. Grain length and length to breadth ratio determines the grain size and shape. Among them three thousand eight hundred seventeen (3817) LST (Salinity tolerance, Boro, Salinity tolerance T. Aman, T. Aus, Favorable and cold tolerant Boro and cold tolerant Boro) lines 44 were extra long slender (ELS), followed by 1 was extra long medium, 729 were long slender, 1486 were long medium, one was long bold, 83 were medium slender, 884 were medium medium, 144 were medium bold, one was medium round, 285 were short medium, 144 were short bold, 12 were short round and three were short short.

Among two thousand two hundred twenty eight (2228) OYT materials, (Salinity tolerance, Boro, Salinity tolerance T. Aman, T. Aus, Favorable and cold tolerant Boro and cold tolerant

Boro) 85 were long slender, 873 were long bold, 455 was medium slender, 759 were medium bold, three were medium round and 53 were short bold.

In Bangladesh, medium slender and medium bold grains are suitable for milling. But long slender rice is sold at high price in the market. Rice contains two types of starch namely amylose and amylopectin. Amylose content of rice grain determines the hardness and stickiness of cooked rice. More than 25% amylose content gives nonsticky cooked rice; 20-25% amylose containing rice gives soft and comparatively sticky cooked rice. Out of 2,228 LST and OYT lines, 1,784 were more than 25.0% amylose, 380 lines were amylose content between the range of 20-25% and 64 lines had less than 20% amylase (**Table-4**).

Milling is one of the parameters determining milled rice yield per unit paddy weight. Among 2,487 PYT lines, 1,387 lines had more than 70% and 877 had 68-70% total milled rice percentage. 223 had less than 68% milling outturn. Less than 68% milled rice is not desirable. One thousand sixty one lines had more than 60% followed by 906 within 50-60% and 520 with less than 50% head rice recovery percentage. Out of 2,487 lines, 1,567 were translucent (Table-2). Appearance or colour of milled rice is one of the important physical properties to attract consumer's attention. All of the lines were brown in colour. The consumers in our country prefer long and medium slender grain. Grain length and length to breadth ratio determines the grain size and shape. Out of 2,487 PYT lines, 348 were long slender, followed by 1,107 were long bold, seven were medium slender, 991 were medium bold, 25 were medium round. In Bangladesh, medium slender and medium bold grains are suitable for milling. But long slender rice is sold at high price in the market (**Table-5**).

Amylose content determines the quality of cooked rice. Out of 2,487 lines, 2,031 were more than 25% amylose, 385 lines were amylose content between the range of 20-25% and 71 lines had less than 20% amylose (Table 3). Protein content is measure the nutritional value of rice. In total 1,592 lines had high (>9%) and 846 lines had intermediate (7.0-9.0%) protein content. Generally, a variety, having less than 7% protein content in brown rice, is not recommended for release as a variety (Table-3). Alkali spreading value has inverse relationship with gelatinization temperature. Among the 2,487 breeding lines 671 had alkali spreading value ranging 6.0-7.0 and 1,442 had 3.1-5.9. Grain with high gelatinization temperature is not desirable. In total 2,164 lines had cooking time between the ranges of 15-20 minutes. Imbibition ratio (Volume expansion) is one of the important parameters for rice quality. It shows the value of expansion of rice after cooking. Hard working people of our country prefer rice having more volume expansion.

Out of 2,487 PYT lines, volume expansion ratio of 2,263 lines were less than 3.5 (Table 3). The elongation ratio is one of the important parameters for cooked rice. Elongation ratio is responsible for fine or coarse cooked rice. If rice elongation is more, it gives a finer appearance, but if expands in breadth, gives a coarse look. Long slender and medium slender rice should elongate more, as they are consumed mostly by people having comparatively a higher income. The elongation ratio of most of the lines varied between 1.3-1.5 (**Table 6.**)

Table 4. Physicochemical properties of Transforming Rice Breeding (LST and OYT) lines.

Parameter and total number of sample	Classification	Number of Sample
Size and Shape (Brown rice) (Total sample no. 3,817)	Extra long slender	44
	Extra long medium	1
	Long Slender	729
	Long medium	1486
	Long Bold	1
	Medium slender	83
	Medium medium	884
	Medium bold	144
	Medium round	1

	Short medium	285
	Short bold	144
	Short round	12
	Short short	3
Size and Shape (Milled rice)	Long slender	85
(Total sample no. 2,228)	Long bold	873
	Medium slender	455
	Medium bold	759
	Medium round	3
	Short bold	53
Amylose content (%)	High	1784
(Total sample no. 2,228)	Intermediate	380
	Low	64

Table 5. Physical properties of Transforming Rice Breeding (PYT) sample

Range	Properties and sample number
	Milling Outturn (%) (total sample no. 2,487)
>70.0	1387
68.0-70.0	877
<68.0	223
	Head rice recovery (%) (Total sample no. 2,487)
>60.0	1061
50.0-60.0	906
<50.0	520
	Length (mm) (Total sample no. 2,487)
>6.0	1455
5.0-6.0	1023
<5.0	9
	L/B ratio (Total sample no. 2,487)
3.0>	355
2.0-3.0	2098
<2.0	34
	Chalkiness (%) (Total sample no. 2,487)
(0) Tr	1567
<10	597
10.0-20.0	199
>20.0	100
Opaque	24

Table 6. Chemical and cooking properties of Transforming Rice Breeding (PYT) samples

Range	Properties and sample no.
	Amylose content (%) (Total sample no. 2,487)
>25.0	2031
20.0-25.0	385
<20.0	71
	Protein content (%) (Total sample no. 2,487)
>9.0	1592
7.0-9.0	846
<7.0	49
	Alkali spreading value (Total sample no. 2,487)
1.0-3,0	374
3.1- 5.9	1442
>6.0	671
	Cooking time (min.) (Total sample no. 2,487)
>20	25
15-20	2164

<15	298
	Elongation ratio (Total sample no. 2,847)
>1.5	96
1.3-1.5	2306
<1.3	85
	Volume expansion ratio (Total sample no. 2,847)
>4.0	50
3.4-4.0	174
<3.5	2263

This study identified 36 of the promising lines for high milling and acceptable other physicochemical properties (**Tables 7, 8,9,10,11 and 12**)

Table 7. Promising genotypes for (AYT# 3, 4), CTR, Haor.

Genotype	Head rice Recovery (%)	Size and shape	Amylose Content (%)
BR8910-B-6-3-CS1-5-CS2-P3-1-5	65.3	LS	27.5
BR8938-30-2-4-2-1	61.2	LS	26.8

Table 8. Promising Genotypes for (SYT# 1, 2.3), Boro

Genotype	Head Rice recovery (%)	Size and shape	Amylose content (%)	Elongation ratio
IR2-8-L15-S2-L2	47.8	MB	25.8	1.5
IR1-DQ189-R1-L2	54.1	LB	27.4	1.5
GSR IR 1-DQ125-R4-Y1	46.2	MB	27.1	1.5

Table 9. Promising genotypes for favorable Boro and cold tolerant rice

Genotype	Head rice Recovery (%)	Size and shape	Amylose content (%)	Elongation ratio
BR11894-R-R-R-R-94	61.6	MB	27.7	1.6
BR11894-R-R-R-R-187	63.7	MB	24.3	1.6
BR11894-R-R-R-R-328	58,6	MB	27.0	1.6
BR11894-R-R-R-R-220	65,0	LB	29.5	1.6
BR11662-18-3-3	59.6	MB	30.0	1.6
BR11894-R-R-R-R-258	59.2	LB	27.3	1.6
BR11337-5R-151	60,3	MR	29.3	1.6
BR11337-5R-37	57.6	MR	26.5	1.6
BR11337-5R-166	61.3	MB	26.7	1.6
BR11338-5R-48	67.6	MR	26.8	1.6
BR11338-5R-96	59.8	MB	26.3	1.6
BR11338-5R-30	61.5	SR	27.0	1.8
BR11338-5R-114	63.0	MB	27.4	1.6

Tabl 10. Promising genotypes for IR (AYT) Boro.

Genotype	Head rice recovery (%)	Size and shape	Amylose content (%)	Elongation ratio
BR11583-5R-13	62.2	LB	28.4	1.5
BR11587-5R-45	60.5	MB	26.6	1.5
BR11593-5R-55	55.5	LB	27.2	1.5
BR9667-54-2-2-97	59.6	LB	28.7	1.5

Table11. Promising Genotypes for IR (AYT) T. Aman.

Genotype	Milling outturn (%)	Size and Shape	Amylose content (%)	Elongation ratio
BR11302-4R-197	69.2	MB	25.7	1.5
BR11044-4R-82	65.5	LS	24.6	1.5
BR11302-4R-75	70.1	MB	26.2	1.5
BR11301-4R-10	70.2	MB	27.9	1.5
BR10774-4R-8	69.8	MB	29.2	1.5
BR10766-4R-6	68.5	MB	28.2	1.5
IRBPHN-SVIN049-18	71.6	LS	28.1	1.5

Table12. Promising genotypes for favorable Boro and cold tolerant rice.

Genotype	Head Rice recovery (%)	Size and shape	Amylose content (%)	Elongation ratio
BR11338-5R-109	57.0	MB	28.3	1.6
BR11332-5R-204	60.2	LS	27.0	1.6
BR10599-5R-91	52.8	LB	28.3	1.6
BR11330-5R-35	66.0	MB	30.1	1.6
BR10296-5R-1	60.9	MB	27.5	1.6
BR10589-5R-145	63.8	MB	28.0	1.6
BR10600-5R-168	60.9	MB	29.4	1.6

STUDY ON ANTI-CANCER PROPERTIES OF PIGMENTED (BLACK, RED, PURPLE) RICE VARIETIES IN BANGLADESH.

Black pericarp rice has recently become popular among rice consumers for its diverse health benefits especially anti-cancer effect. Cyanidin-3-Glucosides (C3G), a prominent bioactive component of anthocyanins which is abundantly present in black pericarp rice. We investigated, how effectively it can be used to fortify C3G content in red and white pericarp polished rice or rice-based bakery products for more nutritional value. In the present study, we have characterized several black pericarp rice cultivars along with some red pericarp and white pericarp rice cultivars by physiochemically including mineral profiling, and quantified the C3G by UPLC and LCMS. C3G content was significantly reduced from raw rice to cooked rice condition. All the black pericarp rice cultivars synthesized C3G, while this content was not detected in red and white pericarp rice cultivars.

However, when 25% of black pericarp rice were mixed with 75% red or white pericarp polished rice, C3G content was significantly retained in cooked rice conditions. Formulation of rice-based bakery food product using black pericarp rice powder was also remarkably retained the C3G content as compared to that of cooking. Black rice is harder in texture, difficult to digest and needs higher energy for cooking. Therefore, we tried to circumvent these challenges by fortifying 25% of black pericarp rice with white or red pericarp rice. Fortification of C3G enriched black rice (25%) with red or white pericarp rice (75%) might bring a better nutritional quality in both cooking and baking conditions. This may lead a way to the effective management of the non-communicable disease such as cancer for common rice consuming population.

Fifteen rice cultivars comprised of 11 black pericarps (such as BK1, BK2, BK3, BK4, BK5, BK6, BK7, BK8, BK9, BK10 and BK11), two red pericarp (such as Laxmideega, and BRRI dhan84) and two white pericarp (such as BRRI dhan80 and Gabura) rice were collected and used in this study. We collected black pericarp rice cultivars from hilly regions of Sylhet, Bandarban and Khagrachori districts of Bangladesh and rest of the white red pericarp rice and white pericarp rice were collected from GQN Division. In order to increase the seeds, all these germplasm were grown at area of 5 x 5 square meter for each in BRRI west byed farm located in Gazipur, Bangladesh (BRRI Latitude: 23.99, BRRI Longitude: 90.40) during Aman and Boro 2020-21 season (i.e., Aman season July to November 2020 and Boro season November 2020 to April 2021). Standard agronomic practices were followed to ensure high quality seeds. After maturation, crop was harvested, and seeds were collected. The collected seeds were dried and stored at -20ºC for further use at GQN Division, BRRI. Each sample was milled unparboiled and analyzed for physicochemical properties according to GQN grain quality procedure. Amylose content was determined by the method described in Juliano. Alkali spreading value was determined according to the method of Little etal. Protein contents were calculated from nitrogen, and were determined by the method of Micro Kjeldahl. Each sample was digested, and estimated by the method of the Association of Official Agricultural Chemists. Iron (Fe), zinc (Zn), and calcium (Ca) were determined by the atomic absorption spectrometry (Shimadzu Atomic Absorption Spectrophotometer AA-7000) using a different standard curve at 348.3, 213.8 and 422.7 nm respectively. Only selected germplasm including BK11 (black pericarp rice), BRRI dhan80 (white pericarp rice) and BRRI dhan84 (red pericarp rice) were used in this case. The 5%, 10%, and 25% of BK11 was mixed with both BRRI dhan80 and BRRI dhan84 then cooked at boiling temperature up to respective cooking time (until 90% of gelatinization). These rice samples were cooked using a consistent ratio of 1:1.5 (w/w) using 113 g of deionized distilled water to 75 g of rice. This rice to water ratio resulted in the complete absorption of water by the rice at the end of the cooking time. Rice was cooked using a commercial National view rice cooker (model NV-1 1.8L, 220-240V, 50/60 Hz). A series of rice samples were presoaked in 113 g of water for one hour before cooking in the rice cooker to compare the effects of presoaking rice on anthocyanidin retention. Rice was cooked for 90 min in the rice cooker. All cooked rice was allowed to steam-cool for five minutes. after the heating stopped. Two aliquots of cooked rice, about 20 g each, were randomly selected from each sample and immediately frozen at -80°C before freeze-drying. Each cooking test was performed three times on independent samples. Rice-based bakery product such as rice cakes were prepared at GQN bakery laboratory at BRRI, Gazipur with a minimum of 10 g of protein 100^{-1}g. Ingredients were used as a mixture of rice and sago flours (4:1), vegetable fat or butter, rice bran oil, powder sugar, salt, milk, and egg. In adding the rice powder portion, we used 25% black rice powder with 75% white rice powder (4:1). In the mixing process, all the ingredients were put together for batter formation. The ingredients were fed into the dough mixer, where they were mixed properly for 10-15 minutes. In the baking process, cake batter was put into the baking pan at 190°C for 30 minutes. After baking cakes, they were passed on to cooling conveyors for natural cooling. We preferred natural cooling as it helps to maintain the texture quality of the cake.

Shimadzu UFLC system (Japan) was used to identify the anthocyanins from black rice extraction. The diode array detector (SPD-M20A) was set at 520 nm. The anthocyanins were separated by a Prevail C18 (4.6 mm × 250 mm) with an average particle size of 5.0 μm at 0.2 mLmin-1. at room temperature. The mobile phase consisted of A (water: formic acid = 99:1, v: v) and B (acetonitrile: formic acid = 99:1, v:v), with a binary gradient elutions. UFLC peak of Cyanidin-3-glucoside (Retention Time; 12.99±0.2 min.) in raw black pericarp rice (BK11) and cooked rice were monitored at 520 nm and 280 nm, respectively.

In this study, we used different pigmented rice cultivars along with high-yielding varieties (HYVs) (Fig.1). Among them, BK1 was a mixture of both black and white pericarp rice, while BK2, BK3, BK4, BK5, BK6, BK7, BK8, BK9, BK10 and BK11 were solely black pericarp rice. Laxmidigga was the mixture of black and red pericarp rice, while BRRI dhan84 was exclusively red pericarp rice. On the other hand, BRRI dhan80 and Gabura were white pericarp rice. The decorticated brown rice length ranged from 5.9 to 7.6 mm (Table 1). BK2 and BK11 exhibited the highest length (7.6 mm) of brown pericarp rice, and these cultivars were also extra-long slender and extra-long bold type grain, respectively. BK3, BK4. BK5. BK6, BK8, BK9, BK10, BRRI dhan84 and Gabura were categorized as long bold type rice grains, while BK1 and Laxmideega were medium bold type rice grain. Among the tested cultivars and HYVs, only BK6 and BK9 have strongly scented aroma (Table 13 and Fig.1).

The protein content was significantly varied in these cultivars and HYVs (Fig.2A). This content varied from 8.52 to 12.16% (g 100-1g). Remarkably the highest protein content was obtained in BK7 (12.16%) followed by BK9 (11.43%) and BK2 (11.30%). Indeed, more than 10% (g 100-1g) protein content was detected in all the black pericarp rice cultivars except BK6 (9.44%) (Fig.2A). However, BRRI dhan80 contained the lowest protein content. Like protein content, AAC was also incredibly different in these cultivars which ranges from 2.97% to 25.74% (Fig. 2B). BRRI dhan84 produced the maximum AAC (25.74%) followed by Laxmidigga (24.61%) and BK10 (24.14%). Overall, black pericarp rice cultivars contained very low to intermediate level of AAC. Among the black pericarp rice cultivars, BK10 constructed the highest level of AAC (24.14%) which resembles intermediate AAC. We did not find any high AAC (>25.0%) in black pericarp rice cultivars (Fig.2B). The minimum AAC was found in BK3 (2.9) which resemble very low or waxy type rice.

We quantified different mineral contents including Fe, Zn and Ca in all the rice cultivars. Fe, Zn and Ca content were found to be considerably varied in these cultivars. The content of Fe, Zn and Ca fluctuated from 18.51 to 32.06, 3.65 to 20.15 and 8.63 to 72.71 $mgKg^{-1}$, respectively (Fig. 3). BK5 contained the highest level of Zn (32.06 $mgKg^{-1}$), Fe (20.15 $mgKg^{-1}$), and Ca (72.71 $mgKg^{-1}$) followed by BK11 (28.11, 19.28 and 33.2 $mgKg^{-1}$, Zn, Fe, and Ca, respectively mg) among the tested rice samples. BRRI dhan84 exhibited the highest mineral enriched HYV inbred (Zn 27.55 mgKg-1, Fe 10.21 mgKg-1, and Ca 33.24 $mgKg^{-1}$). Thus, black pericarp rice might contain higher level of Zn, Fe, and Ca as compared to that of inbred HYVs and local germplasms.

The C3G content was considerably varied in the rice cultivars. The C3G content was not detected in both red and white pericarp rice (such as Laxmideega, BRRI dhan84, BRRI dhan80 and Gabura), while all the black pericarp rice synthesized this compound (Fig. 4). Among the tested black rice cultivars, the highest C3G (806.17 $mgKg^{-1}$) was obtained in BK11 which is popularly grown in Khagrachori district, Bangladesh followed by BK10 (608.81 $mgKg^{-1}$) and BK8 (337.89 $mgKg^{-1}$) (Fig. 4).

Cooking has a significant effect on C3G content. While cooking, C3G content was significantly reduced from raw rice to cooked rice. In this study, C3G content in BK11 was reduced 48.05% while cooking. In order to retain the C3G while cooking, we mixed 5%, 10%, and 25% BK11 with red pericarp rice BRRI dhan84 and white pericarp rice BRRI dhan80. We found fortification of 25% in both red and white pericarp rice, the C3G content retained 13.34% and 12.98%, respectively (Table 14), while fortification of 5% in both red and white pericarp rice, the C3G content retained only 3.24% and 3.76%, respectively (Table 14). On the other hand, 4.66 and 6.75% of C3G retained in both red and white pericarp rice, respectively when fortified up to 10%.

We compared the retention of C3G in the baked cake of black and white pericarp rice, and cooked rice (Fig. 6). Interestingly, the retention of C3G in the baked cake of black and white pericarp rice was higher than the cooked rice. We also prepared the rice-based cake using 25% BK11 (black rice) with 75% BRRI dhan80 (white rice) as an active ingredient of carbohydrate source. In this case, C3G content was found to be 196.4± 1.65 mgKg-1in the rice-based cake which resemble higher content than the cooked rice of similar proportion (Table 2 and Fig. 6). We also examined C3G at 520 nm for raw rice and 280 nm for cooked rice and baked cake in UFLC, and m/z (499.0) of C3G has validated in LCMS accordingly (Data not shown).

Rice is an important source of energy, hypoallergenic, easily digested, providing protein with higher nutritional quality, and has versatile functional nutraceutical properties. Rice has an important role in the relation between diet and health. Black rice is especially rich in anthocyanin pigments, phytochemicals, protein, vitamins, minerals and antioxidant properties. The bran hull of black rice is the outermost layer of the rice grain which contains one of the highest levels of the anthocyanin found in any known food. Anthocyanins are the flavonoid pigments of black rice and are the source of antioxidants that have the ability to inhibit the formation or to reduce the concentrations of reactive cell damaging free radicals. Anthocyanin antioxidants help to prevent cardiovascular disease, protecting against cancer that can be caused by free radical damage, improving brain function, reducing inflammation. Black rice rich in Cyanidin 3-Glucoside (C3G) and has hypolipidaemic effects through regulating hepatic lipogenic enzyme activities [18]. It also ameliorates diabetic nephropathy via reducing blood glucose, suppressing oxidative stress and inflammation. Chen, P.N., et al. (2006) gave molecular evidence associated with the anti-metastatic effects of Peonidin 3-Glucoside and cyanidin 3-glucoside, major anthocyanins extracted from black rice (Oryza sativa L. indica), by showing a marked inhibition on the invasion and motility of SKHep-1 cells. This effect was associated with a reduced expression of matrix metalloproteinase (MMP)-9 and urokinase-type plasminogen activator (u-PA). C3G is the active component of anthocyanin in black rice. In our study we were aimed to estimate C3G content in our Bangladeshi available black rice cultivars from different parts of Bangladesh. We also brought some red and white pericarp rice for comparative analysis along with black rice. We characterized our black rice cultivars and found very high level of protein content (≥10%) and low to intermediate level of apparent amylose content (AAC) compared to the other red and white rice. Black rice cultivars possess higher mineral contents such as Zn, Fe and Ca than the other rice. Zinc content of Black rice cultivars varied ranges from 21.44 ppm (mgKg^{-1}) to 32.06 ppm (mgKg-1). Our data reveals diverse range of C3G content in black rice cultivars in Bangladesh. C3G content in black rice cultivars varied ranges from 2.58 ppm to 806.17 ppm. BK11 is the highest C3G content black rice cultivars in Bangladesh followed by BK10, BK8, BK9. But we could not get confirm C3G content in both red and white pericarp rice by UFLC and LCMS in this study. Due to the nutraceutical enriched properties black rice has got immense potential both in domestic as well as overseas market and become expensive to purchase. Since black rice yield is lower than modern HYVs, so expenses of cultivating black rice is costlier than HYVs.

Thermal effect reduces the concentration of C3G in cooking condition than raw. Considering this into account we aimed to investigate whether proportionate use of black rice with other red and white pericarp rice could bring effectiveness regarding availability of C3G as consumption of red and white rice is not able to provide C3G alone. Our data revealed that the proportionate mixture (1:3) of the highest C3G enriched black rice

(BK11) and white (BRRI dhan80) or red (BRRI dhan84) pericarp rice retained 12.98 and 13.34% of C3G, respectively at cooked rice condition. In addition, we investigated whether C3G can effectively be used in baking condition over cooking condition. Our data suggested that black rice would be used as active ingredient of rice flour in baking condition it can retain higher C3G than cooking alone which resemble black rice flour can effectively be utilize in rice-based baking industries.

Our data concluded that black rice should be consumed with white or red polished rice so that the nutraceutical properties of common rice will be fortified which ultimately bring better nutritional value to humans. The use of black rice flour can fortify more bioactive compounds such as C3G in rice-based bakery products than rice. A combination of black rice along with red or white pericarp rice will be able to play a significant role in managing non-communicable diseases. Since black rice cultivars have poor yield gain so, BK11 can further be utilized as a superior crossing parent in the molecular breeding of indica-type black HYV rice research programme.

Fig 1. Pigmented rice including black, red and white pericarp rice of both local and HYVs.

2.A **2.B**

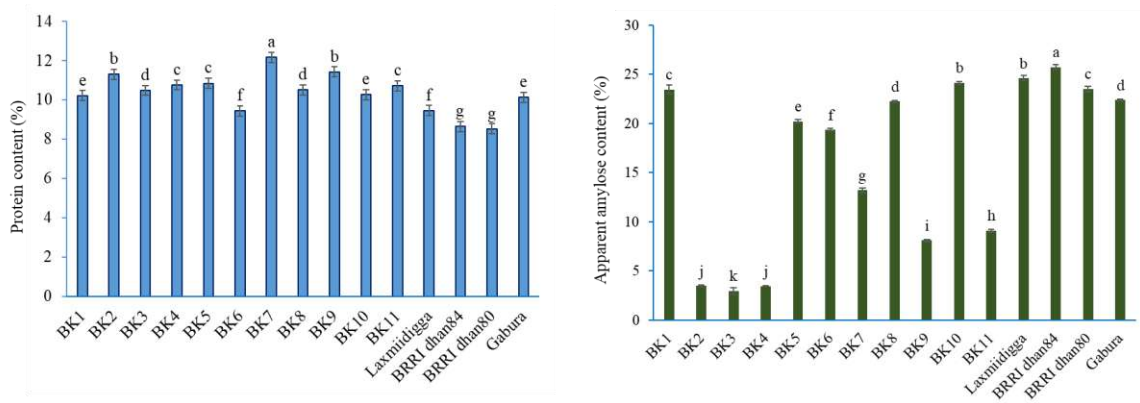


Fig 2. Chemical properties of selected rice samples (Protein content Fig. 2.A and AAC % in Fig.2.B).

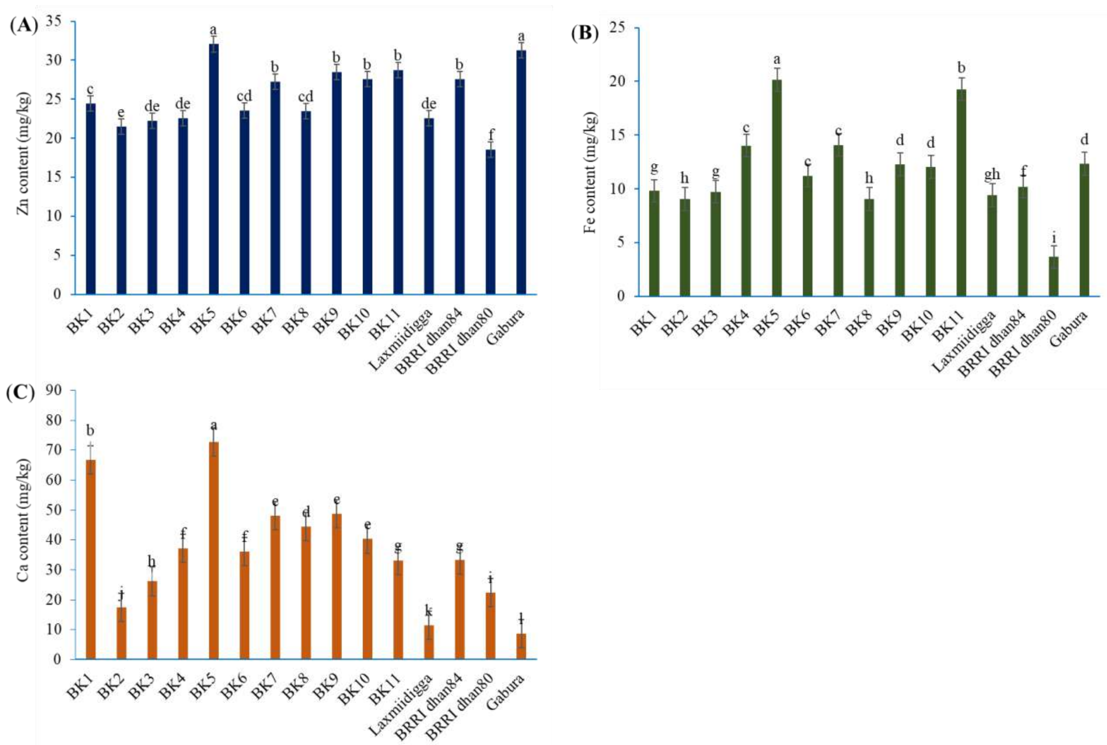


Fig. 3. Mineral profiling of selected rice samples of Zn (mg/Kg or ppm, Fig. 3A), Fe (mg/Kg or ppm, Fig.3B) and Ca (mg/Kg or ppm, Fig. 3C).

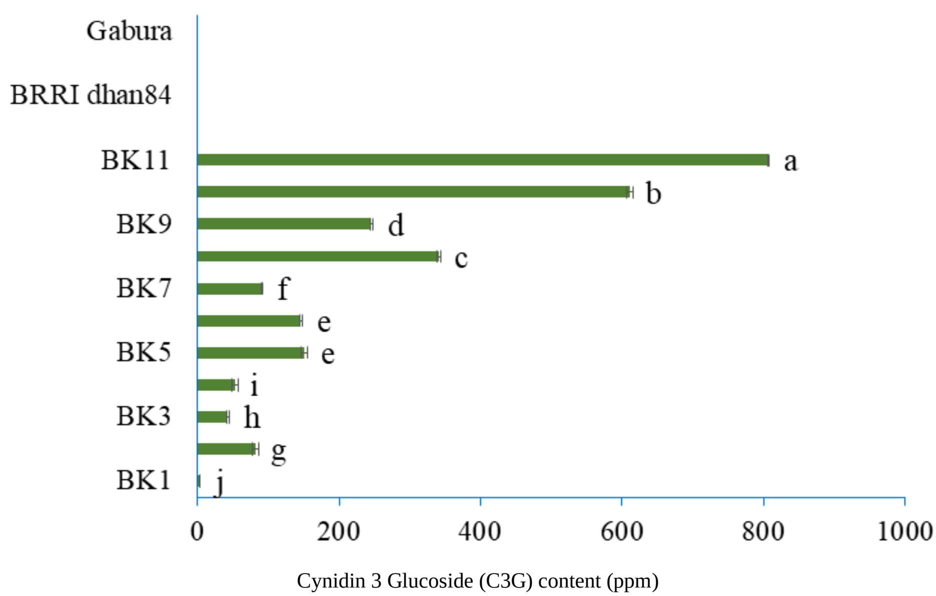


Fig 4. Cynidin 3 Glucoside (C3G) content (mg/kg) of selected rice samples.

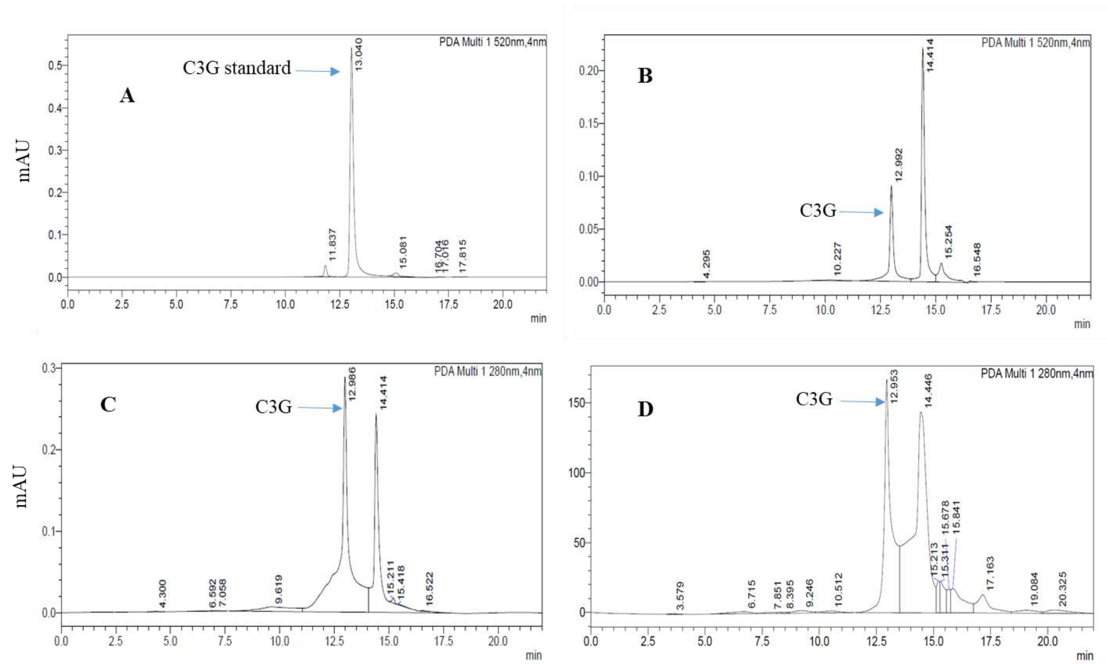


Fig 5. UFLC peak of Cyanidin-3-glucoside (RT;13.04 mins) in standard solution (A) at 520 nm. UFLC peak of Cyanidin-3-glucoside (RT;12.99 mins) in raw and cooked rice (BK11) was monitored at 520 nm (B) and 280 nm (C) respectively. UFLC peak of C3G in black rice (BK11) based cake (D).

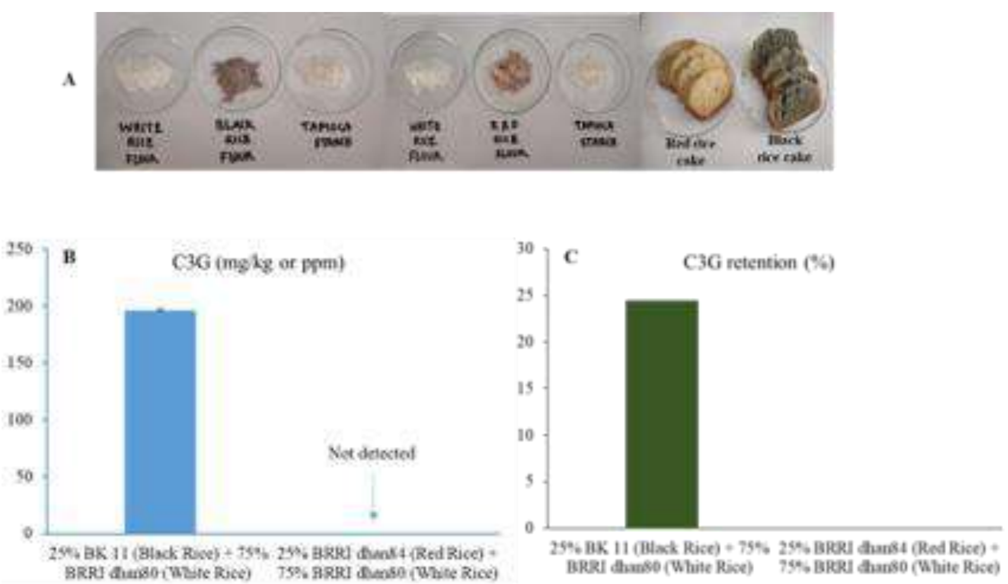


Fig. 6. Pictorial view of brown rice flour powder of red (BRRI dhan84), black (BK11), and white (BRRI dhan80) pericarp rice including Tapioca starch powder (Fig. 6.A) and Pictorial view of black and red pericarp rice flour in preparation of rice-based cake (Fig. 6.A). Graphical representation of C3G content in proportionate mixture of black and white rice, and red and white rice at cooking condition.

Table 13. Physicochemical parameters of local germplasms and HYVs.

Germplasms	Pericarp color	Length (mm)	Breath(mm)	L/B ratio	Grain size and shape	Aroma
BK1	Black and white	5.9	2.5	2.4	Medium bold	-
BK2	Black	7.6	2.2	3.4	Extra-long slender	-
BK3	Black	6.7	2.5	2.7	Long bold	-
BK4	Black	6.5	2.5	2.6	Long bold	-
BK5	Black	6.5	2.3	2.8	Long bold	-
BK6	Black	6.5	2.6	2.5	Long bold	+
BK7	Black	6.6	2.1	3.1	Long slender	-
BK8	Black	6.2	2.3	2.6	Long bold	-
BK9	Black	6.5	2.1	3.0	Long bold	+
BK10	Black	6.3	2.5	2.5	Long bold	-
BK11	Black	7.6	2.5	3.0	Extra-long bold	-
Laxmideega	Black and red	5.7	2.4	2.3	Medium bold	-
BRRI dhan84	Red	6.5	2.2	3.0	Long bold	-
BRRI dhan80	White	6.8	2.1	3.2	Long slender	-
Gabura	White	6.6	2.7	2.5	Long bold	-

Table 14. Retention of C3G in cooked black rice and mixed with red and white pericarp HYVs.

Sample	C3G (mg kg^{-1})	C3G retention (%)
100% BRRI dhan80 (cooked)	Not detected	Not detected
5% BK 11 + 95% BRRI dhan80 (cooked)	25.04 ± 0.99f	3.24
10% BK 11 + 90% BRRI dhan80	38.94 ± 1.51e	4.66
25% BK 11 + 75% BRRI dhan80 (cooked)	109.26 ± 5.24c	12.98
100% BK11 (raw)	806.17 ±1.06a	Not applied
100% BK11 (cooked)	387.40 ±1.44b	47.85
100% BRRI dhan84 (cooked)	Not detected	Not detected
5% BK 11 + 95% BRRI dhan84 (cooked)	36.38 ±5.33e	3.76
10% BK 11 + 90% BRRI dhan84 (cooked)	55.78 ±2.67d	6.75
25% BK 11 + 75% BRRI dhan84 (cooked)	109.46 ±6.53c	13.34

Any two-means having common letter (s) are not statistically different at a $P < 0.05$, as measured by the Duncan Multiple Range Test (DMRT).

METHOD DEVELOPMENT AND VALIDATION FOR DETECTION OF BIOACTIVE COMPOUNDS, PHYTOHORMONES, VITAMINS AND AROMA IN RICE GRAIN

A total of 11 methods including nine HPLC and two GCMS methods were developed and validated using Shimadzu Prominence-i Modular HPLC and Shimadzu Nexis GC2030 equipped with MS-QP2020NX at GQN and BCL laboratory respectively. HPLC methods for detection and quantification of rice phytohormones including 3-Indoleacetic acid (IAA), Gibberellic Acid (GA_3) and Abscisic Acid (ABA), Water soluble rice vitamins such as Thiamine ($VitB_1$), Riboflavin ($VitB_2$), Niacin ($VitB_3$), Thyroxine (Vit B_6), Folic acid (Vit B_9) and Cyanocobalamin (Vit B_{12}). GCMS methods are detection and quantification of rice volatile aromatic compounds such as 2AP (2 Acetyl-1-Pyrroline) and rice fatty acid profiling (C14:0 Myristic acid, C14:1 Myristoleic acid, C16:0 Palmitic acid, C16:1 Palmitoleic acid, C18:0 Stearic acid, C18:1 Oleic acid, C18:2/Omega-6 Linoleic acid, C18:3/Omega-3 Linolenic acid, C20:0 Arachidic acid, C20:1 Eicosanoic acid, C22:0 Behenic acid).

The HPLC prominence-i LC2030C Shimadzu machine was equipped with Shim pack GISS RP C18 column (3µm 4.6x150 mm). Methanol (HPLC grade):0.1% Acetic acid >99.0%): Water (MQ) (40:40:20 v/v) were used as mobile phase. The separation was carried out by isocratic elution with a flow of 0.8 ml/min, oven temperature was set at 30°C and injection volume was 10 µl. The standard solution of the individual phytohormones (ABA, GA_3 and IAA) was dissolved in HPLC grade methanol. Signal of the compounds was monitored at 280, 208 and 265 nm by using PDA detector for the detection of specific peak of ABA, GA_3 and IAA respectively (Fig. 1, Fig. 2 and Fig. 3).

Mobile Phase for $VitB_1$ was Methanol: 0.05 M CH3C00Na, pH 6.0 (40:60) in an isocratic solution. Mobile Phase for $VitB_2$, $VitB_3$, $VitB_6$, $VitB_9$ and $VitB_{12}$ was Methanol: 0.05 M NaH_2P0_4

with 0.005 M Hexanesulfonic acid, pH 3.0 in a gradient solution. The standard solution of the individual water soluble vitamins ($VitB_1$,$VitB_2$, $VitB_3$, $VitB_6$,$VitB_9$ and $VitB_{12}$) was dissolved in HPLC grade methanol. Signal of the compounds was monitored at 270, 268, 260, 291, 283 and 362 nm by using PDA detector for the detection of specific peak of $VitB_1$,$VitB_2$,$VitB_3$,$VitB_6$,$VitB_9$ and $VitB_{12}$ respectively (Fig. 4, Fig. 5, Fig. 6, Fig. 7, Fig. 8 and Fig. 9).

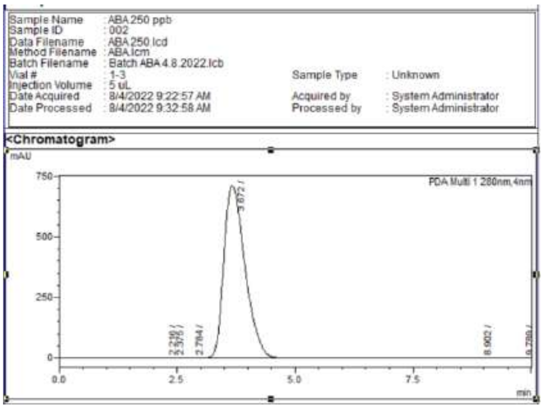


Fig. 1 HPLC peak of ABA (RT 3.67 mins, PDA detector at 208 nm).

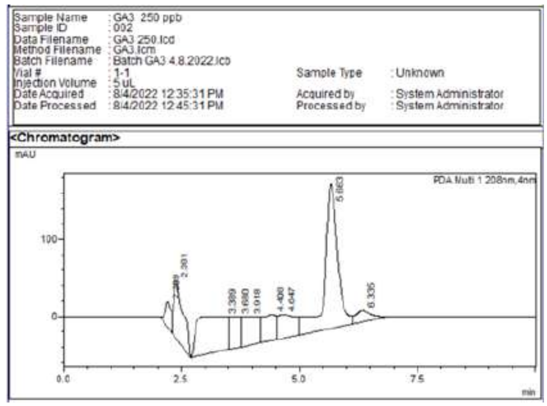


Fig. 2 HPLC peak of GA_3 (RT 5.66 mins, PDA detector at 280 nm).

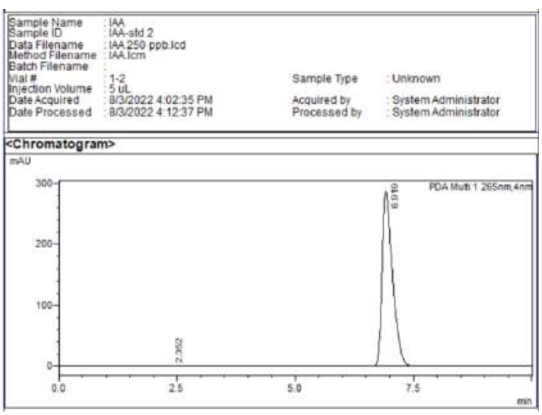


Fig. 3 HPLC peak of IAA (RT 6.91 mins, PDA PDA detector at 270 nm).

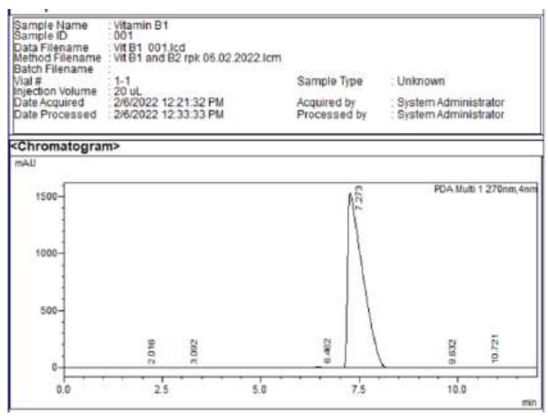


Fig. 4 HPLC peak of $VitB_1$ (RT 7.27 mins, detector at 265 nm).

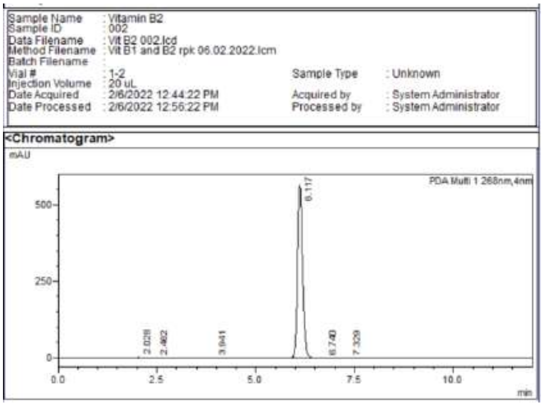


Fig. 5 HPLC peak of VitB$_2$ (RT 6.11 mins, PDA PDA detector at 268 nm).

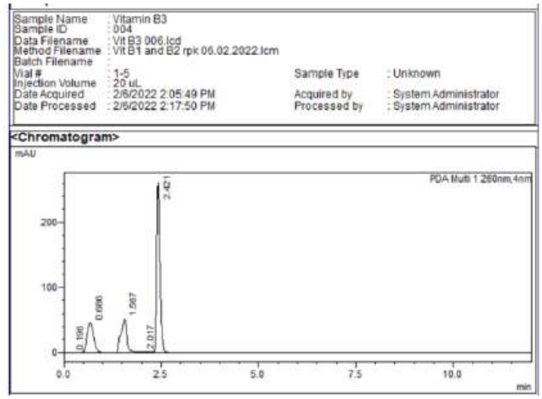


Fig. 6 HPLC peak of VitB$_3$ (RT 2.42 mins, detector at 260 nm).

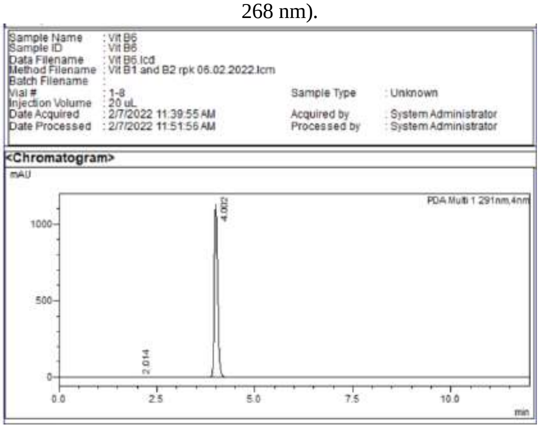


Fig. 7 HPLC peak of VitB$_6$ (RT 4.00 mins, PDA PDA detector at 283 nm).

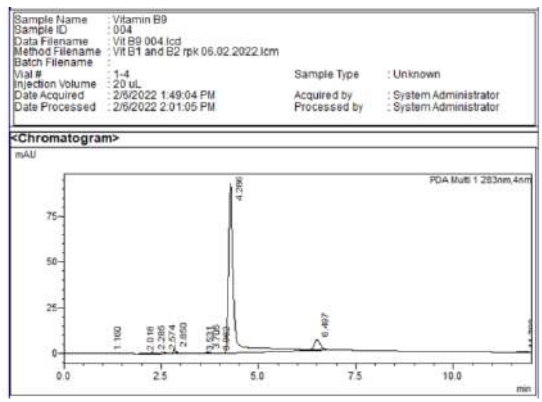


Fig. 8. HPLC peak of VitB$_9$ (RT 4.28 mins, detector at 291 nm).

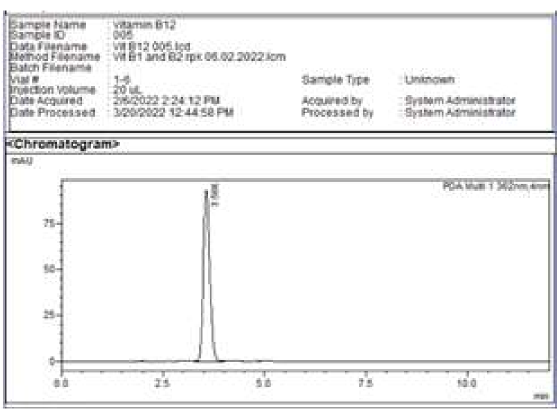
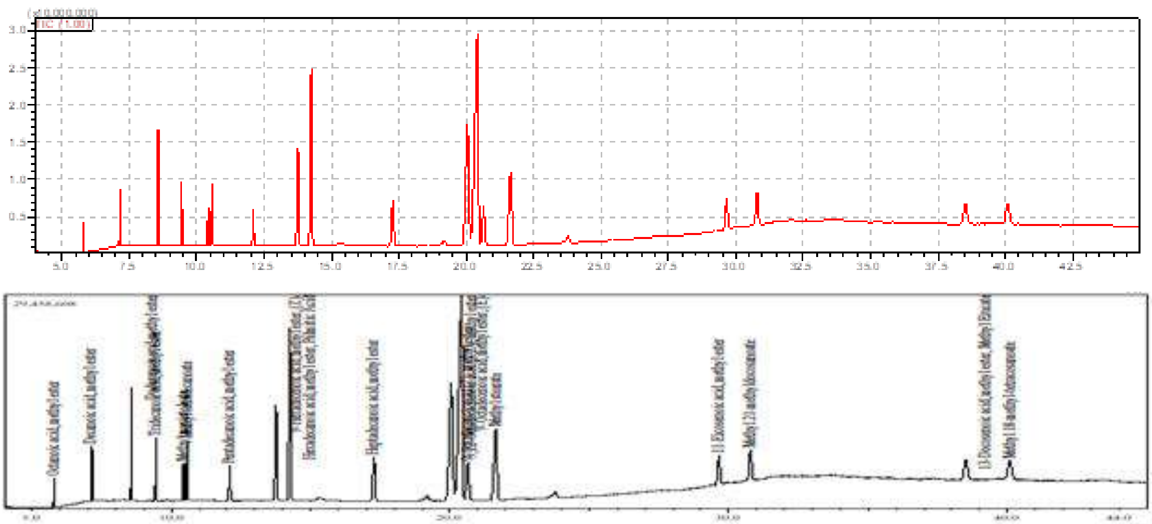


Fig. 9. HPLC peak of VitB$_{12}$ (RT 3.56 mins, PDA detector at 362 nm).

Fatty acids need to be converted into fatty acid methyl esters (FAME) for GCMS analysis. For the purpose, 15 g of each oil sample was poured into a test tube and 2 ml 5M KOH was added. The solution was heated at 85°C for 10 min. The resulting solution was then neutralized with 0.7M HCL. The resulted solution was further heated at same temperature for 10 minutes and methylated oil was extracted with petroleum ether. The fatty acid methyl esters were then separated and subjected to GC2030 equipped with MS-QP2020NX SH-Rxi-5Sil MS (30 m, 0.25 mm ID, 0.25 µm columns) and OPTIC-4. Helium was the carrier gas at the flow rate of 50 psi and SCAN acquisition speed was 1.666 and m/z was between 50 to 500. Interface Temperature was 250°C. The temperature was programmed at holding temperature at 50°C for 1 minute then increased temperature at 200°C at a rate of 25°C per minutes and then hold for 15 mins. Later on increased temperature at 230°C ant rate of 3°C per mins and finally hold at 230°C for 13 mins. In total run time of sample was 45 mins.

Identification and quantification of the methyl esters were made by comparison of retention time with standard fatty acid methyl esters Certified reference materials of Grain FAME Mix CRM47801 Supelco were used in the analysis as reference (Fig. 10). NIST20M1 GCMS library was used for detection and confirmation of fatty acid methyl esters. Data were expressed in percentage format.

2-Acetyl-l-Pyrroline (2AP), volatile aromatic compound was screened and measured in GC2030 equipped with MS-QP2020NX SH-Rxi-5Sil MS (30 m, 0.25 mm ID, 0.25 µm columns) and OPTIC-4. Helium was the carrier gas at the flow rate of 50 psi and SIM acquisition mode was selected for 41, 43, 69, 83 and 111 m/z. Interface temperature was 250°C. The temperature was programmed at holding temperature at 50°C for five minutes then increased temperature at 100°C at a rate of 10°C per minutes. Total run time of sample was 10 minutes. The standard of 2-Acetyl-1-Pyrroline (2AP, 95% purity, Toronto Research Chemicals (TRC) Catalog no.4187225) was used. Four points calibration curve was found linear (y=7569.8x-481224, R^2 :0.997) and standards are ranging from 100 ppb to 500 ppb. Retention time (RT) of 2AP is 6.7 mins and m/z is 43. NIST20M1 GCMS library was used for detection and confirmation of 2AP (Fig. 11).



Quantitative Result Table

ID#	Name	R.Time	m/z	Area	Conc.	Conc.Unit
1	Octanoic acid, methyl ester	5.790	74.00	1845602	1.466	%
2	Decanoic acid, methyl ester	7.156	74.00	3557205	2.825	%
3	Lauric Acid	8.568	74.00	8087145	6.422	%
4	Tridecanoic acid, methyl ester	9.446	74.00	4805808	3.816	%
5	Methyl myristoleate	10.435	55.00	1455737	1.156	%
6	Methyl tetradecanoate/Myristoleate	10.573	74.00	5452136	4.330	%
7	Pentadecanoic acid, methyl ester	12.101	74.00	3808878	3.025	%
8	-Hexadecenoic acid, methyl Palmitat	13.757	55.00	4803076	3.814	%
9	Methyl Palmitoleate	14.257	74.00	23696062	18.818	%
10	Heptadecanoic acid, methyl ester	17.274	74.00	7536716	5.985	%
11	Stearic Acid	20.039	67.00	12501161	9.928	%
12	Elaidic Acid	20.414	55.00	16333050	12.971	%
13	Oleic Acid	20.644	55.00	2510117	1.993	%
14	Linoleic Acid	21.646	74.00	15705063	12.472	%
15	11-Eicosenoic acid, methyl ester	29.656	55.00	2195927	1.744	%
16	Linolenic Acid	30.794	74.00	4909810	3.899	%
17	Behenic Acid	38.500	55.00	2093654	1.663	%
18	Erucic Acid	40.093	74.00	4625327	3.673	%

Fig. 10. Chromatogram view of fatty acid methyl ester (FAME) at GCMS.

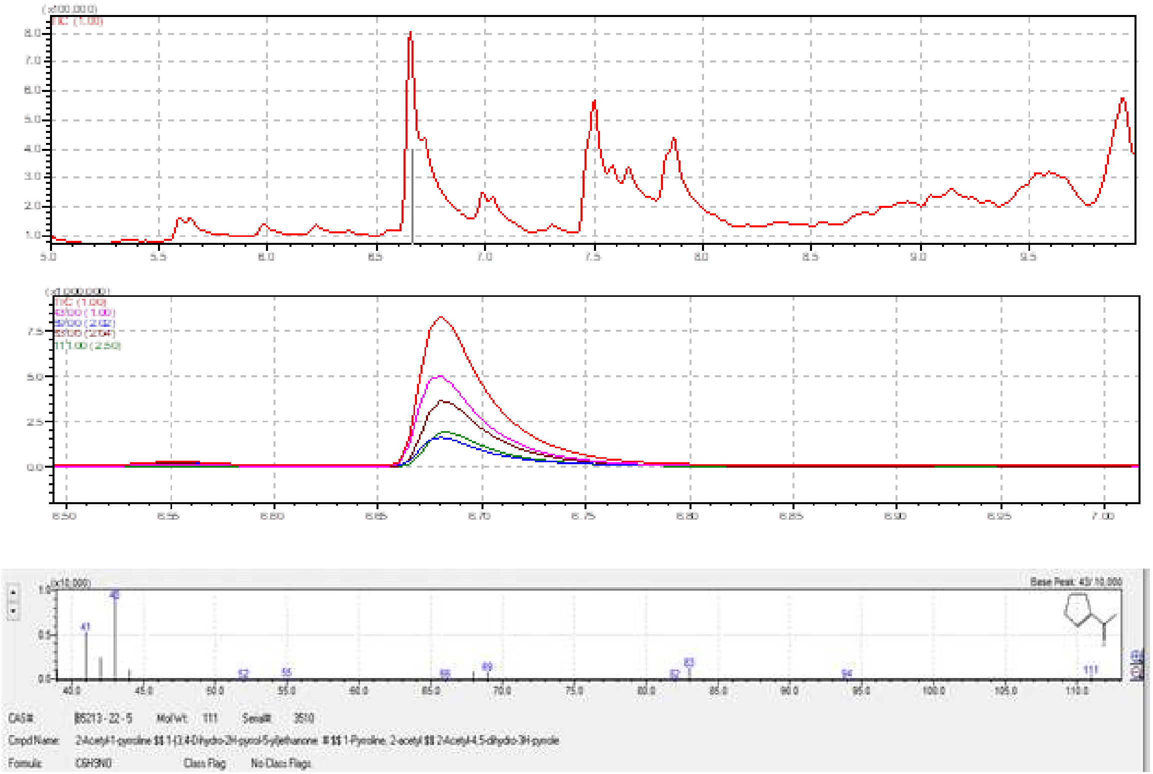


Fig. 11. Chromatogram view of aromatic volatile compound 2-Acetyl-l-Pyrroline (2AP) at GCMS.

COMMERCIAL RICE BASED PRODUCTS

Determination of physicochemical properties and quality of puffed, popped and flattened rice from newly released BRRI varieties

PI: MAH; **CI:** NF, TKS, HBS and MAS

Physical properties viz length, breadth, thickness, increased length and breadth, volume of rice products such as puffed, popped and flattened rice were determined. This study aims to screen out the BRRI released varieties that are suitable for popular snack food products: puffed, popped and flattened rice for instances. BR16 is used as standard for all the products of puffed, popped and flattened rice. Comparing with the standard variety, it is ascertained from the results that BRRI dhan99 and Bangabandhu dhan100 are better in producing fully puffed rice 47.8% and 61.9% respectively followed by BRRI dhan97 (40.7%) and BRRI dhan9 (41.4%) in terms of weight of fully puffed rice. Considering overall parameters, BRRI dhan99 and Bangabandhu dhan100 yielded better results: puffed rice length =11.95 mm and 10.41 mm; increased percentage of puffed rice length= 100.1% and 94.2%; and 50 g puffed rice volume = 530 ml and 550 ml followed BRRI dhan97, (puffed rice length =11.45 mm, increased percentage of length =97.7%, volume =481.7 ml) and BRRI dhan98 (puffed rice length =11.47 mm, increased percentage of length =71.5%, volume =423.3 ml) respectively (Table 15). Results of correlation matrix for relationships ascertained that 1000 puffed rice weight is significant and positively correlated with milled rice length ($r=0.668$, $p<0.05$) and only positively correlated with milled rice breadth. Volume of 50 g puffed rice is highly significant and positively correlated with puffed rice length increased percent ($r=0.832$, $p<0.01$), significant and positively correlated with puffed rice breadth increased percent ($r=0.720$, $p<0.05$) but highly significant and negatively correlated with 1000 puffed rice weight ($r=0.773$, $p<0.05$) (Table 16).

In the case of popped rice, BRRI dhan99 and Bangabandhu dhan100 show excellent performance followed by BRRI dhan96 and BRRI dhan98 considering total popped rice percent, fully popped rice percent, partial and broken popped rice percent. On the other hand, in terms of increased popped rice length and volume of 50 g popped rice, Bangabandhu dhan100 (139.27% and 1050.00 ml) performed better than BRRI dhan99 (112.40% and 816.70 ml). However, BRRI dhan99 (149.66%) and Bangabandhu dhan100 (148.37%) showed the highest potential in increasing breadth percent and fully popped percent (80.01% and 82.28%) respectively after being popped (Table 17). Results of correlation matrix for relationships ascertained that brown rice breadth is significant and positively correlated with total waste ($r=0.779$, $p<0.05$). Fully popped rice weight is highly significant and positively correlated with popped rice length ($r=0.856$, $p<0.01$). It is also significant and positively correlated with popped rice length percent ($r=0.676$, $p<0.05$) increased. Popped rice breadth increased percent is significant and positively correlated with total popped rice weight ($r=0.720$, $p<0.05$) and popped rice length increased percent ($r=0.769$, $p<0.05$). Weight of 1000 popped rice is significant and positively correlated with total waste ($r=0.725$, $p<0.05$), brown rice length ($r=0.715$, $p<0.05$) and brown rice breadth ($r=0.790$, $p<0.05$). Volume of 50 g popped rice is highly significant and positively correlated with popped rice length increased percent ($r=0.876$, $p<0.01$) and popped rice breadth increased ($r=0.861$, $p<0.01$) percent. It is also significant and positively correlated with total popped rice weight ($r=0.738$, $p<0.05$) and fully popped rice weight ($r=0.771$, $p<0.05$) (Table 18).

Similarly, physical properties such as whole, partial and broken flattened rice were considered. Comparing with the standard variety (BR16), it is revealed from the results that in terms of weight of whole, partial and broken flattened rice BRRI dhan98 showed the best performance followed by BRRI dhan96. Moreover, the results demonstrated that BRRI dhan96 showed higher potential in producing flattened rice considering flattened rice length increased percent, thickness of flattened rice and volume of 50 g sample (li=125.40%, t=0.57 mm, vol=170.0 ml) which is better than the standard as of BR16 (li=104.38%, t=0.53 mm, vol=158.3 ml) and other varieties considered for this study (Table 19). It is ascertained from the study that brown rice length and breadth are not insignificantly correlated with the flattened rice length and breadth. Results of correlation matrix for relationships ascertained that flattened rice breadth increased is significant and positively correlated with broken flattened rice wt. ($r=0.733$, $p<0.05$). Similarly, 1000 Flattened rice weight is significant and positively correlated with flattened rice breadth ($r=0.827$, $p<0.05$) and flattened rice breadth increased ($r=0.765$, $p<0.05$) (Table 20) percent.

Table 15. Physical properties of puffed rice of BRRI modern varieties.

Variety name	Fully puffed rice wt. (%)	Partial puffed rice wt. (%)	Milled rice length (mm)	Milled rice breadth (mm)	Puffed rice length (mm)	Puffed rice length increased (%)	Puffed rice breadth (mm)	Puffed rice breadth increased (%)	1000 Puffed rice wt. (g)	50 gm Puffed rice volume (ml)
BR16	74.0A	25.9F	6.62	2.23	11.90A	79.8D	4.18C	87.3BC	17.50D	423.3E
BRRI dhan96	17.8EF	82.2AB	5.60	2.09	11.15C	99.0A	4.16C	99.0A	11.78H	530.3B
BRRI dhan97	40.7D	59.2C	5.79	2.53	11.45B	97.7A	4.75A	87.7BC	11.81H	481.7C
BRRI dhan98	41.4	58.6C	6.69	2.07	11.47B	71.5F	3.83E	85.0CD	15.17E	423.3E
BRRI dhan99	47.8C	50.9D	5.97	2.09	11.95A	100.1A	3.99D	91.1B	13.66F	530.0B
Bangabandhu dhan100	61.9B	38.1E	5.36	2.02	10.41D	94.2B	3.67F	81.5D	12.36G	555.0A

BRRI hybrid dhan3	13.2F	86.7A	5.75	2.67	10.04E	74.6E	4.08CD	52.9G	17.83C	366.0G
BRRI hybrid dhan5	21.5E	78.2B	6.92	2.53	11.60B	67.7G	4.12C	62.7F	21.68A	416.0F
Hybrid hera	13.4F	86.5A	5.86	2.54	11.18C	90.7C	4.34B	71.0E	18.15B	440.0D
Range	13.2-74.0	25.9-86.7	5.4-6.9	2.0-2.7	10.04-11.95	67.7-100.1	3.67-4.75	52.9-87.3	11.78-21.68	366.0-555.0
Mean±SD	36.8±22.0	62.9±22.1	6.1±0.54	2.3±0.26	11.238±0.64	86.14±12.8	4.1244±0.31	79.815±17.74	15.549±3.45	462.85±64.35
SE	2.918	2.924	0.0	0.0	0.078	1.388	0.047	2.0	0.1	3.0
CV%	9.7	5.7	0.0	0.0	0.9	2.0	1.4	3.0	0.7	0.8

Table 16. Correlation among the physical properties of puffed rice of BRRI modern varieties

Correlations

Parameter	Fully puffed rice wt. (%)	Partial puffed rice wt. (%)	Milled rice length (mm)	Milled rice breadth (mm)	Puffed rice length (mm)	Puffed rice length increased (%)	Puffed rice breadth (mm)	Puffed rice breadth increased (%)	1000 Puffed rice wt. (g)
Partial puffed rice wt. (%)	-1.000**								
Milled rice length (mm)	.122	-.122							
Milled rice breadth (mm)	-.577	.580	.090						
Puffed rice length (mm)	.348	-.355	.611	-.246					
Puffed rice length increased (%)	.133	-.139	-.753*	-.338	.059				
Puffed rice breadth (mm)	-.265	.267	-.032	.620	.264	.244			
Puffed rice breadth increased (%)	.477	-.480	-.161	-.754*	.518	.645	.044		
1000 Puffed rice wt. (g)	-.298	.300	.668*	.573	.077	-.787*	-.014	-.750*	
50 gm Puffed rice volume (ml)	.329	-.335	-.569	-.683*	.105	.832**	-.175	.720*	-.773*

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Table 17. Physical properties of popped rice of BRRI modern varieties.

Variety name	Total popped rice wt. (%)	Total waste (%)	Fully popped rice wt. (%)	Partial popped rice wt. (%)	Broken popped rice wt. (%)	Brown rice length (mm)	Brown rice breadth (mm)	Popped rice length (mm)	Popped rice length increased (%)	Popped rice breadth (mm)	Popped rice breadth increased (%)	1000 Popped rice wt. (g)	50 gm Popped rice volume (ml)
BR16	51.79A	33.55D	82.75A	16.21E	1.16EF	6.83	2.08	13.69A	100.44C	4.86C	133.65B	19.72E	780.0C
BRRI dhan96	44.95D	41.26BC	43.45C	49.59B	6.87A	5.8	1.93	10.62F	83.16H	3.93E	103.80C	13.13I	586.0E
BRRI dhan97	32.37E	46.63B	40.47C	59.32A	0G	6.07	2.55	11.30E	86.21G	4.96ABC	94.38D	20.18D	525.0G
BRRI dhan98	45.82C	38.62CD	78.51A	20.56E	0.80FG	6.59	2.02	12.82C	94.54E	3.95E	95.38D	17.29F	690.0D
BRRI dhan99	45.99C	38.67CD	80.01A	17.76E	2.06DE	6.34	2.02	13.47B	112.40B	5.04AB	149.66A	16.16G	816.7B

Bangabandhu dhan100	47.33B	37.45CD	82.28A	14.78E	2.84CD	5.61	1.95	13.42B	139.27A	4.84C	148.37A	13.25H	1050.0A
BRRI hybrid dhan3	30.99F	54.67A	56.62B	40.99C	2.23D	6.22	2.47	12.28D	97.48D	5.07A	105.26C	21.55B	555.7F
BRRI hybrid dhan5	24.36H	60.09A	63.33B	31.06D	5.41B	7.26	2.35	13.82A	90.31F	4.097D	74.33E	24.86A	529.3G
Hybrid hera	25.97G	58.19A	59.17B	37.23CD	3.45C	6.06	2.45	12.29D	102.8C	4.90BC	100.14CD	20.51C	533.3G
Range	24.36-51.79	33.55-60.09	40.47-82.75	14.78-59.32	0.80-6.87	5.61-7.26	1.93-2.55	10.62-13.82	83.16-139.27	3.93-5.07	74.33-149.66	13.13-24.86	525.0-1050.0
Mean±SD	38.8±10.34	45.5±9.87	65.2±16.56	32.0±15.98	2.8±2.21	6.3±0.52	2.2±0.25	12.6±1.1	100.7±17.0	4.6±0.48	111.7±26.1	18.5±3.9	674.0±179.5
SE	0.1675	2.6445	3.4155	3.2718	0.4651	0	0	0.0858	1.3389	0.0677	3.208	0.0385	9.0117
CV%	0.53	7.12	6.42	12.54	20.67	0	0	0.83	1.63	1.79	3.52	0.25	1.64

Table 18. Correlation among the physical properties of popped rice of BRRI modern varieties.

Correlations

Parameter	Total popped rice wt. (%)	Total waste (%)	Fully popped rice wt. (%)	Partial popped rice wt. (%)	Broken popped rice wt. (%)	Brown rice length (mm)	Brown rice breadth (mm)	Popped rice length (mm)	Popped rice length increased (%)	Popped rice breadth (mm)	Popped rice breadth increased (%)	1000 Popped rice wt. (g)
Total waste (%)	-.980**											
Fully popped rice wt. (%)	.562	-.503										
Partial popped rice wt. (%)	-.549	.471	-.991**									
Broken popped rice wt. (%)	-.213	.337	-.303	.175								
Brown rice length (mm)	-.198	.222	.276	-.278	-.054							
Brown rice breadth (mm)	-.857**	.779*	-.556	.605	-.226	.162						
Popped rice length (mm)	.152	-.105	.856**	-.857**	-.207	.579	-.196					
Popped rice length increased (%)	.356	-.330	.676*	-.677*	-.164	-.374	-.381	.539				
Popped rice breadth (mm)	-.066	.012	.114	-.045	-.528	-.273	.391	.166	.447			
Popped rice breadth increased (%)	.720*	-.699*	.621	-.606	-.249	-.385	-.574	.351	.769*	.527		
1000 popped rice wt. (g)	-.743*	.725*	-.182	.204	-.122	.715*	.790*	.268	-.425	.120	-.616	
50 gm popped rice volume (ml)	.738*	-.717*	.771*	-.769*	-.201	-.284	-.707*	.515	.876**	.218	.861**	-.633

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Table 19. Physical properties of flattened rice of BRRI modern varieties

Variety name	Fully flattened rice wt. (%)	Partial flattened rice wt. (%)	Broken flattened rice wt. (%)	Brown rice length (mm)	Brown rice breadth (mm)	Flattened rice length (mm)	Flattened rice length increased (%)	Flattened rice breadth (mm)	Flattened rice breadth increased (%)	Flattened rice thickness (mm)	1000 Flattened rice wt. (g)	50 gm Flattened rice volume (ml)
BR16	75.61B	2.08D	22.21D	6.77	2.18	13.84A	104.38D	4.38D	101.1C	0.53C	18.37E	158.33C
BRRI dhan96	73.35B	4.26BC	22.24D	5.76	2.11	12.98C	125.4A	4.22E	100.0C	0.57BC	16.30F	170B
BRRI dhan97	34.09F	6.25A	59.57A	6.62	2.08	12.94C	95.42E	4.78B	129.97A	0.63B	22.28B	140E
BRRI dhan98	92.43A	1.28D	6.25E	6.17	2.66	11.73F	90.06F	3.72F	39.97E	0.58BC	13.78H	150D
BRRI	62.81	3.76C	33.34C	6.41	2.18	13.35	108.22	4.87B	123.24	0.71A	27.19	140E

dhan99	C					B	C		B		A	
Bangabandhu dhan100	55.93 DE	6.07A	37.91B	5.59	2	12.03 E	115.27 B	3.82F	90.83D	0.61B	15.62 G	120F
BRRI hybrid dhan3	55.57 E	5.49AB	38.87B	6.39	2.66	12.29 D	92.33F	5.04A	89.77D	0.62B	20.06 C	181.67 A
BRRI hybrid dhan5	59.57 CD	1.2D	39.12B	7.28	2.45	12.29 D	68.77G	4.64C	89.25D	0.56BC	19.93 D	160C
Range	34.09-92.43	1.2-6.25	6.25-59.57	5.59-7.28	2.0-2.66	11.73-13.84	68.77-125.4	3.72-5.04	39.97-129.97	0.53-0.71	13.78-27.19	120-181.67
Mean±SD	63.669±17.3	3.7975±2.1	32.439±15.8	6.3738±0.6	2.2900±0.3	12.680±0.8	99.981±17.4	4.4338±0.5	95.514±27.2	0.6000±0.1	19.191±4.3	152.50±19.4
SE	1.8465	0.7638	1.8028			0.0924	1.4091	0.0509	2.2912	0.0325	0.041	1.1785
CV%	3.55	24.63	6.81	0	0	0.89	1.73	1.41	2.94	6.64	0.26	0.95

Table 20. Correlation among the physical properties of flattened rice of BRRI modern varieties.

Correlation

Parameter	Fully flattened rice wt. (%)	Partial flattened rice wt. (%)	Broken flattened rice wt. (%)	Brown rice length (mm)	Brown rice breadth (mm)	Flattened rice length (mm)	Flattened rice length increased (%)	Flattened rice breadth (mm)	Flattened rice breadth increased (%)	Flattened rice thickness (mm)	1000 Flattened rice wt. (g)
Partial flattened rice wt. (%)	-.724*										
Broken flattened rice wt. (%)	-.996**	.658									
Brown rice length (mm)	-.185	-.498	.268								
Brown rice breadth (mm)	.393	-.465	-.367	.314							
Flattened rice length (mm)	-.105	.004	.113	.257	-.518						
Flattened rice length increased (%)	.101	.475	-.174	-.800*	-.654	.367					
Flattened rice breadth (mm)	-.593	.243	.615	.559	.107	.418	-.288				
Flattened rice breadth increased (%)	-.737*	.534	.733*	.175	-.679	.704	.280	.653			
Flattened rice thickness (mm)	-.322	.491	.272	-.418	-.135	-.013	.396	.356	.560		
1000 flattened rice wt. (g)	-.536	.201	.558	.439	-.185	.525	-.108	.827*	.765*	.725	
50 gm flattened rice volume (ml)	.228	-.247	-.216	.289	.581	.099	-.214	.414	-.160	-.303	-.058

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Hybrid Rice Division

SUMMARY

In T. Aman season 2021, a total of 76 test crosses and 611 (A × R) crosses were made from source nursery. Two hundred seven test crosses (F_1s) were evaluated for their pollen fertility status of which one entry has been found heterotic over check varieties. Pollen parent of this combination was regarded as suspected restorer and selected for fertility restoration ability with other CMS lines in the next season. One entry was found completely sterile and their corresponding male parent was regarded as suspected maintainer line. Four backcross entries were advanced as new CMS lines. Other backcross generations were advanced to the next generations except three BC_1 generations which were found unstable in terms of pollen sterility and hence discarded. Ninety CMS lines along with their respective maintainer lines were maintained by hand crossing.

A total of 134 test crosses and 410 (A × R) crosses were made using 13 CMS lines in Boro season 2021-22. One hundred twenty-seven test crosses (F_1s) were evaluated for their pollen fertility status. Among them thirteen entries showed complete sterility and immediately backcrossed with their corresponding male parents for conversion. On the other hand, four entries have been selected for their high yielding ability compared with check varieties. All the backcross entries were advanced for next generations except for three entries. One hundred eighteen CMS lines along with their respective maintainer lines were maintained by hand crossing in CMS maintenance and evaluation nursery for their genetic purity.

In T. Aman, out of 271 test hybrids under observational trials nine (9) hybrid combinations were selected based on yield, duration and grain type and expressed more than 15-30% yield advantage over check variety BRRI hybrid dhan6, 10-25% over AZ7006 and 4-18 % over Dhanny Gold. The heritability obtained from growth duration, spikelet fertility and grain yield were 78%, 81% and 69% respectively, indicating high level of precision in this experiment. In Boro, out of 429 test hybrids 14 hybrid combinations were selected based on yield, duration and grain type. The selected hybrid combinations expressed 7-30% yield advantage over BRRI hybrid dhan5, 14-38% over SL8H and 24-51% over Suborno. The heritability obtained from growth duration and grain yield was 88% and 80% respectively, indicating high level of precision in this experiment.

Under parental line improvement programme (B × B and R × R) 15 B × B and 11 R × R crosses were confirmed based on different cyto-sources and amylose content in T. Aman, 21 and 10 BxB and 12 R×R crosses were made based on different cyto-sources, grain type and amylose content in Boro 2021-22. Under field rapid generation advancement program 16,819 F_2 and F_3 progenies of B×B, R×R and A×R were advanced in T Aman and 54,163 progenies of F_2, F_3 and F_4 generations of B×B, R×R and A×R crosses were advanced in Boro 2021-22.

In T. Aman, preliminary yield trials, three hybrids were selected out of 14 and showed yield advantage 12-14 % over BRRI hybrid dhan6, 21-24 % over AZ7006 and 6-8 % over Dhanny Gold. In T. Aman under multi-location trials three hybrids out of 18 gave 11-18% yield advantage over BRRI hybrid dhan6, 11-17% over AZ7006 and 20-27% over Dhanny Gold. In Boro, Twenty-seven hybrids were evaluated under two sets along with three hybrids as check variety. In the first set, none of the hybrids showed superiority over BRRI hybrid dhan5 but two hybrids were found promising in second set and expressed yield advantage 12-14% over BRRI hybrid dhan5, 27-29% over Suborno-3 and 22-24% over Teea check variety.

Adaptability under saline condition of BRRI released and popular company hybrids along with popular saline tolerant inbred check BRRI dhan67 and BINA dhan10 along with locally adapted inbred IT was done at three coastal locations of Satkhira. The highest water salinity was found in Assasuni (7.65 dS/m) followed by Kaliganj (7.36 ds/m) and Debhata (6.81 ds/m). We found that the top three highest yielding genotypes were BRRI hybrid dhan3 (7.00 t ha-1), BRRI hybrid dhan5 (6.93 t ha-1) and BRRI hybrid dhan4 (6.88 t ha-1) followed by BRRI99A/EL254R (6.49), BRRI hybrid dhan6 (6.37 t ha-1), IT (6.35 t ha-1), BRRI hybrid dhan7 (6. 28 t ha-1), BRRI99A/BRRI31R (6.11 t ha-1), Binadhan-10 (5.85 t ha-1), BRRI hybrid dhan2 (5.75 t ha-1), BRRI dhan67 (5.75 t ha-1), Janokraj (5.60 t ha-1),

SL-8 (5.47 t ha-1), Gold (Lal teer) (5.45 t ha-1), Heera (Supreme) (5.34 t ha-1). Therefore, we can conclude that BRRI hybrid dhan3, BRRI hybrid dhan5 and BRRI hybrid dhan4 can be cultivated profitably in areas where water salinity level of the paddy field remains 3 dS/m to 6 dS/m.

Fifteen CMS lines including promising and released hybrids were multiplied during Boro 2021-22 and got seed yield ranging from 5.2 kg to 1300 kg/plot equivalent to 0.74 to 1.91 t/ha. Experimental F_1 seed production was made using fifteen CMS with six different restorer lines and seed yield was ranging from 0.8 to 40 kg/plot out of selected promising hybrid combinations during T. Aman 2021 which was equivalent to 0.02 to 1.14 t/ha. Eighty Experimental hybrids were evaluated in augmented design during Boro 2021-22 and selected four hybrids expressed more than 10% yield advantages over check varieties. In Boro 2021-22, a total of 960 kg (2.4 t/ha) from BRRI hybrid dhan5 and 1,246 kg (2.6 t/ha) from BRRI hybrid dhan6, 2,800 kg (2.7 t/ha) from BRRI hybrid dhan7 and 88 kg (2.2 t/ha) from BRRI hybrid dhan8 were obtained. From production side (Ishwardi, Mymensingh and Barishal) 1430 kg (1.8 t/ha) from BRRI hybrid dhan2, 10400 kg (2.4 t/ha) from BRRI hybrid dhna3, 2,460 kg (2.05 t/ha) from BRRI hybrid dhan4, 10,210 kg (2.04 t/ha) from BRRI hybrid dhan5, 6,000 kg (2.5 t/ha) from BRRI hybrid dhan6 and 6,060 (3.03 t/ha) from BRRI hybrid dhan7 was obtained.

In T. Aman 2021, hybrid rice division supplied 6,750 kg of parental lines and F_1 seeds to 90 farmers, 10 seed companies, scientists, extension people, project people and staffs of BRRI. In Boro 2021-22, hybrid rice division supplied 15,000 kg of parental lines and F_1 seeds to 130 farmers, 24 seed companies, scientists, extension people, projects and staffs of BRRI. In T Aus 2022, 4,357 kg F_1 seeds of BRRI hybrid dhan7 was distributed free of cost among farmers through different regional stations of BRRI and department of agricultural extension. Twenty-six stake holders produced more than 325 MT F_1 seeds using BRRI developed hybrid rice parental lines during Boro 2021-22.

DEVELOPMENT OF PARENTAL MATERIALS

Source nursery

Seventy-six test crosses and 611 (A x R) crosses were made during T. Aman season 2021. Ninety-five test crosses and 410 (A × R) crosses were made using 13 CMS lines during Boro season 2021-22.

Test cross nursery

In. Aman 2021, two hundred and seven test crosses (F_1s) were evaluated for their pollen fertility status of which one entry have been found heterotic over check varieties. Pollen parent of this combination was regarded as suspected restorer and selected for fertility restoration ability with other CMS lines in the next season. One entry was found completely sterile and its corresponding male parent was regarded as suspected maintainer line.

In Boro 2021-22, One hundred and twenty-seven test crosses (F_1s) were evaluated for their pollen fertility status. Among them 13 entries showed complete sterility and immediately backcrossed with their corresponding male parents for conversion. On the other hand, four entries have been selected for their high yielding ability compared with the check varieties.

Back cross nursery

In T. Aman 2021, four backcross entries were advanced as new CMS lines. Other backcross generations were advanced to next generations except three BC_1 generations which were found unstable in terms of pollen sterility and hence discarded.

In Boro 2021-22, all entries advanced for next generation except three for their pollen sterility fluctuation.

CMS maintenance and evaluation nursery

Ninety CMS lines were maintained by hand crossing for seed increase and genetic purity in T. Aman 2021 and in Boro 2020-21, 118 CMS lines were maintained through hand crossing for seed increase and genetic purity.

EVALUATION OF PARENTAL LINES AND HYBRIDS

In T Aman 2021, out of 271 test hybrids under observational trials nine hybrid combinations were selected based on yield, duration and grain type and expressed more than 15-30% yield advantage over check variety BRRI hybrid dhan6, 10-25% over AZ7006 and 4-18 % over Dhanny Gold. The heritability obtained from growth duration, spikelet fertility and grain yield were 78%, 81% and 69% respectively, indicating high level of precision in this experiment (Table 1). Upon commercial seed production feasibility of these selected hybrid combinations and grain quality assessment it will be tested under preliminary yield trial (PYT) and multi-location yield trials (MLT). Upon satisfactory yield advantage over check variety it is subjected to registration under National Hybrid Rice Yield Trial (NHRYT) for releasing as new hybrid rice of BRRI. In Boro, out of 429 test hybrids 14 hybrid combinations were selected based on yield, duration and grain type. The selected hybrid combinations expressed 7-30% yield advantage over BRRI hybrid dhan5, 14-38% over SL8H and 24-51% over Suborno-3. The heritability obtained from growth duration and grain yield was 88%% and 80% respectively, indicating high level of precision in this experiment (Table 2).

Table 1. List of experimental hybrids found heterotic over check variety during T. Aman 2021.

Designation	DTM	SF%	GT	PY(kg) $2m^2$	Yield (t/h)	Heterosis (%) Ck-1	Ck-2	Ck-3
BRRI99A/IR86411-2-1-1-1-2-1R	109	89.5	MS	1.54	7.7	17	12	5
BRRI97A/IR85551-9-1-1-1-2-1-1-1R	112	92.3	MS	1.7	8.5	29	23	16
BRRI109A/BRRI37R	113	90.2	LS	1.52	7.6	15	10	4
BRRI110A/BRRI42R	110	88.2	MS	1.72	8.6	30	25	18
BRRI109A/BRRI41R	114	85.2	MS	1.66	8.3	26	20	14
IR79125A/BRRI39R	116	87.4	MS	1.58	7.9	20	14	8
IR78369A/BRRI43R	112	84.2	LS	1.54	7.7	17	12	5
IR102758A/BRRI46R	117	87.3	LS	1.64	8.2	24	19	12
IR79156A/BRRI46R	113	89.4	LS	1.56	7.8	18	13	7
BRRI hybrid dhan6 (ck-1)	111	84.2		1.32	6.6			
AZ7006 (ck-2)	114	79.1		1.38	6.9			
Dhanny Gold (ck-3)	116	82.4		1.46	7.3			
Heritability	0.78	0.81		0.69	0.69			
$LSD_{(0.05)}$	4.9	4.1		2.3	0.8			

Yield data counted from 30 hills per entry, spacing was 20 cm×15 cm (R × P)
DS: 11 Jul 2021; DT: 1 Aug 2021
Legend: DTM = Days to maturity; SF (%) =Spikelet fertility; GT= Grain type

Table 2. List of the hybrid combinations found heterotic from observational nursery during Boro 2021-22.

Entry	Designation	DTM	PY (kg) $2m^2$	Yield (t/h)	Heterosis (%) Ck-1	Ck-2	Ck-3
OT-68	BRRI50A/SyngentaR (Slender)	147	2.48	12.41	29	37	49
OT-127	BRRI99A/727R	148	2.50	12.49	29	38	50
OT-132	BRRI109A/BRRI41R	147	2.20	11.02	14	21	32
OT-139	BRRI99A/EL86R	146	2.07	10.33	7	14	24
OT-144	IR105688A/WinR New	148	2.47	12.35	28	36	48
OT-145	BRRI99A/ZYB-1	147	2.49	12.45	29	37	49
OT-148	BRRI99A/ SyngentaR (Slender)	146	2.38	11.91	23	31	43
OT-155	BRRI99A/IR85503-3-3-A-1-1-1-1-1R	147	2.26	11.29	17	24	36
OT-164	IR105687A/PR585R	149	2.06	10.32	7	14	24
OT-191	IR105687A/IR85503-3-3-A-1-1-1-1-1R	142	2.10	10.50	9	16	26
OT-213	IR105688A/EL108R	146	2.17	10.84	12	19	30

OT-247	IR79125A/CHH56R	150	2.51	12.56	30	38	51
OT-288	IR79156A/BRRI38R	151	2.13	10.67	11	18	28
OT-290	IR79156A/CHH32R	148	2.47	12.33	28	36	48
ck-1	BRRI hybrid dhan5	152	1.93	9.65			
ck-2	SL8H	151	1.82	9.08			
ck-3	Shuborno-3	138	1.67	8.33			
Heritability		0.88	0.80	0.80			
LSD $_{(0.05)}$		5.79	4.21				

DS: 12 Dec 2021; DT: 12 Jan 2022; Plot size: 2 m^2

Preliminary yield trials of promising hybrids

Under preliminary yield trials three hybrids were selected out of 14 and showed yield advantage 4-14 % over BRRI hybrid dhan6, 4-24 % over AZ7006 and 2-8 % over Dhanny Gold in T. Aman 2021 (Table 3). In Boro, fifteen hybrids were evaluated along with three hybrids as check variety. Three hybrids were selected based on yield, grain quality and amylose content. All the selected hybrids showed yield advantage ranging from 5-7 % over BRRI hybrid dhan5, 32-34 % over Suborno-3 and 22-25 % over Tej Gold (Table 4).

Table 3. Results of preliminary yield trials in T. Aman 2021.

Genotype	PHT	Tiller	D50%F	DM	SF (%)	Yield		Heterosis (%)		
						BLUP	BLUE	Ck-1	Ck-2	Ck-3
IR79125A/BRRI31R	118	8	91	117	83.82	5.58	5.79	14.13	23.63	8.22
BRRI97A/BRRI31R	118	8	95	121	87.56	5.11	5.09	0.33	8.68	
BRRI35A/BRRI31R	103	8	95	121	85.45	5.23	5.27	3.94	12.60	
IR79125A/IR86526-11-6-2-1-1-1-1-1R	109	8	91	117	87.25	4.87	4.71		0.64	
IR79156A/IR86526-11-6-2-1-1-1-1R	104	7	91	117	87.25	5.23	5.26	3.75	12.38	
IR58025A/IR86526-11-6-2-1-1-1-1R	103	8	91	117	88.35	5.07	5.03		7.40	
BRRI11A/BRRI44R	105	7	95	121	89.2	5.22	5.25	3.48	12.10	
BRRI97A/BRRI44R	103	8	95	121	88.32	5.05	5.00		6.8	
BRRI99A/BRRI44R	119	7	95	121	89.32	5.53	5.72	12.7	22.1	6.85
IR79125A/IR77498-45-1-2-2R	103	7	92	118	88.34	5.07	5.03		7.4	
IR79156A/IR77498-45-1-2-2R	105	8	91	117	89.34	5.48	5.65	11.4	20.6	5.61
IR102758A/IR77498-45-1-2-2R	103	7	91	117	90.32	4.73	4.50			
IR78369A/IR77498-45-1-2-2R	102	8	91	117	88.23	5.35	5.45	7.4	16.4	1.87
IR58025A/IR77498-45-1-2-2R	104	7	92	117	89.2	4.96	4.86		3.7	
BRRI hybrid dhan6 (Ck-1)	110	8	95	121	87.36	5.10	5.07			
AZ7006 (Ck-2)	119	7	95	121	88.23	4.85	4.68			
Dhanny Gold (Ck-3)	118	7	91	117	89.5	5.29	5.35			
LSD	2.27	0.80	1.21	1.28		0.35	0.61			
CV	1.25	6.38	0.78	0.65		7.12	7.12			
Heritability	0.99	0.36	0.96	0.95		0.66				

DS: 12 Jul 2021; DT: 06 Aug 2021; Plot size=10 m^2; PHT (cm) = Plant height (cm); DM = Days to maturity; SF (%) = Spikelet fertility

Table 4. Result of preliminary yield trial (PYT) during Boro 2021-22.

Designation	PHT (cm)	GD (days)	GT	Yield (t/h)	AC (%)	Heterosis (%)		
						Ck-1	Ck-2	Ck-3
BRRI7A/IR77498-45-1-2-2R	105	146	MS	9.93	22.4	-	25.7	16.8
IR79125A/IR77498-45-1-2-2R	97	145	MS	10.06	23.3	1.6	27.3	18.4
IR105687A/IR77498-45-1-2-2R	108	146	MS	9.70	23.4	-	22.8	14.1
IR102758A/IR77498-45-1-2-2R	105	147	S	10.5	22.7	6.1	32.9	23.5
BRRI99A/IR86526-11-6-2-1-1-1-1R	103	147	S	10.16	23.0	2.6	28.6	19.5
IR105687A/IR86526-11-6-2-1-1-1-1R	107	143	S	9.2	22.7	-	16.5	8.23
IR79156A/IR86526-11-6-2-1-1-1-1R	111	146	S	10.23	22.4	3.3	29.5	20.4
IR58025A/IR86526-11-6-2-1-1-1-1R	106	144	S	9.13	23.6	-	15.6	7.4
IR79125A/BRRI44R	109	152	S	10.6	23.0	7.0	34.2	24.7
BRRI48A/BRRI38R	109	151	S	10.06	24.2	1.6	27.3	18.4
BRRI11A/BRRI49R	110	148	S	10.33	20.0	4.3	30.8	21.5
BRRI97A/BRRI53R	89	148	S	10.4	21.3	5.0	31.6	22.4
BRRI99A/BRRI53R	104	149	S	9.8	23.1	-	24.0	15.3
BRRI109A/BRRI53R	107	153	S	9.6	24.0	-	21.5	12.9
BRRI109A/BRRI42R	108	149	S	9.7	23.0	-	22.8	14.1
BRRI hybrid dhan5(ck-1)	103	145	LB	9.9				
Shuborno-3(ck-2)	105	141	S	7.9				
Tej Gold(ck-3)	112	146	S	8.5				
Mean	105.4	147.0		9.8				
CV (%)	6.1	2.2		8.9				
Lsd (0.05%)	3.3	1.9		0.4				

DS: 4 Dec 2021; DT: 17 Jan 2022; Plot size: 10 m^2

PH=Plant height (cm), GD= Growth duration (days), AC (%) = Amylose content, GT= Grain type, MS= Medium slender, S = Slender, LB= Long bold

Multi-location yield trials of promising hybrids

In T. Aman 2021, under multi-location trials three hybrids out of eighteen produced 11-18% yield advantage over BRRI hybrid dhan6, 11-17% over AZ7006 and 20-27% over Dhanny Gold (Table 5). In Boro 2021-22, twenty-seven hybrids were evaluated along three check varieties under two sets. None of the tested entries performed well than BRRI hybrid dhan5 in set-I. In setr-II, two hybrids were selected based on stable yield performance and advantage over check across location. The selected hybrids showed yield advantage ranging from 12-14 % over BRRI hybrid dhan5, 26-29 % over Suborno-3 and 22-24 % over Teea (Table 6).

Table 5. Results of multi-location yield trials during T. Aman 2021.

Hybrids	PH (cm)	DTM (days)	Yield (t/ha)					SF (%)	GT	Amy (%)	Aver Advantage Ck (%)		yield over	Remarks
			Gaz	Ish	Bari	Mym	Av				Ck-1	Ck-2	Ck-3	
BRRI97A/BRRI46R	105	107	6.3	6.5	5.8	4.3*	5.73	76.7	MS	24.0	-	-	4.6	*Rat damage and some entries submerged
BRRI99A/BRRI46R	110	110	6.5	6.7	6.0	4.2*	5.85	79.2	MS	23.4	-	-	6.8	
IR105688A/BRRI46R	107	108	5.9	6.0	5.8	3.7*	5.35	75.0	S	23.4	-	-	-	
IR79156A/BRRI46R	110	114	7.2	7.5	6.3	6.7	6.93	81.7	S	23.5	17.9	16.9	26.5	
IR78369A/BRRI46R	112	117	6.2	6.8	5.8	3.3*	5.53	78.6	M	23.6			0.9	
IR58025A/BRRI46R	115	115	6.8	7.2	7.4	3.4*	6.20	73.2	S	24.2	5.4	4.6	13.1	
BRRI35A/BRRI45R	109	110	6.0	7.3	5.8	4.0*	5.78	74.7	M	23.4			5.5	
IR79156A/BRRI45R	111	117	6.5	7.1	6.4	6.2	6.55	80.2	MS	23.4	11.4	10.5	19.5	
BRRI35A/BRRI50R	111	113	6.1	6.3	5.9	6.4	6.18	80.1	M	24.0	5.1	4.2	12.8	
IR79156A/BRRI50R	112.0	114	6.4	7.3	6.5	5.8	6.50	79.3	S	23.7	10.5	9.6	18.6	
BRRI11A/BRRI38R	108.0	116	7.4	6.8	6.7	3.2*	6.03	78.7	MS	23.6	2.6	1.7	10.0	
IR105688A/BRRI38R	112.0	110	5.8	6.1	5.76	3.8*	5.37	76.5	MS	23.5	-	-	-	
BRRI11A/BRRI37R	110.0	116	6.8	7.7	6.5	6.1	6.78	80.3	M	24.0	15.3	14.3	23.7	

	IR79125A/BRRI44R	113.0	118	6.0	5.8	5.7	6.4	5.98	80.0	M	22.8	1.7	0.8	9.1
	IR79156A/BRRI44R	116.0	117	5.8	5.5	5.9	4.9*	5.53	77.4	MS	23.6	-	-	0.9
	IR102758A/BRRI44R	111.0	119	5.9	6.2	5.5	4.8*	5.60	75.7	M	23.4	-	-	2.2
	IR78369A/BRRI44R	115.0	121	6.8	7.3	6.7	4.2*	6.25	79.4	M	23.5	6.3	5.4	14
	IR58025A/BRRI44R	120.0	122	5.5	5.4	5.8	4.5*	5.30	77.6	MS	23.0	-	-	-
Ck-1	BRRI hybrid dhan6	112.0	115	5.8	6.2	5.7	5.8	5.88	78.5	S	24.0			
Ck-2	AZ-7006	113.0	132	5.8	5.8	6.1	6.0	5.93	79.3	S				
Ck-3	Dhanny Gold	110.0	126	6.0	5.5	5.3	5.1	5.48	77.8	MS				
Mean		112	116	6.3	6.5	6.1	6.1	5.9	78.1					
CV (%)		2.9	5.1	8.1	11.0	8.1	7.7	7.9	2.8					
LSD (0.05%)		1.84	3.34	0.28	0.40	0.28	0.26	0.26	1.21					

DS: 7 Jul 2021; DT: 26 Jul 2021; Unit plot size: 30 m^2

Table 6. Results of multi-location yield trials during Boro 2021-22.

	Hybrids	PH	DTM	Yield (t/h)					Yield advantage over check (%)		
				Gaz	Ishw	Bar	Rang	Mean	Ck-1	Ck-2	Ck-3
	BRRI97A/BRRI46R	105	148	9.3	9.0	8.5	7.92	8.7	-	3.6	-
	BRRI99A/BRRI46R	107	145	10.8	11.8	11.6	8.88	10.8	13.7	28.6	24.1
	BRRI109A/BRRI46R	109	150	9.1	9.5	9.3	7.83	8.9	-	5.6	2.3
	IR105687A/BRRI46R	89	149	9.2	10.3	9.1	7.80	9.1	-	8.3	4.6
	IR79156A/BRRI46R	110	152	8.9	8.7	8.8	7.34	8.4	-	-	-
	IR58025A/BRRI46R	108	149	9.3	9.5	7.9	8.04	8.7	-	3.6	-
	BRRI97A/BRRI37R	102	145	10.7	11.3	11.5	8.90	10.6	11.6	26.2	21.8
	BRRI109A/BRRI37R	114	151	9.9	9.6	9.2	8.84	9.4	-	11.9	8.0
	BRRI110A/BRRI37R	110	149	8.8	9.7	8.7	8.22	8.9	-	5.6	2.3
	BRRI97A/BRRI36R	103	145	8.8	9.3	8.9	7.63	8.7	-	3.6	-
	BRRI99A/BRRI36R	105	145	8.7	9.6	9.3	7.93	8.9	-	5.6	2.3
	BRRI109A/BRRI36R	110	146	9.3	9.5	9.0	7.81	8.9	-	5.6	2.3
	BRRI110A/BRRI36R	113	151	9.8	9.3	8.8	7.86	8.9	-	5.6	2.3
Ck-1	BRRI hybrid dhan5	107	145	9.7	9.9	9.7	8.51	9.5			
Ck-2	Suborno-3	111	141	8.7	8.5	8.2	8.29	8.4			
Ck-3	Teea	110	146	9.3	8.4	8.7	8.49	8.7			
Mean		107.1	147.3					9.1			
CV (%)		5.5	2.0					7.6			
$LSD_{(0.05)}$		3.8	1.9	0.4	0.6	0.7	0.3	0.4			

Gazipur: DS: 8 Dec 2021; DT: 17 Jan 2022; Barishal: DS: 15 Dec 2021; DT: 20 Jan 2022
Ishwardi: DS: 10 Dec 2021; DT: 15 Jan 2022; Rangpur: DS: 17 Dec 2021; DT: 25 Jan 2022; PH (cm) = Plant height; DTM = Days to maturity; Unit plot =20 m^2

Development of maintainer and restorer lines through (B×B) and (R×R) crosses

Fifteen B×B and 11 R×R crosses were confirmed based on different cyto-sources and amylose content in T. Aman season 2021. In Boro, ten B×B and twelve R×R crosses were made. 54,163 progenies from 74 crosses (23 R × R, 17 A × R and 34 B × B) were advanced to F_2 to F_4 generations using field rapid generation advance (FRGA) technique (Table 7).

Table 7. Progenies selected through field RGA, during Boro 2021-22.

	B x B		R x R		A x R	
	Cross	Population	Cross	Population	Cross	Population
F_2	14	15210	7	5655	14	4772
F_3	15	13883	6	3874	-	-
F_4	5	3763	10	5831	3	1175
Sub-total	34	32856	23	15360	17	5947
Total crosses		74				
Total population		54163				

Evaluation of Fatema dhan

Twenty-one Fatema dhan derived fixed lines were evaluated in T. Aman 2021 and four lines were found having yield potentiality > 5.5 t/ha. In Boro 2021-22, Twenty-one separate lines were selected based on red stigma, white stigma, awn less, with awn, plant type, panicle size, yield and other agronomic performances.

Generation Advancement of Parental Lines having multi stress genes (HRDC materials) at Restorer (R) and Maintainer (M) background

Genotyping of parental lines against diagnostic SNP markers (34 F_7 generations) and Progenies were selected based on their genotypic value (Table 8).

Table 8. Genotyping of parental lines against diagnostic SNP markers during T. Aman 2021.

Pedigree	Identified Trait Marker
IR126044-76-2-2-B	xa5 + Waxy + Chalk5
IR126044-76-2-1-B	xa13 + Waxy + Chalk5
IR126044-15-5-1-B	xa13 + Waxy + Chalk5
IR126055-82-2-2-B	qPi33 + Chalk5 + Gn1a
IR126055-46-3-2-B	qPi33
IR126055-30-5-1-B	Chalk5
IR126055-22-4-1-B	Waxy + Chalk5 + Gn1a
IR126066-15-1-2-B	-
IR126066-21-2-2-B	-
IR126066-85-5-2-B	Pita
IR126069-100-3-2-B	-
IR126069-83-2-2-B	-
IR126069-56-1-2-B	Gn1a
IR126069-48-3-2-B	Pita + Gn1a
IR126069-3-1-1-B	Pita + Gn1a
IR126072-257-1-3-B	Gn1a
IR126072-115-6-1-B	Gn1a
IR126072-91-1-2-B	Gn1a + qNa1L + Saltol
IR126072-83-3-3-B	Chalk5 + qNa1L+ Saltol
IR126072-83-3-1-B	Chalk5 + Gn1a+ qNa1L+ Saltol
IR126076-122-1-1-B	Gn1a + Saltol
IR126076-67-3-2-B	Pita + qPi33
IR127275-36-5-2-B	Chalk5 + Gn1a
IR127275-14-2-2-B	qPi33 + Gn1a
IR127275-9-1-2-B	qPi33 + Chalk5 + Gn1a
IR127278-152-1-3-B	xa5 + xa13 + Gn1a + qNa1L
IR127278-114-3-3-B	waxy + Gn1a + qNa1L
IR127278-55-2-2-B	waxy + Gn1a + qNa1L
IR127278-102-3-1-B	Pita + Gn1a + qNa1L
IR127270-80-2-1-B	Gn1a
IR127270-65-2-4-B	waxy + Gn1a
IR127270-40-6-2-B	Pi9 + waxy + Gn1a
IR126037-59-3-2-B	Pita + waxy + Gn1a
IR126037-20-1-1-B	waxy + Gn1a

Legend: Blast (Pb1, Pi9, Pita and qPi33); Bacterial leaf blight (Xa21, xa13 and xa5); Amylose (waxy); Chalkiness (Chalk5); Grain number (Gn1a); Salinity seedling (qNa1L and Saltol)

Blast tolerant parental line development

Six blast tolerant test crosses were evaluated in T. Aman 2021 and isolated two suspected restorer and two suspected maintainer lines based on microscopic pollen analysis using Iodine potassium iodide solution. Seed multiplication was done and ample amount of pure seed was harvested during Boro 2021-22.

Hybrid rice parental lines development for deep water ecosystem

Deep water donor parent derived test crosses were evaluated in T. Aman 2021 and one test cross was confirmed presence of Rf4 gene from dry lab analysis of 3K rice genome project. In Boro 2021-22, one restorer line was isolated based on microscopic pollen analysis using Iodine potassium iodide solution and dry lab analysis. The hybrid plant showed 10 cm internode elongation during 16 days of submerged condition in deep water tank. After removal of water hybrid plant also showed kneeing ability which is special feature of deep water rice.

Assessment of specific and general adaptability for selection of suitable rice hybrids under saline prone areas for Boro season

Adaptability under saline condition of BRRI developed and popular company hybrids along with popular saline tolerant inbred checks BRRI dhan67, Bina dhan-10 and locally cultivated rice IT was done at three coastal locations of Satkhira. Top three highest yielding genotypes were BRRI hybrid dhan3 (7.00 t ha-1), BRRI hybrid dhan5 (6.93 t ha-1) and BRRI hybrid dhan4 (6.88 t ha-1) followed by BRRI99A/EL254R (6.49), BRRI hybrid dhan6(6.37 t ha-1), IT (6.35 t ha-1), BRRI hybrid dhan7 (6. 28 t ha-1), BRRI99A/BRRI31R (6.11 t ha-1), Binadhan-10 (5.85 t ha-1), BRRI hybrid dhan2 (5.75 t ha-1), BRRI dhan67 (5.75 t ha-1), Janokraj (5.60 t ha-1), SL-8 (5.47 t ha-1), Gold (Lal teer) (5.45 t ha-1), Heera (Supreme) (5.34 t ha-1). Therefore, we can conclude that BRRI hybrid dhan3, BRRI hybrid dhan5 and BRRI hybrid dhan4 can be cultivated profitably in areas where water salinity level of the paddy field remains 3 dS/m to 6 dS/m (Table 9 and Fig. 1).

Table 8. Yield and agronomic performance of sixteen genotypes from adaptive trial in Boro 2021-22.

Genotype	BLUP			Yield (t/ha) BLUE			Combined Yield (t/ha)	
	D50% F	GD	PH	Assasuni	Debhata	Kaliganj	BLUP	BLUE
BRRI hybrid dhan2	113	139	109	6.39	5.52	5.34	5.78	5.75
BRRI hybrid dhan3	114	139	99	7.21	6.91	6.90	6.94	7.01
BRRI hybrid dhan4	117	140	105	7.06	6.80	6.79	6.82	6.88
BRRI hybrid dhan5	114	139	101	7.40	6.59	6.80	6.87	6.93
BRRI hybrid dhan6	113	138	103	6.38	6.25	6.48	6.35	6.37
BRRI hybrid dhan7	115	140	101	6.32	5.87	6.64	6.26	6.28
BRRI99A/BRRI31R	113	138	101	6.55	5.62	6.18	6.11	6.11
Gold (Lal teer)	117	140	94	5.51	5.30	5.55	5.50	5.45
Heera (Supreme)	117	138	111	5.47	5.22	5.34	5.40	5.34
SL-8 (BADC)	118	141	110	5.59	5.40	5.42	5.52	5.47
BRRI dhan67	115	138	87	5.75	5.96	5.52	5.77	5.75
Binadhan-10	120	142	90	5.93	5.80	5.84	5.87	5.85
IT	115	141	120	6.25	6.83	5.98	6.34	6.35
Janokraj	113	137	101	5.79	5.70	5.33	5.64	5.60
BRRI99A/EL254R	115	138	103	6.89	6.11	6.48	6.46	6.49
Heritability	0.98	0.99	0.99				0.92	
LSD (0.05%)	0.48	0.22	0.81	0.35	0.40	0.35	0.30	0.45
CV (%)	0.47	0.21	1.16	3.40	4.06	3.51	3.63	3.63

GD=Growth duration (day), PH=Plant height (cm), D50%F=Days to 50% flowering.

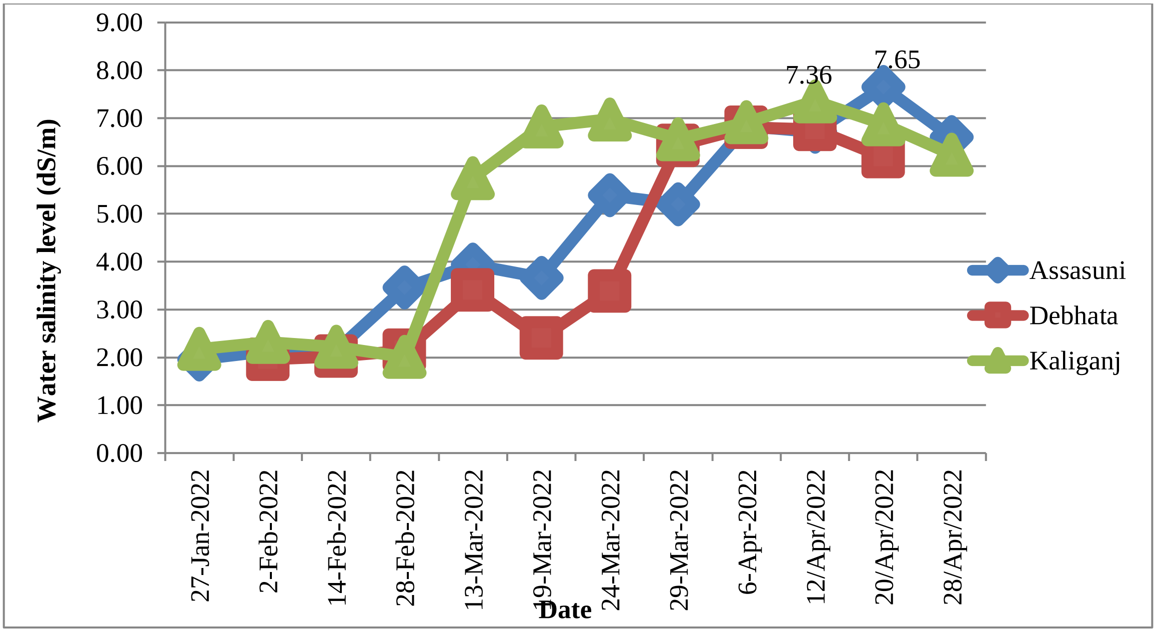


Fig. 1. Water salinity levels (dS/m) of the experimental field during Boro 2021-22.

SEED PRODUCTION OF PARENTAL LINES AND HYBRIDS

CMS line multiplication of released hybrids

Fifteen CMS (Released hybrids CMS and promising CMS lines) were used to multiply using standard CMS multiplication protocol during Boro 2021-22 and seed yield obtained ranging from 5.2 kg/plot (0.74 t/ha) to 1300 kg/plot (1.91 t/ha) depending on plot size and total CMS seeds achieved 4759 kg (Table 9).

Table 9. CMS lines multiplication of released and promising hybrids during Boro 2021-22.

	Designation	Plot yield (Kg)	Yield (t/ha)	Out cross potential (%)	Remarks
	BRRI7A/B	426	1.33	40	CMS line of BHD5
	BRRI10A/B	191	1.36	41	CMS line of BHD2
	BRRI11A/B	892	1.38	42	CMS line of BHD3
	BRRI48A/B	192	1.92	46	
	BRRI99A/B	371	1.86	45	
	BRRI109A/B	56	0.93	30	Rainfall during pollination hamper seed yield
	BRRI110A/B	96	1.37	41	
	BRRI110A/B	12.1	1.73	43	Nucleus seed
	BRRI125A/B	5.2	0.74	27	Nucleus seed
	IR102758A/B	326	1.36	41	
	IR105687A/B	227	1.89	45	
	IR105688A/B	172	1.43	43	
	IR79156A/B	1300	1.91	47	CMS line of BHD6
	IR79125A/B	100	1.0	33	
	IR78369A/B	60	0.6	20	Rainfall during pollination hamper seed yield
16	IR58025A/B	333	1.33	40	CMS line of BHD4
Total CMS seeds achieved		4,759			

Experimental F_1 seed production of promising hybrids during T. Aman, 2021

Fifteen CMS lines were used along with six restorer lines. Individual R lines were isolated with cloth barrier during flowering time. Standard seed production protocol was maintained

Seed yield ranging 0.8 to 40 kg/plot from selected promising hybrid combinations. Some combinations did not produce sufficient seeds due to lack of flowering synchronization and frequent raining during flowering time (Table 10).

Table 10. Experimental F_1 seed obtained from different hybrid combinations during T Aman 2021.

Designation	PH (cm)		D50% F		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg/plot)	Seed yield (kg/ha)
	A Line	R line	A line	R line					
IR58025A/ BRRI36R	110	112	87	95	68	11	450	9.50	211
IR78369A/BRRI36R	111	115	88	99	65	9	450	6.22	138
IR79125A/BRRI36R	112	116	86	96	64	6	450	4.14	92
IR102758A/BRRI36R	110	114	86	94	70	13	450	12.47	277
IR105687A/BRRI36R	92	109	84	91	72	15	300	8.88	296
IR105688A/BRRI36R	101	110	87	93	73	17	300	9.77	326
IR79156A/BRRI36R	112	116	86	92	75	22	550	28.72	522
BRRI99A/BRRI36R	102	109	85	91	70	18	550	19.36	352
BRRI 11A/BRRI36R	102	110	86	91	84	7	550	5.42	99
BRRI97A/BRRI36R	103	108	86	89	82	10	550	7.90	144
BRRI50A/BRRI36R	106	110	87	83	80	07	500	1.67	33
BRRI109A/BRRI36R	102	109	79	85	85	13	500	10.59	212
BRRI7A/BRRI36R	87	108	76	87	67	06	250	1.44	58
BRRI110A/BRRI36R	97	108	79	86	69	17	150	4.76	320
BRRI97A/BRRI46R	102	108	87	95	72	14	450	16.8	373
BRRI99A/BRRI46R	110	113	88	99	82	30	350	33.8	966
BRRI109A/BRRI46R	122	116	86	96	69	13	400	12.4	310
BRRI110A/BRRI46R	113	114	86	94	67	3	350	1.20	34
IR105687A/BRRI46R	100	109	84	91	69	11	370	10.4	281
IR105688A/BRRI46R	101	110	87	93	72	17	400	18.0	450
IR79156A/BRRI46R	112	118	89	98	73	20	400	25.8	645
IR102758A/BRRI46R	110	116	84	93	70	15	350	13.5	386
IR79125A/BRRI46R	115	118	96	105	70	16	350	14.9	426
IR78369A/BRRI46R	112	116	90	99	68	13	400	12.2	305
IR58025A/BRRI46R	110	115	86	97	69	15	400	15.4	385
BRRI97A/BRRI53R	102	112	87	95	70	12	450	13.1	291
BRRI99A/BRRI53R	110	115	88	99	68	15	350	8.5	243
BRRI109A/BRRI53R	116	120	86	96	72	16	400	13.1	328
BRRI110A/BRRI53R	113	114	86	94	67	5	350	1.1	31
IR79156A/BRRI53R	112	116	84	91	73	28	470	38.8	826
IR105687A/BRRI53R	101	114	87	93	65	3	400	0.8	20
IR105688A/BRRI53R	102	114	89	98	71	17	400	14.6	365
IR102758A/BRRI53R	110	116	84	93	70	22	350	21.4	611
IR79125A/BRRI53R	115	118	96	105	69	17	350	15.0	429
IR58025A/BRRI53R	112	116	90	99	68	6	400	4.6	115
IR78369A/BRRI53R	110	115	86	97	70	19	400	16.8	420
BRRI48A/BRRI42R	99	110	87	95	70	12	350	11.0	314
BRRI50A/BRRI42R	100	110	88	99	65	4	350	1.8	51
BRRI97A/BRRI42R	102	112	86	96	68	10	350	8.7	249
BRRI99A/BRRI42R	110	116	86	94	67	10	350	8.4	240
BRRI109A/BRRI42R	112	118	84	91	71	15	350	13.5	386

BRRI110A/BRRI42R	108	114	87	93	67	8	350	6.6	189
IR79156A/BRRI42R	112	118	89	98	74	32	350	40.0	1143
IR102758A/BRRI42R	110	116	84	93	67	9	350	8.7	249
IR79125A/BRRI42R	115	120	96	105	67	7	350	5.9	169
IR78369A/BRRI42R	112	118	90	99	72	20	350	15.0	429
IR105687A/BRRI42R	101	115	86	97	65	3	350	1.2	34
IR58025A/BRRI42R	110	116	87	95	66	10	350	7.8	223
BRRI7A/BRRI37R	99	110	87	95	73	29	350	28.0	800
BRRI11A/BRRI37R	100	110	88	99	69	15	350	13.5	386
BRRI48A/BRRI37R	102	112	86	96	65	5	350	5.5	157
BRRI50A/BRRI37R	110	116	86	94	69	13	350	12.0	343
BRRI97A/BRRI37R	112	118	84	91	71	27	350	26.0	743
BRRI99A/BRRI37R	108	114	87	93	72	29	350	28.0	800
BRRI109A/BRRI37R	112	118	89	98	70	21	350	19.8	566
BRRI110A/BRRI37R	110	116	84	93	64	2	350	3.8	109
IR105687A/BRRI37R	115	120	96	105	63	2	350	3.1	89
IR105688A/BRRI37R	112	118	90	99	70	15	350	13.5	386
IR79156A/BRRI37R	101	115	86	97	70	17	350	16.2	463
IR102758A/BRRI37R	110	116	87	95	69	15	350	13.0	371
IR79125A/BRRI37R	114	118	95	103	65	5	350	5.8	166
IR78369A/BRRI37R	115	120	96	105	68	14	350	12.5	357
IR58025A/BRRI37R	112	117	87	96	68	12	350	11.0	314
BRRI11A/BRRI43R	111	117	87	95	68	11	300	10.0	333
BRRI50A/BRRI43R	100	110	88	99	65	2	300	2.0	67
BRRI97A/BRRI43R	102	112	86	96	68	11	300	10.0	333
BRRI99A/BRRI43R	110	116	86	94	67	10	300	9.50	317
IR79156A/BRRI43R	112	118	84	91	74	34	300	38.4	1280
IR105687A/BRRI43R	102	114	87	93	68	4	300	4.5	150
IR105688A/BRRI43R	104	118	89	98	71	30	300	28.1	937
IR102758A/BRRI43R	110	116	84	93	69	16	300	13.4	447
IR79125A/BRRI43R	115	120	96	105	68	15	300	12.50	417
IR78369A/BRRI43R	112	118	90	99	70	28	300	24.2	807
IR58025A/BRRI43R	110	115	86	97	70	15	300	11.5	383

DS: 15 Jul 2021; DT: 4 Aug 2021

F_1 seed production of BRRI hybrid dhan5, BRRI hybrid dhan6, BRRI hybrid dhan7 and BRRI hybrid dhan8 in Boro 2021-22

Seed yield 960 kg (2.4 t/ha), 1,246 kg (2.59 t/ha), 2,800 kg (2.69 t/ha) and 88 kg (2.2 t/ha) was obtained from BRRI hybrid dhan5, BRRI hybrid dhan6, BRRI hybrid dhan7 and BRRI hybrid dhan8, respectively (Table 11).

Table 11. F_1 seed production of BRRI hybrid dhan5, BRRI hybrid dhan6, BRRI hybrid dhan7 and BRRI hybrid dhan8 during Boro 2021-22 Gazipur.

Hybrid	PHT (cm)		D50%F		PER (%)	OCR (%)	Yield	
	A line	R line	A line	R line			kg/plot	t/ha
BRRI hybrid dhan5	88	97	124	140	82	43	960	2.4
BRRI hybrid dhan6	85	94	126	129	89	47	1246	2.59
BRRI hybrid dhan7	89	98	125	133	88	50	2800	2.69
BRRI hybrid dhan8	87	96	126	134	83	42	88	2.20

DS: R_1 = 15 Nov 2021; R_2 = 22 Nov 2021; A = 11 Dec 2021; DT: R = 20 Dec 2021; A = 11 Jan 2022;
DS: R_1 = 1 Dec 2021; R_2 = 05 Dec 2021; A = 14 Dec 2021; DT: R and A = 19 Jan 2022. PER (%) = panicle exertion rate, OCR (%) = Out crossing rate

F_1 seed production at Ishwardi, Barishal and Mymensingh during Boro 2021-22

We had F_1 seed production programme in Ishwardi, Barishal and Mymensingh during Boro 2021-22 with our strict supervision. 1,430 kg (1.8 t/ha), 12,205 kg (2.4 t/ha), 2,460 kg (2.05 t/ha), 10,210 kg (2.04 t/ha), 6000 kg (2.5 t/ha) and 6,060 kg (3.03 t/ha) seed yield was obtained from BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5, BRRI hybrid dhan6 and BRRI hybrid dhan7, respectively (Table 12).

Table 12. F_1 seed production of BRRI released hybrids during Boro 2021-22 at different locations.

Variety	Area (Acre)	Seed yield (kg)	Yield t/ha)	Remark
BRRI hybrid dhan2	2.0	1430	1.80	Ishwardi
BRRI hybrid dhan3	5.0	4550	2.28	Ishwardi
BRRI hybrid dhan3	5.0	5655	2.83	Mymensingh
BRRI hybrid dhan3	2.5	2000	2.00	Barishal
BRRI hybrid dhan4	3.0	2460	2.05	Ishwardi
BRRI hybrid dhan5	7.0	5460	1.95	Ishwardi
BRRI hybrid dhan5	3.5	3250	2.32	Mymensingh
BRRI hybrid dhan5	2.0	1500	1.86	Barishal
BRRI hybrid dhan6	6.0	6000	2.50	Ishwardi
BRRI hybrid dhan7	5.0	6060	3.03	Ishwardi
Total=	41	38365		

Dissemination of hybrid rice technology

In the reporting year, under T. Aman season HRRI Hybrid Rice Division supplied 6,750 kg of parental lines and F_1 seeds to 90 farmers, 10 seed companies, scientists, extension people, projects and staffs of BRRI (Table 13), 15000 kg of parental lines and F_1 seeds to 130 farmers, 24 seed companies, scientists, extension people, project people and staffs of BRRI during 2021-22 (Table 14) and 4,357 kg F_1 seeds of BRRI hybrid dhan7 was distributed among different stake holders during T. Aus 2022 (Table 15). Around 4 MT parental seeds (A & R line) distributed among different stake holders during Boro 2021-22 (Table 16).

Table 13. Amount of parental line and hybrid seeds supplied to different organization during T Aman 2021.

Recipient	Nos.	F_1 (kg)	A line (kg)	B line (kg)	R line (kg)
Seed Companies	10	550	170	-	64
Farmers	90	1216	-	-	-
BRRI Scientists + staffs	45	1200	-	-	-
BRRI, RS (5)+DAE	21	3550	-	-	-
Total	166	6516	170	0.00	64.00
Grand total			6750 Kg		

Investigator: All staff of BRRI Hybrid Rice Division.

Table 14. Amount of parental line and hybrid seeds supplied to different organization during Boro 2021-22.

Recipient	Nos.	F_1 (kg)	A line (kg)	B line (kg)	R line (kg)
Seed Companies	24	1650	2869	-	959
Farmers	130	1350	-	-	-
BRRI Scientists + staffs +DAE	85	3672	-	-	-
BRRI, RS	11	4500	-	-	-
Total	250	11172	2869	0.00	959
Grand Total		15000			

Investigators. All staff of hybrid rice division.

Table 15. Amount of BRRI released Aus hybrid seeds distributed during T. Aus 2022.

Variety	Institute/ Organization/ Farmers	Seed amount supplied (Kg)	Area covered with supplied seeds	Remark
BRRI hybrid dhan7	BRRI R/S	2945	196	
BRRI hybrid dhan7	DAE	950	63	
BRRI hybrid dhan7	Farmers	462	31	
Total=		4357	290	

Investigators. All staff of BRRI Hybrid Rice Division.

Table 16. Amount of parental lines seed distribution during Boro 2021-22.

Variety	CMS(A) line (kg)	R line (Kg)	Area covered (Acre)
BRRI hybrid dhan1	30	09	3.0
BRRI hybrid dhan2	49	16	5.0
BRRI hybrid dhan3	1050	350	105.0
BRRI hybrid dhan4	123	43	15.0
BRRI hybrid dhan5	387	130	43.0
BRRI hybrid dhan6	947	316	118.0
BRRI hybrid dhan7	283	95	35.0
Total=	**2869**	**959**	**324**

Agronomy Division

SUMMARY

To achieve higher yield, medium and long duration T. Aman rice varieties should preferably be transplanted on 1st week of August (5th to 10th). BRCC266-5-1-1-1 produced lower grain yield than the check entries and matured 5-6 days earlier irrespective of planting time. From 10 to 25 July transplanting BRRI dhan93 and BRRIdhan94 displayed similar grain yield and growth duration. In case of BRRI dhan95, the growth duration and grain yield decreased from 10 August to 10 September transplanting. BRRI dhan91 was found neither suitable for ratoon crop nor suitable to grown in Boro season might be due to its photosensitivity and long growth duration (182 days). However, among the supplied advanced lines, BRH11-9-11-4-5B yielded the highest grain yield (5.46 t/ha) in Boro season as the main crop without having the ratooning ability. Both BRRI dhan93 and BRRI dhan95 produced higher grain yield in STB (Soil test based) treatment than BRRI dhan87 with 16% less Nitrogen compared to BRRI recommended fertilizer dose. Growth stage-based fertilizer application on BRRI dhan92 produced the highest grain yield (6.23 t $ha^{=1}$) on STB + 10% additional dose. On the other hand, BRRI dhan96 produced the highest grain yield (5.53 t ha^{-1}) on STB treatment. Both BRRI dhan73 and BRRI dhan87 could not tolerate 50 mM NaCl (Approximately 5.25 ds m^{-1}) salinity level. The economic N rate appeared as 56 and 55 kg for BRRI dhan34 and BRRI dhan90, respectively where initial soil N was 0.10% and organic matter was 1.47%. The application of 50 % RDF (recommended doses of fertilizer) along with cowdung @5 t ha^{-1} or poultry manure @3 t ha^{-1} is recommended for getting higher grain yield of BRRI dhan87 in Sirajganj farm. In saline condition, 250 ppm of chitosan enhanced the chlorophyll content and photosynthetic activity of both BRRI dhan28 and BRRI dhan67 produced 35% higher grain yield than without spray. Mungbean (BARI Mung-6)-T. Aus (BRRI dhan48)-T. Aman (BRRI dhan62)-Potato (BARI Alu41) four crops pattern was economic, profitable and not harmful in terms of soil fertility when proper agronomic management was given. New molecule herbicide showed better weed control efficiency (>80%) in both T. Aman and Boro season. Weeding cost is higher in hand weeding compared to herbicide and BRRI weeder and late weeding also reduced grain yield in the farmer's field. The degradation of a widely used insecticide (virtako) by the two PGPR strains *Proteus sp* and *Bacillus sp* showed a reduction of concentration by 20.96% and 70.69%, respectively over the control. Among the two bacterial strains, *Bacillus tequilensis* was identified as a potential strain for virtako degradation under laboratory conditions.

SCIENTIFIC INFORMATION

Planting Practices

Influence of transplanting dates on the yields of rice in north, central and south region of Bangladesh.

The experiment was conducted at BRRI R/S Rangpur, Cumilla and Barishal farms aimed to identify a suitable planting window of short, medium and long duration T. Aman rice cultivars to maximize grain yield. The selected cultivars were transplanted from 5 July to 5 September Twenty-five-day-old seedlings were transplanted following split-plot design with three replications. At Rangpur region, early transplanting of BRRI dhan75 (10 to 20th of July) produced higher grain yield than the delayed transplanting. BRRI dhan87 and BRRI dhan93 transplanted on 10 August produced higher grain yield (Table 1). The tested varieties transplanted on 30 of July were found to have less grain yield. This happened due to the continuous rainfall with wind (depression) at flowering stage in the 1st week of October that hampered pollination and seed setting. At BRRI R/S Cumilla farm, all the varieties produced higher yield transplanted on 5 August. After 20th August, the yield of all tested varieties decreased sharply (Table 2). At BRRI R/S Barisal farm, from 5-20 August transplanting, BRRI dhan23 produced the highest grain yield followed by BRRI dhan72 and BRRI dhan76 with 121-135 days growth duration (Table 3). However, considering the grain yield and growth duration, early transplanting on 5 August was found suitable with BRRI dhan72 (5.49 t/ha) and late transplanting on 20 August was found suitable with BRRI dhan23 (5.59 t/ha). In conclusion, to achieve appreciable better yield, medium and long duration aman rice varieties should preferably be transplanted on 1st week of August (5 to 10).

Table 1. Effect of planting time on the GDD accumulation and rice yield in T. Aman, 2021 season at BRRI R/S Rangpur.

Variety	Date of transplanting									
	10 Jul		20 Jul		30 Jul		10 Aug		20 Aug	
	Yield (t ha^{-1})	GDD (ºC)	Yield (t ha^{-1})	GDD (ºC)	Yield (t ha^{-1})	GDD (ºC)	Yield (t ha^{-1})	GDD (ºC)	Yield (t ha^{-1})	GDD (ºC)
BRRI dhan75	5.30	2051	5.46	2090	3.76	2116	4.90	2174	4.84	1962
BRRI dhan87	3.68	2284	5.19	2281	4.01	2199	5.92	2098	5.71	2028
BRRI dhan93	4.48	2510	6.17	2441	5.43	2324	7.05	2232	6.76	2119
$LSD_{(0.05)}$	0.81	52	1.13	17	1.23	54	1.43	139	0.81	45
CV (%)	8.1	1.00	8.9	0.30	12.3	1.10	10.4	2.80	5.9	1.00

Table 2. Effect of planting time on yield and growth duration of T. Aman rice varieties, 2021, BRRI RS Cumilla.

	Transplanting date				
Variety	5 Jul	20 Jul	5 Aug	20 Aug	5 Sep
BRRI dhan75	3.42 (121)	4.02 (119)	4.82 (119)	4.46 (123)	3.96 (117)
BRRI dhan87	3.52 (130)	3.97 (128)	5.43 (131)	4.97 (132)	4.37 (129)
BRRI dhan90	2.98 (121)	3.57 (121)	4.54 (119)	3.91 (121)	3.49 (119)
BRRI dha95	3.90 (137)	4.65 (136)	5.18 (132)	4.95 (124)	4.40 (123)
BR22	3.59 (163)	4.03 (154)	4.67 (144)	4.37 (133)	3.91 (131)
	LSD	CV(a)%	CV(b)%		
	0.18 (4.69)	3.01 (1.72)	3.96 (2.22)		

- Data on parenthesis indicates growth duration

Table 3. Effect of planting time of newly released transplanted Aman varieties on yield in T. Aman 2021 at BRRI RS Barishal farm.

	Transplanting date			
Variety	20 Jul	5 Aug	20 Aug	5 Sep
BRRI dhan72	4.82 (124)	5.49 (121)	5.22 (118)	4.91 (116)
BRRI dhan76	5.02 (130)	5.32 (128)	4.67 (125)	3.82 (123)
BRRI dhan77	4.37 (143)	5.07 (139)	4.82 (132)	3.54 (126)
BRRI dhan78	4.59 (125)	4.78 (123)	4.22 (118)	3.94 (122)
BRRI dhan87	4.79 (127)	5.29 (126)	4.70 (124)	4.22 (130)
BR23	4.94 (150)	5.36 (143)	5.59 (135)	5.12 (132)
$LSD_{(0.05)}$	0.42 (1.20)			
CV%	9.64 (1.5)			

- Data on parenthesis indicates growth duration

Effect of time planting on grain yield and growth duration of ALART, low glycemic index rice line in Boro, 2021-22 season at BRRI HQ farm Gazipur

The experiment was conducted to determine the suitable planting time and potential yield of ALART line BRCC266-5-1-1-1 with check BR16 and BRRI dhan58 at BRRI HQ farm, Gazipur during Boro 2021-22. Forty days old seedlings were transplanted on 20 December, 5 Jany, 20 January and 5 February. The treatments were distributed in a split-plot design with three replications when planting time was in the main plot and variety was in the subplot.

Results indicated that from 5-20 January transplanting, BR16 produced the highest grain yield followed by BRRI dhan58 and BRCC266-5-1-1-1 with 162-148 days growth duration (Table 4). Advanced line BRCC266-5-1-1-1 mature 5-6 days earlier than BRRI dhan58 and 7-8 days earlier than BR16.

Table 4. Effect of planting time on grain yield and growth duration of ALART, Low glycemic index rice line in Boro, 2020-21 season at BRRI farm Gazipur.

Variety/lines	20 Dec	5 Jan	20 Jan	5 Feb	20 Feb
BRCC266-5-1-1-1	5.20 (161)	6.04 (156)	5.57 (149)	5.44 (145)	5.11 (142)
BR16 (Ck)	6.51 (168)	6.59 (163)	6.86 (157)	6.12 (153)	5.50 (149)
BRRI dhan58 (Ck)	5.70 (163)	6.23 (159)	5.99 (155)	5.72 (151)	5.18 (147)
LSD $_{(0.05)}$			NS (0.87)		
CV (%)			8.02 (0.33)		

Enhancing rice yield by optimizing planting time of newly released T. Aman varieties.

The experiment was conducted at the BRRI HQ farm, Gazipur, during Aman, 2021 to determine the effect of variable planting time on the growth and yield of newly released transplanted Aman varieties. The treatments were A: Time of planting: i) 10 July, 25 July, 10 August, 25 August and10 September t B. Varieties: BRRI dhan93, BRRI dhan94 and BRRI dhan95. The treatments were distributed in split plot design with three replications (Planting time in main plot and variety in sub plot). Twenty-five days-old seedlings were transplanted at 20 × 20 cm spacing. Results indicated that 10 to 25 July transplanting of BRRI dhan93 and BRRIdhan94 produced similar grain yield and growth duration (Table 5). After 25 July grain yield was decreased but growth duration increased gradually. In case of BRRI dhan95 growth duration as well as grain yield were decreased from 10 July to 10 September transplanting. BRRI dhan95 produced flowering in October at all transplanting dates. It may due to the variety is weakly photosensitive.

Table 5. Effect of planting time of newly released transplanted Aman varieties on yield, T. Aman 2021 at BRRI HQ farm, Gazipur.

Variety	Grain yield (t ha^{-1})				
	10 Jul	25 Jul	10 Aug	25 Aug	10 Sep
BRRI dhan93	5.14 (142)	5.24 (140)	4.54 (145)	4.08 (148)	2.91 (153)
BRRI dhan94	4.97 (141)	5.10 (140)	4.41 (144)	3.87 (148)	2.90 (152)
BRRI dhan95	5.09 (140)	5.08 (135)	4.28 (127)	3.12 (121)	2.56 (113)
LSD $_{(0.05)}$			0.37		
CV%			7.1		

* Growth duration (day) (in the parenthesis)

Evaluation of the ratooning performance of selected rice genotypes in Boro season, 2021-22 at BRRI HQ farm Gazipur.

The experiment was conducted to observe the ratooning ability of advanced breeding lines including some released varieties at BRRI HQ farm, Gazipur during Boro 2021-22. The treatments were distributed in a randomized complete block design with three replications. Forty day old seedlings were transplanted on 20 January. All agronomic management was done per BRRI recommendation when necessary. The main crop was harvested at 20-30 cm height from the ground soil surface. Top dress of urea and MoP fertilizer was applied at 35 kg/ha and 30 kg/ha, respectively at 3-5 days after harvesting and fertilizer was properly mixed along with hand weeding. Irrigation was assured till to the hard dough stage of the ratoon crop.

In the main crops stage, BRRI dhan88 produced the highest grain yield (5.48 t ha^{-1}) followed by BRH11-9-11-4-5B (5.46 t ha^{-1}) and BRRI dhan100 (5.45) with 140-148 days growth duration (Table 6). Consequently, BRRI dhan88 produced the highest tiller and panicles among other entries. In the ratoon crop's stage, BRRI dhan100 produced the highest grain yield (1.00 t/ha) followed by BRRI dhan28 (0.91 t/ha) and BRRI dhan49 (0.83 t ha^{-1}) within 54-59 days of growth duration. BRRI dhan91 was found neither suitable for ratoon crop nor suitable to grown in Boro season might be due to its photosensitivity and long growth duration (182 days).

Table 6. Evaluation of ratooning ability of selected rice genotypes in Boro season, 2021-22 at BRRI HQ farm Gazipur.

Variety/Entry	Grain yield main crop ($t\ ha^{-1}$)	Tiller no. m^{-2}	Panicle no. m^{-2}	Growth duration of main crop (day)	Grain yield ratoon crop ($t\ ha^{-1}$)	Duration of ratoon crop (day)
BRRI dhan91	1.33	261	245	182	-	-
BR9377-2-1-3B	4.72	227	214	133	-	-
BR9390-6-2-1B	1.09	237	227	192	-	-
BR9392-6-2-3B	5.05	256	248	138	0.76	55
BR9396-6-2-2B	5.25	247	240	143	-	-
BRH11-9-11-4-5B	5.46	220	208	148	-	-
BRRI dhan28	5.19	240	233	141	0.91	57
BRRI dhan49	4.85	251	240	145	0.83	59
BRRI dhan88	5.48	275	261	140	0.80	59
BRRI dhan100	5.45	235	229	144	1.00	54
LSD $_{(0.05)}$	0.64	NS	NS	0.99	0.08	0.87
CV%	8.47	9.89	10.62	0.51	11.09	1.79

FERTILIZER MANAGEMENT

Effect of Nitrogen management to maximize grain yield of Swarna type varieties in T. Aman season.

The experiment was conducted at the Bangladesh Rice Research Institute BRRI farm, Gazipur, during Aman 2021 to find out optimum nitrogen management for BRRI dhan93 and BRRI dhan95. The treatments were: A: N rate: i) N_1 = STB (N-P-K-S= 77-13-47-6 kg ha^{-1}), ii) N_2= STB + 10%, iii) N_3 = STB - 10%, iv) N_4= BRRI Recommended dose (N-P-K-S= 92-12.5-42-10 kg ha^{-1}) and v) N_5= Control (0 N); and B. Varieties: i) V_1: BRRI dhan93, ii) V_2: BRRI dhan95 and iii) V_3: BRRI dhan87. The treatments were distributed in split plot design with three replications (Nitrogen management in the main plot and variety in the sub plot). Twenty-five days-old seedlings were transplanted at 20 × 20 cm spacing.

Table 7. Effect of nitrogen management of Swarna type varieties on yield during T. Aman 2021 at BRRI HQ farm, Gazipur.

Treatment	Grain yield ($t\ ha^{-1}$)		
Nitrogen level (kg ha^{-1})	BRRI dhan93	BRRI dhan95	BRRI dhan87
N_1: STB	5.33	5.25	4.38
N_2: STB + 10%	5.29	5.10	4.75
N_3: STB - 10%	4.86	4.72	4.23
N_4: BRRI recommended	5.22	5.29	5.42
N_5: Control (N_0)	3.486	3.87	2.84
LSD $_{(0.05)}$		0.43	
CV (%)		6.9	

Result indicates that BRRI dhan93 and BRRI dhan95 produced higher grain yield in STB treatment which is similar with STB + 10% and BRRI recommended dose (Table 7). Grain yield was significantly higher in N_1, N_2 & N_4 treatments than STB – 10% and control. On the other hand, BRRI dhan87 produced higher yield in BRRI recommended dose, which was also similar to the STB + 10% treatment. BRRI dhan93 and BRRI dhan95 produced higher grain yield in STB treatment than BRRI dhan87 by using 16% less nitrogen than BRRI recommended fertilizer dose.

Effect of N levels and growth stage-based N application on growth, yield and nitrogen use efficiency of BRRI dhan92 and BRRI dhan96.

The experiment was conducted at the Bangladesh Rice Research Institute (BRRI) farm, Gazipur, during Boro,2021-22 to find out the influence of growth stage-based nitrogen application on growth and yield of rice. The treatments were: A: Nitrogen level (kg ha^{-1}): i) N_1: STB (V_1=147, V_2=118), ii) N_2: BRRI recommended (V_1=138, V_2=120), iii) N_3: STB + 10% (V_1=161, V_2=130), iv) N_4: STB + 20% (V_1=176, V_2=141), v) T_5: Control (0 N); and B. Varieties: i) V_1: BRRI dhan92 and ii) V_2:

BRRI dhan96. The treatments were distributed in RCB two factor design with three replications. Thirty-five day-old seedlings were transplanted at 20 × 20 cm spacing. Result indicates that BRRI dhan92 and BRRI dhan96 produced highest grain yield on STB + 10% and STB treatment, respectively (Table 8) and consequently panicle m^{-2}, grains/panicle also higher in these treatments. So, more Nitrogen is required than BRRI recommended dose in case of BRRI dhan92.

Effect of different N levels on growth, yield, nitrogen use efficiencies (NUEs) and grain quality of aromatic rice varieties.

Therefore it is necessary to know the best N application rate for each variety, as well as its influence on components of yield and other agronomic paramet

The experiment was conducted at BRRI farm Gazipur during T. Aman 2021 with two factors. The different N rates N_0, N_{30}, N_{60}, N_{90}, N_{120} and USG (1.8 g 4 $hill^{-1}$) were applied in BRRI dhan34 and in BRRI dhan90. The experiment followed factorial RCB design with three replications. Twenty-five-old seedlings were transplanted on 10 August 2021 having 20 × 20 cm spacing with two seedlings $hill^{-1}$. The variation of grain yield of BRRI dhan34 and BRRI dhan90 at different nitrogen rates was determined through regression equation (Fig 1). Differentiating the quadratic equation of yield response with respect to applied different N doses the optimum N rate and economic N rate appeared as 57 and 56 kg ha^{-1} and 56 and 55 kg for BRRI dhan34 and BRRI dhan90, respectively. After calculation of regression model the economic N rate appeared as 56 and 55 kg for BRRI dhan34 and BRRI dhan90, respectively where initial soil N was 0.14% and organic matter was 1.47%.

Table 8. Effect of nitrogen levels on yield of BRRI dhan92 and BRRI dhan96 during Boro 2021-22 at BRRI HQ farm, Gazipur.

Treatment	Panicle number m^{-2}	Grain $panicle^{-1}$	1000 grain weight (g)	Grain yield (t ha^{-1})
V_1N_1	252	117	23.43	5.90
V_1N_2	246	115	24.10	5.74
V_1N_3	270	117	24.03	6.52
V_1N_4	241	115	23.60	5.55
V_1N_5	193	106	23.53	3.50
V_2N_1	275	118	20.06	6.01
V_2N_2	257	116	86.73	5.46
V_2N_3	263	116	20.30	5.65
V_2N_4	246	113	19.86	5.31
V_2N_5	191	105	19.83	3.13
$LSD_{(0.05)}$	13.73	4.12	0.70	0.47
CV (%)	3.29	2.11	1.88	6.85

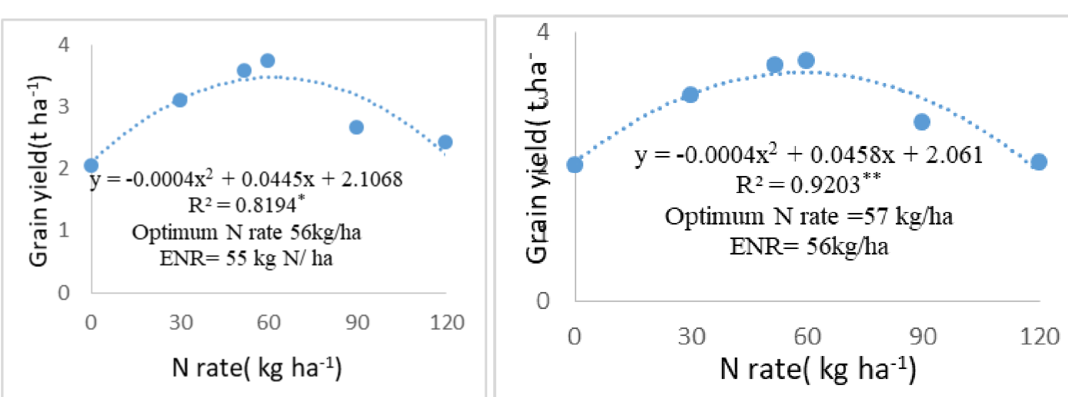


Fig 1. Determination of optimum and economic nitrogen rate of BRRI dhan34 and BRRI dhan90 .

4. Growth and yield improvement of T. Aman rice in Sirajganj farm through integrated nutrient management. It was conducted at BRRI R/S, Sirajganj farm during T. Aman season, 2021. The experiment was carried out following RCB design with three replications. The treatment was included inorganic and organic combinations of nutrient management and varieties. The nutrient management treatments were: T_1 = Control (No fertilizer), T_2 = BRRI Recommended dose of fertilizer (RDF) (N-P-K-S @ 69-10.4-41-10.8 kg ha^{-1}) , T_3 = Vermicompost (1 t ha^{-1}) + 50% of RDF , T_4 = Cowdung (5 t ha^{-1}) + 50% of RDF , T_5 = AEZ Based fertilizer dose (N-P-K-S-Zn @ 76-15-42.5-8.1-1.8 kg ha^{-1}), T_6 = Tricho-compost (2 t ha^{-1}) + 50% of RDF, T_7 = Poultry Manure (3 t ha^{-1}) + 50% of RDF.). Initial soil nutrient status of the experimental field was pH = 6.7, Total N (%) = 0.13, OC (%) = 1.35, P = 10.34 ppm, K = 0.16 meq/100g, S = 28.4 ppm and Zn = 8.5 ppm. Grain yield variation was significant due to higher number of panicles and higher number of grains $panicle^{-1}$. Significantly higher grain yield (6.14 and 5.78 t ha^{-1}) was observed in BRRI dhan87 with treatment T_4 (cow dung @ 5 t ha^{-1}) + 50% of RDF) followed by treatment T_7 (Poultry manure @ 3 t ha^{-1} + 50% of RDF). The lowest yield (4.02 t ha^{-1}) was found in control (Table 9). All the yield attributes were higher with the substitution of cow-dung or poultry manure in combination with 50% RDF due to slow release and continuous supply of nutrients in balanced quantity throughout the various growth stages, resulted in the production of increased panicles with higher number of fertile grains, lowest sterility (%) and grain yield. About 15-22% higher grain yield was obtained in 50% RDF along with cow-dung or poultry manure applied plots compared to BRRI recommended practices.

Table 9. Yield and yield components of BRRI dhan87 as influenced by integrated nutrient management at BRRI R/S, Sirajganj farm 2021.

Treatment	Panicles m^{-2}	Grain $panicle^{-1}$	1000 grain wt. (g)	Grain yield (t ha^{-1})	Sterility%
Nutrient management					
T_1	171	101	23.1	4.02	31.0
T_2	180	120	23.4	5.02	21.1
T_3	198	114	23.4	5.44	16.1
T_4	213	125	23.6	6.14	12.3
T_5	195	115	23.0	5.07	24.1
T_6	178	114	23.2	4.71	22.1
T_7	208	124	23.5	5.78	14.1
$LSD_{(0.05)}$	24.9	9.07	NS	0.85	7.90
CV (%)	7.3	4.39	2.03	9.3	21.1

T_1 = Control (No fertilizer), T_2 = Recom. dose of fertilizer (RDF) (N-P-K-S @ 69-10.4-41-10.8 kg ha^{-1}) , T_3 = Vermicompost (1 t ha^{-1}) + 50% of RDF , T_4 = Cowdung (5 t ha^{-1}) + 50% of RDF, T_5 = AEZ based fertilizer Dose (N-P-K-S-Zn@ 76-15-42.5-8.1-1.8 kg ha^{-1}), T_6 = Tricho-compost (2 t ha^{-1}) + 50% of RDF, T_7 = Poultry Manure (3 t ha^{-1}) + 50% of RDF.

Application of chitosan to improve salt tolerance in rice in reproductive stage.

A pot experiment was conducted at rain-out shelter of Agronomy Division, BRRI HQ Gazipur in Boro 2021-22 to find out the effect of chitosan on growth and yield of rice in saline condition. The pots were set as split-split design with three replications. The main plots represented two salinity levels of 0 mM NaCl and 65 mM NaCl (Approximately 6.5 dS m^{-1}). Sub-plots represented two concentrations of chitosan;0 ppm and 250 ppm. Sub-sub-plots represented two varieties of rice; i. BRRI dhan28 (salt sensitive), ii. BRRI dhan67 (salt tolerant). The highest chlorophyll content; chlorophyll a (35.6 mg g^{-1} FW) was measured in BRRI dhan67. Salt stress (65 mM) caused a drastic reduction in Chl ‘a’, Chl ‘b’ content compared to non-stress condition in the BRRI dhan28, whereas salt tolerant cultivar BRRI dhan67 showed a slight reduction. On contrary, supplementation of CS the showed significant alleviation of Chl ‘a’, Chl ‘b’ content and photosynthetic activity in both the varieties. Photosynthetic rate was significantly higher in BRRI dhan67 (22.1 μmol CO^2 m^{-2} s^{-1}) supplemented with chitosan with non-saline condition and salt stress reduced the photosynthetic rate in BRRI dhan28 and BRRI dhan67 (13.1 and 15.4 µmol CO_2 m^{-2} s^{-1}). (Table 10). Grains panicle^{-1} were significantly influenced by different treatments in BRRI dhan28 compared to BRRI dhan67. In saline condition, yield reduction was found from both the varieties and chitosan spray could slightly mitigate the saline stress in BRRI dhan28. In BRRI dhan67, grains panicle^{-1} and yield reduced in saline condition but with 250 ppm chitosan spray affected grains panicle^{-1} and yield increased in both saline and non-saline condition (Table 11). In 65 mM salinity level BRRI dhan67 produced 35% higher yield with 250 ppm chitosan spray than without spray. In control condition, BRRI dhan67 gave 12% higher yield with 250 ppm chitosan spray than without spray (Table 11).

Table 10. Effect of salinity and chitosan spray on chlorophyll content and photosynthetic activity of BRRI dhan28 and BRRI dhan67 in Boro 2021-22, BRRI HQ Gazipur.

Salinity level	Chitosan spray	Variety	Chlorophyll a (mg g^{-1} FW)	Chlorophyll b (mg g^{-1} FW)	Photosynthesis rate (µmol CO_2 m^{-2} s^{-1})
0 mM	0 ppm	BRRI dhan28	2.66	0.70	17.1
		BRRI dhan67	3.02	1.05	19.7
	250 ppm	BRRI dhan28	3.11	0.94	21.1
		BRRI dhan67	3.56	1.42	22.1
65 mM	0 ppm	BRRI dhan28	1.87	0.50	13.1
		BRRI dhan67	2.34	0.68	15.4
	250 ppm	BRRI dhan28	2.84	0.94	17.5
		BRRI dhan67	3.49	1.27	18.0
LSD $_{(0.05)}$			0.48	0.30	2.07
CV%			9.6	18.2	6.5

Table 11. Effect of salinity and Chitosan spray on growth and yield components of BRRI dhan28 and BRRI dhan67 in Boro 2021-22, BRRI HQ Gazipur

Salinity level	Chitosan spray	Variety	Panicle hill^{-1}	Grains panicle^{-1}	1000 GW (g)	Yield (g pot^{-1})	Sterility%
0 mM	0 ppm	BRRI dhan28	21	79	18.21	37.1	15.1
		BRRI dhan67	22	107	16.84	47.4	7.5
	250 ppm	BRRI dhan28	20	92	18.51	41.1	14.5
		BRRI dhan67	23	120	17.34	53.3	5.7
65 mM	0 ppm	BRRI dhan28	13	44	15.10	8.6	18.1
		BRRI dhan67	18	79	14.16	24.6	10.6
	250 ppm	BRRI dhan28	20	55	16.15	12.5	15.0
		BRRI dhan67	22	92	14.50	34.2	7.0
LSD $_{(0.05)}$			4.76	20.7	1.76	6.98	5.44
CV%			13.4	13.7	6.1	12.2	26.1

Improvement of soil health in four crops pattern through agronomic management.

A study was under taken in 2021-22 at BRRI farm Gazipur to improve the soil health and to increase the cropping intensity and productivity HQ. Cropping pattern was the Mungbean (BARI Mung-6)-T. Aus (BRRI dhan48)-T. Aman (BRRI dhan62)-Potato (BARI Alu41); besides agronomic management was 1. Incorporation of mungbean stubble with soil before T. Aus 2. Incorporation of compost @ 2.0 t ha^{-1} with soil before potato sowing and 3. Recommended dose of chemical fertilizers was applied for all crops as per schedule.

Results indicated that potato yield was not so satisfactory because soil is newly developed and not yet suitable for potato. It was not possible to harvest mungbean because of poor germination. The rice equivalent yield was 29.5 t ha^{-1} (23.0 t ha^{-1} potato = 20.7 t ha^{-1} rice, Rice = Tk 20/kg, Potato = Tk 18/kg) (Table 12). Initial soil of each crop was collected before starting sowing/ transplanting. The results showed that there was increasing trend in soil OM, total N, P, K and S with few exceptions (Table 13). However, despite cultivation of four crops in same land, are not harmful in terms of soil fertility if the proper management is given.

Table 12. Yield of different crops in four crops systems BRRI HQ farm, Gazipur, 2021-22.

Crop	Field duration	Variety	Yield (t ha^{-1})	Remark
T. Aus	10 May to 6 Aug 2021	BRRI dhan48	4.55	-
T. Aman	11 Aug to 5 Nov 2021	BRRI dhan62	4.25	-
Potato	16 Nov 19 to 19 Feb 2022	BARI Alu41	23.00	-
Mungbean	1 Mar 2022 (Sowing)	BARI mung6	-	Poor germination

Table 13. Initial Soil status of experimental plots in four crops system, BRRI HQ Gazipur, 2021-22.

Crop	pH	OM	Total N	P (ppm)	K (meq/100 g)	S (ppm)	Zn (ppm)
T. Aus	7.41	2.15	0.13	8.90	0.136	11.77	-
T. Aman	7.25	2.03	0.12	9.55	0.152	9.68	-
Potato	7.22	2.22	0.14	11.90	0.203	6.73	-
Mungbean	7.02	2.12	0.13	15.28	0.210	13.33	-

YIELD MAXIMIZATION

Maximizing yield of BRRI developed new varieties through influencing some agronomic critical factors in different seasons

A study of the individual agronomic critical factor together with their possible combinations has been taken to find out the effect of agronomic critical factors for yield maximization of newly BRRI developed varieties. Split plot design was followed where management in main plot and variety was in sub plot. Different agronomic critical factors based six managements were considered, where M_1 = BRRI Recommended practices, M_2 - M_6 were different agronomic management. The detailed treatment description is as follows:

Critical factor	M_1	M_2	M_3	M_4	M_5	M_6
Transplanting time	Jan 1st week	Dec 2nd week	Dec 3rd week	Dec 4th week	Dec 2nd week	Dec 3rd week
Seedling age	35 days	15 days	20 days	25 days	15 days (tray)	20 days (tray)
Spacing	20 × 20 cm	30 × 30 cm	30 × 25 cm	25 × 25 cm	30 × 30 cm	30 × 25 cm
Seedling/hill	2	1	2	2	1	2
Upper soil Stirring	0	20 DAT & 35 DAT	20 DAT & 35 DAT	20 DAT & 35 DAT	20 DAT & 35 DAT	20 DAT & 35 DAT
Inorganic Fertilizer	BRRI RR	STB +1% MoP solution*	STB +1% MoP solution*	STB +1% MoP solution*	STB +1% MoP solution*	STB +1% MoP solution*

*Sprayed at 35 and 45 DAT

The varieties were: V_1= BRRI dhan88, V_2= BRRI dhan89 and V_3= BRRI dhan29.

Experiment result showed significant yield differences among the treatments (Table 14). The highest grain yield was observed in long duration variety BRRI dhan89 in all management treatments followed by BRRI dhan29 than short duration BRRI dhan88. For obtaining higher yield, it may be recommended that seeding would be done on last week of December, younger seedling (15 to 25-day old) should be transplanted following wider spacing (30 × 25 or 25 × 25 cm) on 3rd week of December. Upper soil stirring should be done on at 20 and 35 DAT. STB fertilizer management would be followed and additionally 1% MoP solution to be sprayed on 30 and 45 DAT.

Table 14. Effect of some agronomic critical factors on yield of different growth duration of Boro varieties at BRRI HQ farm Gazipur, 2021-22.

Management	V1=BRRI dhan88	V2=BRRI dhan89	V3=BRRI dhan29
M_1	6.18	6.72	7.17
M_2	6.26	7.58	7.28
M_3	6.45	7.53	7.03
M_4	6.14	7.65	7.05
M_5	6.38	7.76	6.98
M_6	5.86	7.79	7.00
LSD $_{(0.05)}$ for variety = 0.361373			
LSD $_{(0.05)}$ for management = 0.511059			
LSD $_{(0.05)}$ for V × M = 0.885180			
CV(Rep*Management*Variety) = 7.7			

(Note: The field performance of M_2, M_3, M_4, M_5 and M_6 treatment was very good in both the years up to heading stage, after hard dough stage 30 to 70% lodging was occurred)

Maximizing yield of some local fine aromatic cultivars through influencing some Agronomic management in Aman seasons A study of some agronomic factors together with their possible combinations was undertaken in T. Aman 2021 to find out the effect of agronomic management on yield maximization of some local fine aromatic popular varieties. Seven locally popular fine aromatic rice varieties including one check variety were tested under four different agronomic management practices. The agronomic management were: M_1 = BRRI Recommended practices, M_2 - M_4: Proposed agronomic management treatments. The agronomic management treatments in details are described bellow:

Management	M_1	M_2	M_3	M_4
Seeding time	2nd week of Jul	4th week of Jul	4th week of Jul	1st week of Jun
Transplanting time	2nd week of Aug	1st week of Aug	2nd week of Aug	1st TP: Jun 3rd week 2nd TP: Aug 1st week
Seedling age	30 days	10 days	15 days	1st TP: 20-25, 2nd TP: 35-40 days
Spacing	20 × 20 cm	20 × 25 cm	20 × 25 cm	1st: 15 × 10 cm 2nd: 20 × 20 cm
Seedling/hill	3-4	1-2	1-2	1st TP: 5-6 2nd TP: 3
Soil Stirring	0	25 & 40 DAT	25 & 40 DAT	0
Inorganic Fertilizer	BRRI RR (kg ha^{-1}) N=40 (at 0, 25 and 7 days before PI), P=10, K=30, S=8	70% of RR+ 1% MoP solution spray	70% of RR+ 1% MoP solution spray	1st TP: N @ 30 kg ha^{-1} 2nd TP: BRRI RR (kgha^{-1}) N=40 (at 0, 25 and 7 days before PI), P=10, K=30, S=8
Vermicompost	0	1 t ha^{-1}	1 t ha^{-1}	2 t ha^{-1}

The experiment was laid down in Split plot design with three replications where Management was in the main plot and variety was in the sub plot. Results (Table 15) showed that there was management sensitivity among tested local fine rice varieties, but some varieties had not on grain yield. Among the eight tested variety, BRRI dhan34, Tulshi Mala and Kathari Voaug have higher sensitivities to agronomic management and produced higher grain yield in respective to other tested varieties. Kalo Malshira and Gobidha Voaug have les management sensitivity on grain yield production, as a result has produced similar yield at all agronomic managements. Among the four agronomic managements, Management 2 and Management 3 have more effect on grain yield production rather than other two tested agronomic management. So, to obtain the higher yield from local varieties, following agronomic management should be: Seeding and transplanting should be completed within 4th week of July and 2nd week of August, respectively with 15-day-old seedling. Spacing will be line to line 25 cm and plant to plant 20-cm. Upper soil will be needed to stirring on 25 and 40 DAT. Applied organic and inorganic fertilizers will be vermicompost 1 t ha^{-1} and NPKSZn @ 30-10-30-10 kg per ha, respectively. 1% MoP solution need to be applied as foliar spray on 30, 40 and 50 DAT.

Table 15. Effect of some Agronomic management on some local fine aromatic cultivars for maximizing yield in Aman 2020 seasons at BRRI HQ farm Gazipur.

Variety	Management 1	Management 2	Management 3	Management 4
V_1 = Kalo Malshira	2.34	2.49	2.26	2.39
V_2 = Kalo Shailla	2.20	2.45	2.22	2.42
V_3 = Cini Gura	2.38	2.22	2.43	2.21
V_4 = Gobindha Voaug	2.28	2.26	2.27	2.05
V_5 = Kathari Voaug	1.94	1.94	2.23	2.17
V_6 = Tulshi Mala	2.40	2.31	2.77	2.60
V_7 = Kalo Jira	2.34	2.31	2.09	2.17
V_8 = BRRI dhan34 (Ck)	3.43	3.23	4.06	3.44

$LSD_{(0.05)}$ for variety(V) = 0.387273,
$LSD_{(0.05)}$ for management(M) = 0.273844 and $LSD_{(0.05)}$ for V × M = 0.440094
CV (%) = 19.4 CV(Rep*TP*Variety)

Maximizing yield of new rice varieties through influencing agronomic critical factors

A study of agronomic management with possible combinations was undertaken to find out the effect of critical factors for yield maximization of long (BRRI dhan52), medium (BRRI dhan87) and short duration (BRRI dhan71) varieties in T. Aman. The treatment combinations of agronomic management were as follows: M_1 = BRRI recommended practices and M_2 -M_5= Proposed Agronomic management treatments. The description of the treatment is details is as follows:

Agro. factors	M_1	M_2	M_3	M_4	M_5
Transplanting time	V_1= August 15 V_2= August 10 V_3= July 29	V_1= July 30 V_2= July 25 V_3= July 14	V_1= August 05 V_2= July 30 V_3= July 20	V_1= August 01 V_2= August 05 V_3= July 24	V_1= August 10 V_2= August 15 V_3= August 04
Seedling age	30 days	15 days	20 days	25 days	35 days
Spacing (cm × cm)	20 × 20	25 × 25	25 × 20	25 × 15	25 × 10
Seedling/hill	2-3	2	2	2	3-4
Upper soil Stirring	0	20 & 35 DAT	20 & 35 DAT	20 & 35 DAT	20 & 35 DAT
Inorganic Fertilizer	BRRI RR	STB + 1% MoP solution*	STB 1% MoP solution*	STB + 1%MoP solution*	STB + 1%MoP solution*

*Sprayed at 30 and 45 DAT, Manure was applied in M_2-M_5

Split plot design was followed where management in the main plot and variety was in the sub plot. The result (Table 16) shows that BRRI dhan71, BRRI dhan87 and BRRI dhan52 varieties obtained the highest yield by M_4 and M_5 agronomic management combinations than the other tested agronomic management practices.

Table 16. Effect of Agronomic factors for maximizing grain yield of BRRI developed new varieties in T. Aman seasons at BRRI HQ farm Gazipur.

Management	V1=BRRI dhan71	V2=BRRI dhan87	V3=BRRI dhan52
M_1	5.12	4.56	4.68
M_2	4.16	4.03	3.80
M_3	4.85	4.19	4.24
M_4	5.61	5.72	5.62
M_5	5.63	5.63	6.24
$LSD_{(0.05)}$ for Variety = 0.658575			

LSD $_{(0.05)}$ for Management	= 0.850216
LSD $_{(0.05)}$ for V × M	= 1.47262
CV%	= 17.88

WEED MANAGEMENT

Evaluation of candidate herbicides for transplanted rice

During the reporting year (T. Aman 2021 and Boro 2021-22), forty herbicides of 12 different groups were evaluated at field level to evaluate the weed control efficiency of candidate herbicide in transplanted rice. Field-trials were conducted at the BRRI HQ farm, Gazipur during T. Aman 2021 and Boro 2021-22 seasons to evaluate the efficacy of candidate herbicides according to standard protocol. Pre emergence herbicides were applied at 4 DAT and post emergence herbicides at 1-2-leaf-stage of weed. Weed sampling was done at 40 DAT for T. Aman and 45 DAT for Boro season. Weed control efficiency was calculated on weed dry weight basis. Most of the herbicide performed more than 80% weed control efficiency in different weed populations observed in the field (Table 17). Only *Cynodon dactylon* cannot be controled >80% by some herbicide in most cases. Among the herbicides, three herbicides did not control weed effectively and their weed control efficiency were less than 80%. Some herbicides were found highly phytotoxic which were treated not satisfactory. Table 17 showed that post emergence herbicide coming to dominant and most of the herbicide contains combination chemicals which indicates to be more effective where the weed control efficiency of these herbicide was more than 80%.

Table 17. Herbicide chemical name, dose and weed control efficiency of different herbicides evaluated during T. Aman 2021 and Boro 2021-22 at BRRI farm Gazipur.

Chemical name	Dose ha^{-1}	Season	Weed Control Efficiency (%)					Remarks
			Cynodon dactylon	*Echinochloa crus-galli*	*Monochoria vaginalis*	*Scirpus maritimus*	*Cyperus difformis*	
Bispyribac sodium 4% + Metamifop 10% SE	100 g	Aman	86.50	84.50	84.50	88.88	80.90	Pre-emergence satisfactory
		Boro	65.50	82.00	82.85	85.55	79.78	
Pyrazosulfuron ethyl 10% + Bispyribac 20% WP	150 g	Aman	74.50	82.0	84.80	86.28	86.75	Post-emergence Satisfactory
		Boro	72.10	83.65	80.44	80.20	80.50	
Qunichlorac 34% + Bensulfuron methyl 6%	600 g	Aman	87.52	85.50	80.45	70.20	50.50	Post-emergence very sensitive to over dose
		Boro	84.54	85.00	82.30	80.50	80.84	
Sulfentrazone 48% SC	200ml	Aman	65.70	85.00	80.00	82.60	82.70	Pre-plant and pre-emergence Satisfactory
		Boro	78.86	84.50	83.70	81.75	76..47	
Bispyribac sodium 40% SC	150ml	Aman	80.70	82.88	85.00	80.25	83.88	Post-emergence Satisfactory
		Boro	83.00	80.28	86.00	84.50	81.22	
Pyraclonil 2%	152 g	Aman	75.40	83.80	88.4	83.77	80.44	Pre to early Post-emergence Satisfactory
		Boro	70.60	85.77	82.55	84.60	84.20	
Bensulfuron metlyl 4% + Bispyribac sodium	150 g	Aman	70.50	88.65	88.00	84.33	87.00	Post-emergence Satisfactory
		Boro	77.50	83.55	83.00	86.80	84.75	

Cost effective weed management in transplanted rice

The trial was conducted at the Sadar upzilla, Gazipur during Aus 2021 and Tahirpur, Sunamganj and Paba, Rajshahi during Boro 2021-22 seasons to evaluate the method of weed suppression and to find out an appropriate way to reduce weed infestation in farmers' field. The trial was carried out with three treatments viz weed management by pre/post emergence herbicide + 1 HW, Weed management by BRRI weeder just after 1st and 2nd top dress of urea and weed management by farmers' practice. Twenty-five-day-old seedlings of BRRI dhan48, BRRI dhan98 and BRRI hybrid dhan7 were transplanted at 20 × 20 cm spacing with two seedlings hill^{-1} in Aus and forty-day-old seedlings of BRRI dhan67, BRRI dhan75, BRRI dhan81 in Aman and forty-six days old seedlings of BRRI dhan89 were transplanted at Boro season. Fertilizer was applied by following BRRI recommended dose Aus: N:P:K= 62:11:41 kg ha^{-1} and Boro: N:P:K:S:Zn=120:19:60:20:4 kg ha^{-1}. Pre-emergence (Bensulfuran methyl + acetachlor) herbicide was sprayed at five days after transplanting and post-emergence (Penoxulam) herbicide was sprayed at eight days after transplanting with the help of a knapsack sprayer. Weeding was done by BRRI weeder during 1st and 2nd top dress of urea. Results indicated that applying BRRI weeder just after 1st and 2nd top dress of urea showed the highest grain because just after urea top dressing BRRI weeder incorporate in the soil properly and yield reduce the weed infestation. Weed management by pre-emergence herbicide also produce similar grain yield. Farmers have done hand weeding in their plots. So weeding cost is higher for farmers and due to late weeding their yields were also reduced than BRRI treatments.

SOIL MICROBIOLOGY AND MANAGEMENT

Study on biodegradation of pesticides in soil using selected microbial strain

The experiment was conducted in the Agronomy and Entomology division, BRRI to estimate the rate of pesticide degradation by the beneficial soil microbes. The bacterial strains were collected from the soil microbiology laboratory, Soil science division, BRRI. The two PGPR strains *Proteus sp* and *Bacillus sp* and a widely used insecticide, popularly known as virtako (Chlorantraniliprole + thiamethoxam) (CTP) were used in this study. Initially, the bacterial strain was cultured in Tryptic Soy Broth (TSB) medium. The recommended dose of the insecticide was inoculated in each of the bacteria inoculated flask. The flask was allowed for shaking in a rotary shaker until a period of 21 days. The aliquot was collected at 1, 3, 7, 10, 15, and 21 days after pesticide inoculation. The pesticide residue was extracted from the collected samples through centrifugation using acetonitrile (ACN). The extracted liquid was transferred into autosampler vials for analysis using LC-MS. The concentration of insecticide in non-inoculated media was almost consistent over the period. However, inoculation of bacterial strains *Proteus mirabilis* showed a steady fall in concentration from 7 DAI onwards. The concentration of CTP in *Proteus mirabilis* inoculated media at 21 DAI was reduced by 20.96% over the control. Besides, the concentration of CTP in *Bacillus tequilensis* inoculated media reduced drastically at 7 DAI following a gradual decrease thereafter. It showed a 70.69% of decrease at 21 DAI over the control (Fig 2). Among the two bacterial strains, *Bacillus tequilensis was* highly performed to degrade CTP in TSB media.

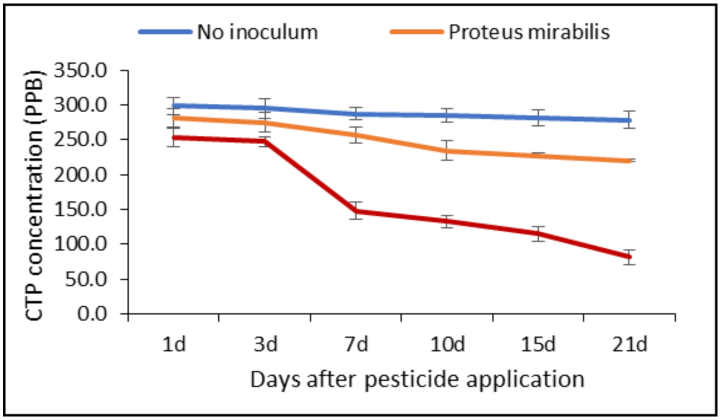


Fig 2. The degradation of CTP inoculated with bacterial strains in TSB media.

Residue analysis of widely used herbicides in the irrigated rice eco-system in 2020-21 season at BRRI HQ farm Gazipur.

Good Agricultural Practices (GAP) were ensured based on a quick, easy, cheap, rugged, safe (QuEChERS) method coupled with LCMS-MS. The experiment was conducted to determine the residue of four popular herbicides, 1) Bensulfuron-methyl + Acetochlor (Pre-emergence), 2) Pyrazosulfuron-ethyl (Post-emergence), 3) Pendimethalin (Pre-emergence), 4) Ethoxysulfuron-ethyl (Post-emergence) compared with the weed-free plot (No chemical) at BRRI HQ farm, Gazipur during Boro 2021-22. The treatments were distributed in an RCB design with three replications. Fortyday-old seedlings of BRRI dhan28 were transplanted on 22 January. All agronomic management was done per BRRI recommendation and when necessary. For the determination of the residue effect, a calibration curve was generated using 11 points in the range of 0.1 to 100ppb with a regression of 0.999. Both of the herbicides, Bensulfuron-methyl and Pendimethalin were dissolved in Acetonitrile LCMS grade (Sigma Aldrich) and passed through a Shim-pack Scepter column (C-18, 2.1 x 150 mm). The limit of detection (LOD) for Bensulfuron-methyl and Pendimethalin was found 0.10 µg/Kg and 0.12 µg/Kg, respectively. The limit of quantification (LOQ) of the two herbicides was observed at 0.35 µg/Kg and 0.31 µg/Kg, respectively (Fig. 3). The maximum residue limit (MRL) of both Bensulfuron-methyl and Pendimethalin is 100 ppb in rice (Brown). Such a method could be used to determine the assessment as well as scientific guidance on the proper and safe application of herbicides in paddy fields.

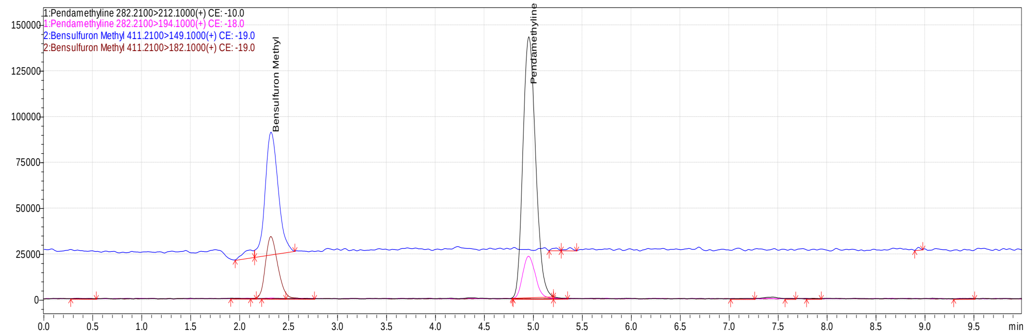


Fig. 3. Herbicides measures and standardized in LCMS-MS.

Soil Science Division

SUMMARY

In T. Aman season, the ZER line BR 9674-1-1-5-2-P4 produced comparatively lower grain yield (5.24 t ha^{-1}) than the check varieties BRRI dhan49, BRRI dhan72 and BRRI dhan87. The economic optimum doses of N for ZER advanced line BR 9674-1-1-5-2-P4 was 64 kg N ha^{-1}, and for the check varieties BRRI dhan49, BRRI dhan72, and BRRI dhan87 were 70, 54 and 64 kg N ha^{-1}, respectively. In Boro season, the PQR-ALART materials BR9930-2-3-2-2 (6.72 t ha^{-1}) and BR9930-2-3-3-1 (6.75 t ha^{-1}) produced higher grain yield than the three PQR check varieties of BRRI dhan50 (6.52 t ha^{-1}), BRRI dhan63 (6.58 t ha^{-1}) and BRRI dhan81 (6.43 t ha^{-1}) in the same dose of N (120 kg N ha^{-1}). The economic optimum N dose for PQR advanced lines BR9930-2-3-2-2 and BR9930-2-3-3-1 were 122 kg and 121 kg N ha^{-1}, respectively. The calculated economic optimum N dose for BRRI dhan95 in T. Aman season was 88 kg N ha^{-1} and in Boro season for BRRI dhan92 it was 180 kg N ha^{-1}.

Urea-HA nanohybrid saves up to 50% urea use providing comparable N use efficiency with widely applied prilled urea. In P deficient soil, the economic optimum dose of P for BRRI dhan87 was 27.5 kg ha^{-1} in T. Aman season and in Boro season of BRRI dhan89 and BRRI dhan96 the P doses were 27 kg and 26.8 kg ha^{-1}, respectively. The optimum N and K rates were 98 and 106 kg ha^{-1}, respectively for BRRI hybrid dhan6 during T. Aman, while for BRRI dhan89 in Boro season, the rates were 128 kg N and 100 kg K ha^{-1}. Result of the pot experiment in T. Aman season showed that application of Cu, Ni, Se and Si along with full dose of chemical fertilizer had positive impact on yield and yield contributing characters of BRRI dhan87. In Gazipur, after 6th crop cycles, it was revealed that AEZ or STB based chemical fertilizers (CF) seemed sufficient to obtain potential yield of each crop in Mustard-Boro-T. Aus-T. Aman (CP-1) or Mustard-Mungbean-T. Aus-T. Aman (CP-2) cropping pattern. Considering rice equivalent yield (REY), CP-1 performed better than CP-2.

Besides N, P and K, omission of S and Zn from balanced complete fertilizer reduced grain yield greatly in both T. Aman and Boro seasons. The annual yield of organic fertilizers with IPNS based chemical fertilizer showed an increasing trend compared to balanced complete fertilizer application. In the continuous wetland, additional application of Zn and Cu once in a year with NPKS increased annual grain yield by more than 1.0 t ha^{-1} than NPKS alone. In T. Aman BRRI dhan87 and BRH11-2-4-7B produced comparatively higher grain yield than the other tested rice genotypes and IIMP performed better than BRRI management.

Application of 100% STB dose or 50% STB + mixed manure showed similar yield trend and increased soil fertility in long-term double and triple rice cropping pattern in HQ, BRRI Gazipur farm soil. Some positive effect on yield increment was observed due to application of vermicompost @ 1 or 2 t ha^{-1} in coastal belt of Borguna and Khulna district. No additional yield advancement was observed in application of vermi-compost (2.5, 5 and 10 tha^{-1}) incombination with silicon (100, 200 and 400 kg ha^{-1}) in both T. Aman and Boro seasons at BRRI HQ, Gazipur.

Soil test-based fertilizer recommendation performed good in both BRRI RS farmers, Cumilla and Sonagazi soil for maximizing rice yield although some organic matter (2 t ha^{-1}) would be need for sustained soil fertility in the long run. Increased grain yield observed in residue management and AEZ based chemical fertilizer (100%) application but crop establishment methods have no positive effect on grain yield.

In considering yield, N use efficiencies and NH_3-N loss, N applied @ 105 kg ha^{-1} from UDP and PU + BRRI-organic fertilizer in Boro season and N applied @ 83 kg ha^{-1} from UDP in T. Aman season could be the most suitable N management interventions to sustain rice production and reduce environmental pollution. In charland, application of biochar @ 4 t ha^{-1} along with chemical fertilizer maximized the grain yield in Boro season. Whereas, some residual effect of biochar in grain yield was observed in the succeeding T. Aman season. Reduced N dose (78 kg N ha^{-1}) with mixed manure (cowdung 2 ton + ash 1 ton) produced the highest yield than the other N management

packages in coastal rice ecosystems of BRRI RS, Satkhira farm.

BRRI-organic fertilizer (2 t ha^{-1}) has potential to supplement 30% N and 100% P requirement for HYV rice without sacrificing yield. Microbial characterization of eight different AEZs soils have been done. Soil bio-physico-chemical properties of different AEZ's, biomolecular characteristics of the isolated strains and formulation of biofertilizer for acid and saline soil were evaluated.

SOIL FERTILITY AND PLANT NUTRITION

Determining N requirement of ZER and PQR ALART materials. N is the most limiting nutrients for rice production. Separate field trials were conducted for ZER (zinc enrich rice) and PQR (premium quality rice) genotypes at BRRI HQ farm, Gazipur (AEZ 28; Modhupur Tract) during T. Aman 2021 and Boro 2021-22 following split-plot design with three replications, where fertilizer doses were assigned in main-plot and rice genotypes in sub-plot. In T. Aman, one ZER line BR 9674-1-1-5-2-P4 was compared with three check varieties viz BRRI dhan49, BRRI dhan72 and BRRI dhan87 and in Boro season, two PQR lines BR9930-2-3-2-2 and BR9930-2-3-3-1 and three rice varieties viz. BRRI dhan50, BRRI dhan63 and BRRI dhan81 as check were evaluated. Six urea-N doses (kg ha^{-1}): N_0, N_{20}, N_{40}, N_{60}, N_{80} and N_{100} with standard doses (soil test based) of P, K, S were applied for T. Aman and in Boro the N doses (kg ha^{-1}): N_0, N_{30}, N_{60}, N_{90}, N_{120} and N_{150} with standard doses of P, K, S and Zn were applied. A quadratic regression model was used to determine the optimum N requirement.

Grain yield and N requirements. In T. Aman, grain yield increased with increasing the N doses up to 80 kg ha^{-1} in most genotypes than decreased. The ZER line BR 9674-1-1-5-2-P4 produced a comparatively lower grain yield (5.24 t ha^{-1}) than the three check varieties. The economic optimum doses of N for ZER advanced line BR 9674-1-1-5-2-P4 was 64 kg N ha^{-1}, and for the check varieties BRRI dhan49, BRRI dhan72, and BRRI dhan87 were 70, 54 and 64 kg N ha^{-1}, respectively. In Boro season, the highest grain yield was obtained in T_5 (120 kg N ha^{-1}) treatment in all the tested genotypes but the result was insignificant compared with T_4 (90 kg N ha^{-1}) and T_6 (150 kg N ha^{-1}) treatments. Comparatively higher grain yield was obtained with two PQR-ALART materials BR9930-2-3-2-2 (6.72 t ha^{-1}) and BR9930-2-3-3-1 (6.75 t ha^{-1}) than the three PQR check varieties BRRI dhan50 (6.52 t ha^{-1}), BRRI dhan63 (6.58 t ha^{-1}) and BRRI dhan81 (6.43 t ha^{-1}) in the same doses of nitrogen (120 kg N ha^{-1}). The economic optimum N dose for PQR advanced lines BR9930-2-3-2-2 and BR9930-2-3-3-1 were 122 kg and 121 kg N ha^{-1}, respectively and for the check varieties BRRI dhan50, BRRI dhan63 and BRRI dhan81 were 115,114 and 114 kg N ha^{-1}, respectively

Determining N doses for MV rice varieties. The experiment was conducted at the experimental field of BRRI HQ, Gazipur in T. Aman 2021 and Boro 2021-22 seasons to determine the optimum N requirement of BRRI dhan95 and BRRI dhan92, respectively. The experiment was laid out in a RCB design with three replications. The applied N doses (kg ha^{-1}) for T. Aman was 0, 30, 60, 90, 120, 150 and Boro was 0, 40, 80, 120, 160, 200, respectively, along with flat doses of P, K, S fertilizer. The grain yields of BRRI dhan95 and BRRI dhan92 were significantly influenced by N rates. The calculated economically optimum N dose for BRRI dhan95 was 88 kg/ha in T. Aman season and in Boro season, for BRRI dhan92 it was 180 kg/ha. However, in case of BRRI dhan92 the grain yield was similar with 120, 160 and 200 kg N ha^{-1}. The slow response to higher N rates might be due to the slow mineralization of N because of low temperature during the growing period.

Increasing N use efficiency and determining nutrient requirements of MV rice. A rice growth pot experiment was set up using a terrace paddy soil of BRRI, Gazipur from January to May 2022 covering 6 fertilizer treatments × 3 replicates. The intention was to investigate the N use efficiency of typically synthesized urea-HA (hydroxyapatite) nanohybrid and urea plus purified natural zeolite (71% SiO_2) over prilled urea. Urea-HA nanohybrids was synthesized according to method by Kottegoda *et al.* (2017). Transplanted rice (BRRI dhan89) was grown in the green house under continuous flooding for 114 days. Six treatments viz T_1: PKSZn, T_2: Urea-N_{120} PKSZn, T_3: Nano fert.-N_{120} PKSZn, T_4: Nano fert.-N_{60} PKSZn, T_5: Urea-N_{120} PKSZn + purified natural zeolite (71% SiO_2) @ 2.5 t ha^{-1} and T_6: Urea-N_{60} PKSZn were tested.

Yield and N use efficiency. Among the studied parameters, the number of effective tiller and panicle, filled grain weight and grain yield were significantly greater in all N fertilizer treated pots (T_2, T_3, T_4, T_5 and T_6) than N untreated pot (T_1) (Table 1). All these parameters were statistically identical between the N fertilizers treatments except greater tiller no. recorded in N applied at 60 kg ha^{-1} from urea (T_6). In nano fertilizer, N applied at 60 kg N ha^{-1} i.e. in T_4, the number of panicle, filled grain weight and grain yield were statistically identical with N applied at 60 kg N ha^{-1} from urea (T_6), as well as N applied at 120 kg N ha^{-1} from urea (T_2), nano fertilizer (T_3) and urea + zeolite (T_5). The agronomic N use efficiencies (AE_N) (kg grain kg^{-1} N applied) were greater in T_4 (15), T_2 (14), T_3 (14) and T_6 (13) and lower in (T_5). Therefore, Urea-HA nanohybrid may save up to 50% urea use providing comparable N use efficiency with widely applied prilled urea but requires characterization of synthesized nanofertilizer and further verification via i*n-situ* research certainly with nanofertilizer in more paddy soils.

Table 1. Typical yield attributes, grain and straw yields, and agronomic N use efficiency (AE_N) of the studied greenhouse rice growth pot experiment during Boro season 2021-22.

Treatment	Plant height (cm)	Tiller no. (pot^{-1} $hill^{-1}$)	Panicle no. (pot^{-1} $hill^{-1}$)	Filled grain wt. (g pot^{-1} $hill^{-1}$)	Grain yield (t ha^{-1})	Straw wt. (g pot^{-1} $hill^{-1}$)	Straw yield (t ha^{-1})	AE_N (kg grain kg^{-1} N applied)
T_1: PKSZn	87ab	13d	13c	33b	8.3b	26.8b	6.7b	
T_2: UreaN_{120}-PKSZn	89ab	17b	16ab	40a	10.0a	31.3ab	7.8ab	14
T_3: Nano fert. N_{120}-PKSZn	85ab	15cd	14bc	40a	10.0a	30.6ab	7.6ab	14
T_4: Nano fert. N_{60}-PKSZn	91a	17bc	17ab	37ab	9.2ab	30.2b	7.5b	15
T_5: UreaN_{120}-PKSZn + Zeolite (2.5 t ha^{-1})	86ab	17bc	17ab	36ab	9.0ab	30.5ab	7.6ab	6
T_6: UreaN_{60}-PKSZn	81b	20a	19a	36ab	9.1ab	36.9a	9.2a	13

Different lower-case letters within the column denote significant differences between the treatments according to ANOVA and Duncan's Multiple Range Post-Hoc Test.

Performance of rice varieties under P deficit conditions. Acute P deficiency reduces rice yield depending on internal and/or external mechanisms that allow greater soil P extraction. The experiments were conducted at BRRI farm, Gazipur during T. Aman 2021 and Boro 2021-22 season having deficit soil available P conditions. Six treatments of P doses calculating from soil test value (STB) viz T_1= P control, T_2= 50% of STB P (11 kg ha^{-1}), T_3= 75% of STB P (16.5 kg ha^{-1}), T_4= 100% of STB P (22 kg ha^{-1}), T_5= 125% of STB P (kg ha^{-1}) and T_6= 150% of STB P (27.5 kg ha^{-1}) were applied in both the seasons. BRRI dhan87 in T. Aman and BRRI dhan89 as well as BRRI dhan96 in Boro season were used as tested rice varieties. Each plot received a flat dose of N-K-S-Zn (kg ha^{-1}) @ 90-42-10-1 in T. Aman and 160-60-20-2 in Boro

Grain yield of T. Aman and Boro. In the P deficient soil, P fertilizer had significant effect on grain yield. The grain yield in the P fertilized plot progressively increased with the increasing level of P fertilizer in both the seasons. In T. Aman season, yield increasing trend was observed up to T_6 treatment. Although the highest grain yield was obtained with T_6 treatment (5.55 t/ha), but it was statistically similar with T_4 (5.52 t/ha) and T_5 (5.42 t/ha). The P control plot yielded only 3.13 t/ha. From the response curve, the economic optimum dose of P for BRRI dhan87 in P deficient soil was found 27.5 kg ha^{-1}. In Boro, under control P condition, grain yield was 1.45 t ha^{-1} only and with 50% and, or 75% applying of fertilizer P, grain yield increased sharply and significantly up to T_4 (7.01 t ha^{-1}) for BRRI dhan89 which was significantly higher than T_3 and T_2 treatment. In BRRI dhan96, the P control plot yielded only 1.99 t ha^{-1}, but the application of P fertilizer in T_2 (50% P), T_3 (75% P) and T_4 (100% P) treatment grain yield increased significantly. Both the rice varieties performed best at 100% STB P condition. Among the tested rice genotypes, BRRI dhan96 performed better in the same level of applied P condition than BRRI dhan89. From the response curve, the economic optimum dose of P for BRRI dhan89 and BRRI dhan96 were found 27 and 26.8 kg ha^{-1}, respectively in P deficient soil in Boro season.

Influence of N and K on the performance of modern rice. The study was conducted to observe the effect of nitrogen (N) and potassium (K) on the yield and nutrition of modern rice at BRRI farm, Gazipur during T. Aman 2021 and Boro 2021-22 season. The experiment was laid out in split-plot design with three replications assigning the rates of K in the main plots and that of N in the subplots. Soil test based flat rates of P and S were applied to all the plots. The application rate of K was 0, 50, 100, 150, and 200 kg ha^{-1} both in T. Aman and Boro seasons. Nitrogen was applied @ 0, 50, 75, and 100 kg ha^{-1}, in T. Aman season, while in Boro season, the rate of N was 0, 100, 150 and 200 kg ha^{-1}. The test varieties were BRRI hybrid dhan6 and BRRI dhan89 in T. Aman and Boro seasons, respectively.

Grain and straw yield. The interaction effect of rice yield between N and K was significant in both T. Aman 2021 and Boro 2021-22 (Table 2). The highest grain yield (5.10 t ha^{-1}) was found when N and K fertilizer was used at 75 kg and 100 kg ha^{-1}, respectively in T. Aman 2021. In Boro 2021-22, grain yield of BRRI dhan89 was significantly affected by the interaction of N and K addition (Table 2). The effect of N on rice grain yield was distinctly dominant over K effect during the Boro season. The highest grain yield (7.19 t ha^{-1}) was achieved with 100 kg N and 100 kg K ha^{-1} (Table 2). The optimum N and K rates that produced the maximum grain yield were determined using the quadratic equations of the response curves. Accordingly, the optimum N and K rates estimated from the equations were 98 and 106 kg/ha, respectively for BRRI hybrid dhan6 during T. Aman, while for BRRI dhan89 in Boro season, the rates were 128 kg N and 100 kg K/ha (Table 2).

Table 2. Effect of N and K on the grain yield (t ha^{-1}) of BRRI hybrid dhan6 in T. Aman 2021 and BRRI dhan89 in Boro 2021-22 at BRRI farm, Gazipur.

K rate (kg ha^{-1})	N rate (kg ha^{-1})							
	0	50	75	100	0	100	150	200
	BRRI hybrid dhan87 (T. Aman)				BRRI dhan89 (Boro)			
0	3.85a	4.43b	3.98c	3.54b	3.61a	4.49c	4.07b	4.09d
50	4.07a	4.66ab	4.91ab	4.73a	3.50a	6.37b	6.44a	5.95c
100	4.21a	4.69ab	5.10a	4.88a	3.65a	7.19a	7.07a	6.84a
150	4.27a	4.97a	4.83ab	4.60a	3.92a	6.84ab	6.83a	6.66ab
200	4.19a	4.90ab	4.47bc	4.03b	4.02a	6.66ab	6.77a	6.08bc
Mean	4.12C	4.73A	4.66A	4.36B	3.74B	6.31A	6.24A	5.93A
ANOVA (p values)								
Nitrogen (N)	0.0000				0.0000			
Potassium (K)	0.0127				0.0000			
N × K	0.0038				0.0000			

Values followed by the same letter are not significantly different at the 5% level of probability

Effect of different micro and beneficial nutrients on growth and yield of rice. The study was undertaken with the objective to determine the effect of micronutrients and beneficial nutrients on growth and yield of rice. A pot experiment was set up in the glass house of Soil Science Division, BRRI, Gazipur. The study was laid out in a completely randomized block design with three replications and five treatments: T_1= NPKSZn, T_2= T_1 + CuNiSeSi, T_3= T_1 + CuNiSi, T_4= T_1 + CuSi and T_5= T_1 + Si. All treatments received a blanket dose of chemical fertilizer i.e. N-P-K-S-Zn @ 120-15-60-

10-1.5 kg ha^{-1}. The Cu, Ni, Se and Si were applied as a foliar spray with the rate of 1%, 0.2%, 10 ppm and 0.2%, respectively. In T. Aman season, the growth and yield of BRRI dhan87 significantly differed with the applied treatments. The highest plant height (96.11 cm) was recorded in T_2 treatment but there is no significant variation with T_5, for number of panicles per hill (22), panicle length (22.47 cm), number of filled grains per panicle (131), grain (76.34 g pot^{-1}) and straw yield (56.99 g pot^{-1}). From the treatment combination it appeared that the increased growth and yield of BRRI dhan87 was attributed to the application of Si.

Nutrient management for growing four crops in a year. The experiment has been initiated in T. Aus 2016 to grow four crops in a year to sustain soil fertility and increase productivity. Three fertilizer treatments viz soil test based (STB) fertilizer (T_1), crop residues (CR) + STB fertilizer (T_2) and fertilizer control i.e. native soil nutrients (T_3) were tested with Mustard-Boro-T. Aus-T. Aman (CP-1) and Mustard-Mungbean-T. Aus-T. Aman (CP-2) patterns. The experimental design was randomized complete block with three replicates. The first crop Mungbean was incorporated in T_2 treatment. After two crop cycles, T_1 and T_2 treatments produced statistically identical grain yield in each crop. In the 3rd year and 3rd crop cycle, both the cropping patterns were also giving their potential yield with AEZ based chemical fertilizer application (T_1) as well as with crop residue incorporation (T_2). After 4^{th}, 5^{th} and 6^{th} crop cycles, it is revealed that AEZ based or soil test based (STB) chemical fertilizers seemed sufficient to obtain potential yield of each crop under both the patterns except for Mungbean 2021-22 (6^{th} crop cycle) in CP-2 (Table 3). In all the cases, incorporation of crop residue had some positive impact on yield, soil organic C and total N (on average soil OC and total N content increased by 0.1% and 0.01%, respectively; data not shown) chemical fertilizer only (Table 3). Considering rice equivalent yield (REY), CP-1 (Mustard-Boro-T. Aus-T. Aman) performed better than CP-2 (Mustard-Mungbean-T. Aus-T. Aman) (Table 3), but postharvest soil nutrients levels will provide detail insights on soil nutrients buildup or mining/depletion.

Table 3. Grain yield and rice equivalent yield (REY) (t ha^{-1}) of CP-1 and CP-2 at BRRI HQ, Gazipur during 2021-22 (6^{th} crop cycle).

Treatment	T. Aus 2021		T. Aman 2021		Mustard 2021-22		Boro 2021-22	Mungbean 2021-22	REY**	
	CP-1	CP-2	CP-1	CP-2	CP-1	CP-2	CP-1	CP-2	CP-1	CP-2
T_1: STB fertilizer dose	3.41a*	3.57a	3.25a	3.29a	0.34a	0.50a	5.02a	0.44	12.6	9.8
T_2: Crop residues (CR) + T_1	3.38a	3.29a	3.54a	3.59a	0.44a	0.66a	5.85a	0.44	14.0	10.3
T_3: Native nutrient	1.43b	2.55b	1.49b	2.18b	0.01b	0.15b	2.53b	0.35	5.5	6.4

*Different lower-case letters within the column denote significant differences of grain yields between the treatments according to ANOVA and DMRT- Post-Hoc Test. **To calculate REY it was assumed that prices of mustard, mungbean and rice are 50, 65 and 18 Tk. kg^{-1}, respectively.

IDENTIFICATION AND MANAGEMENT OF NUTRITION DISORDER

Long-term use of organic and inorganic nutrients in Boro-Fallow-T. Aman rice: A long-term experiment was initiated on a permanent layout at BRRI HQ farm, Gazipur in 1985 Boro season having 12 treatments assigned in RCB design with four replications. The objective of the study was to find out the impact of long-term nutrient management on grain yield and soil health. The treatments were revised according to needs (see BRRI, 2016 and BRRI, 2020). The recent STB doses of NPKSZn were 160-12-80-5-2 kg ha^{-1} and 100-10-80-5-2 kg ha^{-1} for Boro and T. Aman rice, respectively. The tested rice varieties were BRRI dhan87 in T. Aman and BRRI dhan89 in Boro season.

Grain yield of T. Aman and Boro. In the T. Aman and Boro seasons, omission of N, P, K and S decreased grain yield significantly compared to the complete fertilizer treatment **(**Table 4**).** In T. Aman 2021, among the applied organic materials, poultry manure (PM) @ 2 t ha^{-1} as integrated plant nutrient system (IPNS) produced the highest grain yield (5.38 t ha^{-1}) which was statistically similar to complete chemical fertilizer (5.25 t ha^{-1}). Cowdung (CD) @ 3 t ha^{-1}as IPNS (5.0 t ha^{-1}) and vermicompost (VC) @ 2 t ha^{-1}as IPNS (4.85 t ha^{-1}) treated plots produced lower grain yield compared to PM with IPNS treated plots. The omission of N, P and K produced significantly lower grain yield than the complete fertilizer and IPNS treated plots but the omission of S and Zn produced almost similar yield with organic treated plots except PM. In Boro 2021-22, the highest grain yield (7.07 t ha^{-1}) was obtained from PM added IPNS, which was statistically identical with complete fertilizer (6.92 t ha^{-1}) and CD added IPNS (6.70 t ha^{-1}) but VC added IPNS (6.41 t ha^{-1}) produced significantly lower grain yield. In both the seasons, sulfur (4.81 and 6.40 t ha^{-1}) and zinc (4.68 and 6.29 t ha^{-1}) omitted plot produced significantly lower grain yield compared to full dose of chemical fertilizer plot. Moreover, significant yield difference was found among reduced K doses (60 and 40 kg K ha^{-1}) and complete K fertilizer treatment (K 80 kg ha^{-1}) in both the seasons. In case of annual yield, organic with IPNS based chemical fertilizer treatment shows an increasing yield trend compared to complete chemical fertilizer treatment **(**Fig. 1**).**

Table 4. Effect of organic and inorganic amendments on rice grain yield (t ha^{-1}) of BRRI dhan87 and BRRI dhan89 at BRRI HQ, Gazipur, in 2020-21.

Treatment	Grain yield (t ha^{-1})	
	T. Aman 2021	Boro 2021-22
T_1 = NPKSZn@150/100-12/10-80-5-2 kgha^{-1}	5.25 ab	6.92 ab
T_2 = NPSZn (-K)	3.59 ef	3.75 e
T_3 = NKSZn (-P)	2.51 g	1.87 g
T_4 = PKSZn (-N)	3.85 e	2.67 f
T_5 = CD (3 t ha^{-1}) + IPNS	5.00 bc	6.70 abc
T_6 = NPKS (-Zn)	4.68 cd	6.29 cd
T_7 = NPKZn (-S)	4.81 cd	6.40 bcd
T_8 = PM (2 t ha^{-1}) + IPNS	5.38 a	7.07 a
T_9 = NPKSZn @150/100-12/10-60-5-2 kgha^{-1}	4.55 cd	6.22 cd
T_{10} = VC (2 t ha^{-1}) + IPNS	4.85 c	6.41 bcd
T_{11} = NPKSZn@150/100-12/10-40-5-2 kgha^{-1}	4.47 d	6.01 d
T_{12} = Control (native nutrients)	3.37 f	1.85 g
CV (%)	*3.37*	*4.05*

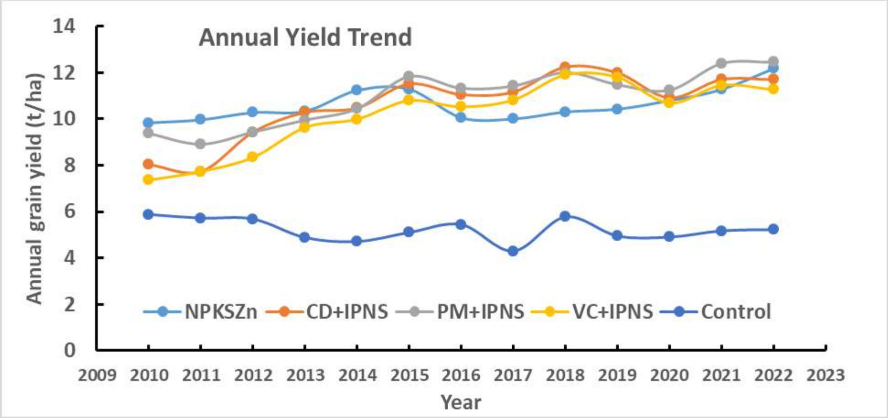


Fig. 1. Annual yield trend of IPNS based treatment compared with complete chemical fertilizer and control treatment, 2021-22, BRRI, Gazipur.

Post-harvest soil pH, %OC and %N.

The post-harvest soil pH, organic carbon and total nitrogen were greatly influenced by long-term (more than ten years) applications of organic and inorganic amendments in both the measures (0-15 cm and 15-30 cm) of depth **(**Table 5**)**. The pH in the upper layer (0-15 cm) slightly acidic than the lower layer (15-30 cm). Slightly increased soil pH was observed in organic amendment plots which was the highest in poultry manure (6.98) treated plot. Soil pH decreased in omission of P, K, S, and Zn in upper layer (0-15 cm depth). Long-term use of balanced and organic fertilizer increased soil organic carbon (SOC) significantly. The highest SOC was found in CD treated plot followed by PM and VC which were significantly higher than complete chemical fertilizer treatment. The omission of other nutrients like P, K, S and Zn showed lower SOC than balanced fertilizer treatment. Like organic carbon, similar trend was observed for total nitrogen in the post-harvest soil.

Table 5. Effect of long-term organic and inorganic amendments on soil pH, organic carbon and total nitrogen in the post-harvest soil of 0-15 cm depth, BRRI, Gazipur, 2021-22.

Treatment	Soil pH		Organic carbon (%)		Total nitrogen (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 = NPKSZn (complete)	6.72	7.62	2.21	1.37	0.191	0.118
T_2 = NPSZn (-K)	6.64	7.68	1.58	1.11	0.136	0.096
T_3 = NKSZn (-P)	6.66	7.90	1.47	1.09	0.127	0.094
T_4 = PKSZn (-N)	6.65	7.75	1.56	1.08	0.135	0.093
T_5 = CD (3 tha^{-1}) + IPNS	6.74	7.80	3.37	1.60	0.290	0.138
T_6 = NPKS (-Zn)	6.68	7.92	2.01	1.33	0.173	0.115
T_7 = NPKZn (-S)	6.65	7.77	1.87	1.32	0.162	0.113
T_8 = PM (2 tha^{-1}) + IPNS	6.98	7.94	2.80	1.64	0.241	0.141
T_{10} = VC (2 tha^{-1}) + IPNS	6.84	7.85	2.27	1.47	0.195	0.126
T_{12}= Fert. control	6.94	7.93	1.20	1.01	0.103	0.086
$LSD_{0.05}$	*0.17*	*0.21*	*0.38*	*0.25*	*0.032*	*0.022*
CV (%)	*0.88*	*0.90*	*6.43*	*6.66*	*6.42*	*6.74*

Effect of intensive rice cropping on rice yield under continuous wetland conditions. The experiment was designed to harvest three rice crops per year with the evaluation of the consequences of intensive rice cropping under continuous wetland conditions and to monitor soil fertility changes over time. This experiment was initiated in 1971 in a permanent layout with NPK fertilizer application. Since Boro 2000, the experiment was modified to accommodate six treatments viz control (native nutrient), reverse control (NPKSZnCu), NPK, NPKS, NPKSZn and NPKSZnCu after several revision in 1982, 1984 and 1991. In Boro 2020-21, the experiment was revised again with the N and K fertilizers from 140 to 160 and 80 to 100 kg ha^{-1}, respectively. The varieties tested in T. Aus, T. Aman and Boro seasons were BRRI dhan48, BRRI dhan87 and BRRI dhan84, respectively. The NPK doses used were 160-25-100, 60-15-80 and 60-10-60 kg ha^{-1} for Boro, T. Aman and T. Aus, respectively. Sulfur, Zn and Cu were applied at 10, 4 and 1 kg ha^{-1} in Boro season only.

Grain yield and yield trend. The annual rice production trend from 1981 to 2021 was decreasing because of continuous rice cultivation with no fertilizer application treatment. However, from 2001 the reverse control treatment produced grain yield almost similar to complete fertilized treatment (Fig. 2). In 2021, annual rice production in the control plot was only 4.94 t ha^{-1} while its reversed management (addition of NPKSZnCu fertilizer) resulted in 13.35 t $ha^{-1}yr^{-1}$ grain production, which was close to complete fertilizer treatment (14.14 t ha^{-1} yr^{-1}). It indicates that complete fertilization can recuperate soil productivity even after a long period of rice cultivation. Results indicated that additional use of Zn and Cu once in a year with NPKS increased annual grain yield by more than 1.0 t ha^{-1} over the application of NPKS alone (Table 6). A similar increasing trend was observed in complete fertilizer (NPKSZnCu) treatment of grain yield in Boro season, 2020-21.

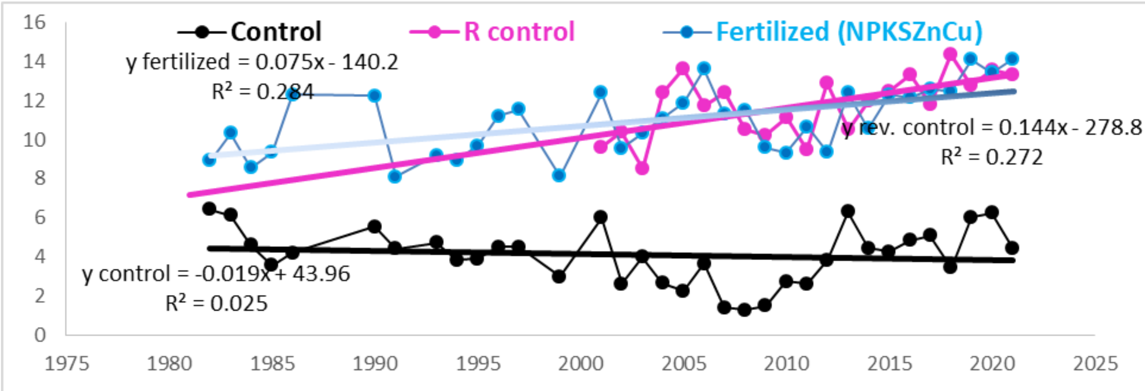


Fig. 2. Annual rice production trend under intensive wetland conditions in BRRI HQ, Gazipur during 1981-2021.

Regional yield maximization trial (RYMT) under recommended management practices. The experiment was conducted at the experimental farm of BRRI, Gazipur in T. Aman 2021 to validate integrated improved management practices (IIMP) compared with BRRI recommended practices (Control) and to maximize proper filling of grains in a panicle under integrated management practices. Five selected genotypes (BRH13-2-4-7-2B, BRH10-1-14-2-7B, BRH11-2-4-7B, Jirasail and BRRI dhan87) were evaluated under integrated improved management practices compared to BRRI recommended practices with split plot design having three replications. Integrated improved management practices were: healthy seedling raising using 60g seeds per square meter seed bed; urea fertilizer application using four splits – basal, 25-30 DAT, 55-60 DAT (before PI) and 75-80 DAT (beginning of heading); harvesting at 90% maturity. BRRI recommended practices were: traditional seedling raising using 100g seeds per square meter seed bed; urea fertilizer application using 3 splits- 10 DAT, 30-35 DAT, 55-60 DAT; harvesting at 80% maturity. Results of T. Aman 2021 showed that BRRI dhan87 (5.4 t/ha) and BRH11-2-4-7B (5.2 t/ha) produced the highest grain yield with sterility 23.3% and 22.1%, respectively. No significant difference between management practices were observed, although IIMP performed better in T. Aman 2021.

INTEGRATED NUTRIENT MANAGEMENT

Integrated nutrient management for double and triple rice cropping. The experiment was initiated in Boro 2008-09 at BRRI HQ, farm Gazipur in a clay loam soil to find the suitable fertilizer management for double and triple rice cropping system and to find out the impact of triple rice cropping on soil health. In Boro-Fallow-T. Aman pattern, BRRI dhan58 and BRRI dhan87 were used. In Boro-T. Aus-T. Aman pattern, BRRI dhan84, BRRI dhan48 and BRRI dhan87 were included as test variety. Fertilizer treatments used were: control, STB dose (NPKS @ 160-25-60-20 kg ha^{-1} for Boro, 70-12-48-10 kg ha^{-1} for T. Aus and 84-21-32-06 kg ha^{-1} for T. Aman), STB (50%) + Mixed manure (MM) (CD @ 2 t ha^{-1} + ash @ 1 t ha^{-1} oven dried), farmers' practice (FP) (NPKS @ 80-10-20-10 kg ha^{-1} for Boro, 70-10-15-0 kg ha^{-1} for T. Aus and 70-10-15-0 kg ha^{-1} for T. Aman). The experiment was laid out in RCB design with three replications.

Grain yield. Figure 3 presents the annual grain yield of double rice cropping pattern from 2008 to 2021. A similar increasing trend of grain yield of 100% STB fertilization and 50% STB with mixed manure were observed from the beginning to till date. But control and farmers practices (FP) showed decreasing trend with the increment of time. Almost similar yield trend was observed in triple rice cropping pattern except FP (Fig. 4). Cumulative yield of triple cropping was always higher than double rice cropping pattern irrespective of treatments. Table 6 shows soil chemical properties changes after certain period of time. Percentage of soil organic carbon, available P and S were increased in 100% STB and 50% STB with mixed manure application plot. Increasing trend was more in 50% STB with mixed manure application plot.

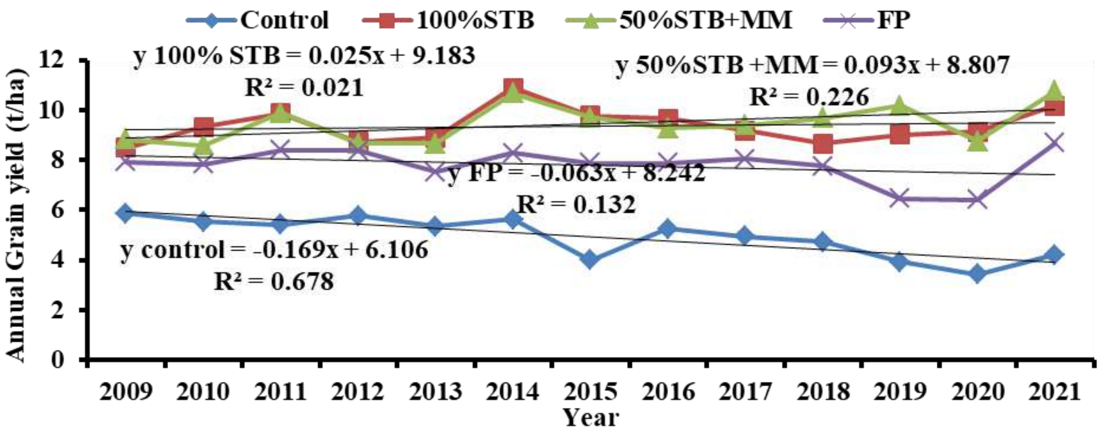


Fig. 3. Annual rice production trend under integrated nutrient management for double rice cropping for maximizing productivity during 2009-2021 in BRRI, Gazipur.

Table 6. Scenario of changes in soil chemical properties after a certain period of time.

Soil parameter	Initial status Boro 2008-09	After Boro 2015-16		After Boro 2020-21	
		STB (100%)	STB (50%) +MM	STB (100%)	STB (50%) +MM
Soil pH (1:2.5)	6.1	7.0	7.1	7.1	7.1
Organic C (%)	1.10	1.11	1.20	1.14	1.25
Total N (%)	0.11	0.11	0.12	0.12	0.12
Available P (ppm)	5.9	5.9	7.4	6.3	9.2
Available K (meq/100g soil)	0.16	0.18	0.18	0.15	0.16
Available S (ppm)	15.3	20.1	17.0	22.5	18.4

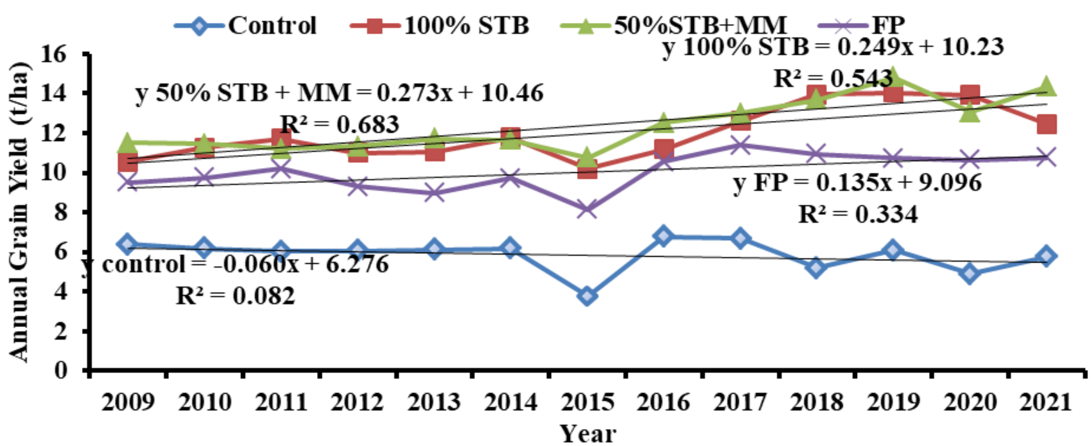


Fig. 4. Annual rice production trend under integrated nutrient management for triple rice cropping for maximizing productivity during 2009-2021 in BRRI, Gazipur.

Increase of rice yield through vermicompost (VC) amendments in coastal land. The experiments were initiated at three farmer's fields each of Dumuria, Khulna and Amtali, Borguna, Bangladesh in T. Aman (wet) season in 2021 to find out the effect of VC on grain yield improvement. Treatments were @ 0, 1, 2 t ha^{-1} (oven dry basis) VC with full dose of chemical fertilizer (FRG, 2018). Grain yield was significantly increasing due to vermicompost added at the rate of 1 and 2 t ha^{-1} in Dumuria, Khulna in T. Aman 2021 but insignificant in Boro 2021-22. In Amtali, Borguna site vermicompost added at the rate of 1 and 2 t/ha with a full dose of chemical fertilizer significantly increased grain yield both in T. Aman 2021 and Boro 2021-22 seasons (Table 7).

Table 7. Yield performance of BRRI rice varieties under vermicompost amendments with recommended chemical fertilizer in coastal land, 2021-22.

Grain yield (t/ha)				
Treatment	Dumuria, Khulna		Amtali, Burguna	
	T. Aman 2021 (BRRI dhan87)	Boro 2021-22 (BRRI dhan28)	T. Aman 2021 (BRRI han87)	Boro 2021-22 (BRRI dhan67)
Vermicompost @ 0 t/ha	6.44b	6.21	6.12b	5.41a
Vermicompost @ 1 t/ha	6.92a	6.57	6.65a	6.41b
Vermicompost @ 2 t/ha	7.14a	6.9	6.60a	6.63b
CV(%)	5.96	7.06	6.60	4.54

Increase rice yield through the organic and inorganic amendment. The experiment was initiated at the experimental field of BRRI, Gazipur in T. Aman 2019 to investigate the effect of vermicompost and silicon on rice grain yield and soil health. Before the initiation of the experiment, soil samples were collected and analyzed. The soil was silty clay loam in texture having pH 7.1, organic carbon 13 g kg^{-1}, total nitrogen 1.2 g kg^{-1}, Olsen available phosphorus 10.1 mg kg^{-1}, exchangeable potassium 44 mg kg^{-1} and available sulfur 31 mg kg^{-1}. The experiment was laid out in a split- plot design with three replications, where main plots comprised of four levels of vermicompost (0, 2.5, 5, 10 t ha^{-1}) and sub-plots had four silicon rates (0, 100, 200, 400 kg ha^{-1}). The variety was BRRI dhan87 in T. Aman and BRRI dhan89 in Boro season. Results of Boro 2020-21 showed that grain yield of BRRI dhan89 with different vermicompost rates did not increased significantly. There was no significant variation on rice yield between two rates (2.5 and 5.0 t/ha) of vermicompost. Among silicon rates, 400 kg ha^{-1} performed better, however, it was statistically similar with all the silicon rates. The highest grain yield (7.42 t ha^{-1}) of BRRI dhan89 was obtained with 10 t ha^{-1} vermicompost and 200 kg ha^{-1} silicon rate. In T. Aman 2021, the highest grain yield (4.57 t ha^{-1}) of BRRI dhan87 was obtained with 10 t ha^{-1} vermicompost application and grain yield was statistically similar with 2.5 and 5 t ha^{-1} vermicompost rates. Silicon application showed insignificant effect on grain yield.

Soil management to maximize the yield of newly released rice varieties. The experiment was initiated in T. Aman 2021 at BRRI RS farms, Cumilla and Sonagazi to find the best soil management to maximize rice yield with organic and inorganic amendment and to maintain soil health. Before the initiation of the experiment, soil samples were collected, analyzed for calculating soil test based fertilizer recommendation in each site. Treatments were T_1= soil test based fertilizer application, T_2= soil test based fertilizer plus 20% more nitrogen T_3= soil test based fertilizer plus 20% more potassium and T_4= soil test based fertilizer with available organic matter (2 t/ha). Vermicompost and cowdung were available in Cumilla and Sonagazi respectively. Soil test based nutrient recommendation in Cumilla and Sonagazi were 96:12:52:10 and 88:15:54:6 kg/ha for T. Aman season 173:18:61:12:1.5 and 178:24:82:10:1.7 kg/ha for Boro season respectively. Annual grain yield was highest in Sonagazi farm irrespective of treatments (Fig. 5). Soil test based fertilizer management was enough for both the locations, although organic matter was required in Cumilla farm along with STB dose.

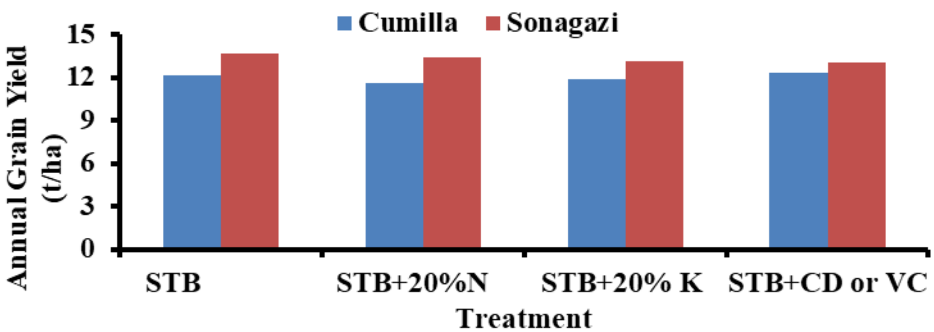


Fig. 5. Annual grain yield under different soil management practices for double rice cropping for maximizing productivity of newly released BRRI rice varieties in BRRI RS farms.

Nutrient management under conservation agriculture (CA) in double rice cropping system. This experiment was initiated at Paba, Rajshahi, in Boro 2018-19 seasons with the objectives to determine the nutrient requirement of rice in Boro-Fallow-T. Aman cropping pattern, and to improve soil health under conservation agriculture practices. Two crop establishment methods (unpuddled and puddled) in the main plot, two residue management practices (straw retained and straw removed) in the sub plot and four fertilizer doses as recommended fertilizer (RD) 100%, 125% of RD, 75% of RD, and 50% of RD were assigned in split-split plot design with three replications.

Grain yield. In Boro 2020-21 and T. Aman 2021, grain yields were insignificant among puddled and unpuddled cultivation, but rice straw incorporation significantly increased the rice yield (Table 8). FRG recommendation (100%) fertilizer application was enough for the grain yield of rice irrespective of residue management and crop establishment method in both the seasons.

Table 8. Effect of crop establishment methods (EM), rice straw incorporation (RS) and fertilizer rates (FR) on grain yield (t ha^{-1}) of Boro and T. Aman rice, Paba, Rajshahi, 2021.

Grain yield (t ha^{-1}								
EM	Boro 2020-21	T. Aman 2021	Rice straw	Boro 2020-21	T. Aman 2021	Fertilizer FRG	Boro 2020-21	T. Aman 2021
Unpuddled	4.28a	4.54a	Yes	4.31a	4.64a	125%	5.14a	4.76b
Puddled	4.22a	4.66a	No	4.18b	4.57b	100%	5.17a	5.50a
						75%	4.38b	4.45c
						50%	2.30c	3.70d

SOIL AND ENVIRONMENTAL PROBLEMS

Management interventions to improve NUE and reduce N losses. The field experiment was conducted during T. Aman (July to November 2021) and Boro (January to May 2022) rice seasons at BRRI farm, Gazipur to quantify the fate of N fertiliser (crop, soil and losses) and N fertilizer use efficiency (NUE) under various N management options. The selected rice cultivars were BRRI dhan87 for T. Aman and BRRI dhan89 for Boro season. In both the seasons, overall 28 (7 treatments × 4 replication), 20 m^2 plots were established. The experiment was laid out in a RCB design. The blocks are separated from each other by 1 m irrigation channel and each plot is separated from each other by 40 cm earth bund to prevent exchange of water and fertilizer across the plots. In T. Aman season, the tested seven treatments were: T_1: no N fertilizer (N0), T_2: 110 kg N ha^{-1} from prilled urea (N110PU), T_3: T_2+25% N (N138PU), T_4: T_2-25% N (N83PU), T_5: Cow dung (CD) (2 t ha^{-1}) + IPNS with T_2 (N110 PU+CD), T_6: Bioorganic fertilizer (2 t ha^{-1}) + IPNS with T_4 (N87 PU+ Bioorganic fert.) and T_7: Deep placed urea alike T_4 (N83 UDP). During Boro season, the tested seven treatments were: T_1: no N fertilizer (N0), T_2: 140 kg N ha^{-1} from prilled urea (N140PU), T_3:

T_2+25% N (N175PU), T_4: T_2-25% N (N105PU), T_5: Cow dung (CD) (2 t ha^{-1}) + IPNS with T_2 (N140 PU+CD), T_6: Bioorganic fertilizer (2 t ha^{-1}) + IPNS with T_4 (N105 PU+ Bioorganic fert.) and T_7: Deep placed urea (UDP) alike T_4 (N105 UDP). The blanket rates of P-K-S-Zn were 20-60-10-1 kg ha^{-1}, respectively in T. Aman and 25-80-10-1 kg ha^{-1}, respectively in Boro season. The whole amount of P, K, S and Zn fertilizers were broadcasted and mixed with soil on the day of transplanting in all seven treatments with a subtracted amount of P and K from CD and Bioorganic fertilizer in T_5 and T_6, respectively. The sources of P, K, S and Zn were triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate monohydrate, respectively. Partially decomposed CD in T_5 and Bioorganic fertilizer in T_6 at the rate of 4 kg $plot^{-1}$ (oven dry basis) (both equals the dose of 2 t ha^{-1}) were applied on 3 (in T. Aman) and 7 (in Boro) days before final land preparation and transplanting. In T_2, T_3, T_4, T_5 and T_6, N fertilizer was applied as urea into three equal splits on 9, 23 and 37DAT (days after transplanting) in T. Aman, and on 15, 35 and 54 DAT in Boro season, respectively. In case of T_7, the full amount of UDP was applied at once on 9 DAT in T. Aman and on 15 DAT in Boro season. In both the seasons, gas samples were collected covering 25 to 26 sampling events to analyze CH_4 and N_2O emission. Locally fabricated lysimeter was installed to analyze NH_4^+-N and NO_3^--N in the collected leachates. Measurement of NH_3 emission (volatilization) was performed by using closed chamber technique and Boric Acid Trap method. At maturity, grain, straw and root yields were recorded. The N concentration in all these samples were analyzed to assess plant N uptake.

Grain yield and N use efficiencies. The grain yield was significantly ($p<0.01$) greater in all N fertilizer applied treatments than no N applied treatment (N0) in dry season (Table 9). In both the seasons, the grain yield was statistically identical between the N fertilizer applied treatments (Table 9). However, in wet season, the grain yield was only significantly ($p<0.05$) greater in N110PU, N138PU, N110 (PU+CD) and N87 (PU+Bio fert.) than no N applied treatment (N0) (Table 9). In T. Aman season, the greater agronomic (AE_N) and recovery (RE_N) N use efficiencies were obtained from the N applied at 83 kg N ha^{-1} from deep placed urea (N83UDP) **(**Fig. 6a**)**. While in Boro season, the greater agronomic (AE_N) and recovery (RE_N) N use efficiencies were obtained from the N applied at 105 kg N ha^{-1} from deep placed urea (N105UDP) followed by prilled urea plus bioorganic fertilizer (N105 PU+ Biofert.) (Fig. 6b).

Table 9. Grain yield (mean ± SE, n=4) impacted by different N management options in T. Aman and Boro rice season 2021-22.

Treatment	N0	N110PU	N138PU	N83PU	N110 (PU+CD)	N87 (PU+Bio fert.)	N83UDP
T. Aman 2021	4.43b*	4.99a	5.04a	4.72ab	5.17a	5.01a	4.98ab
Treatment	N0	N140PU	N175PU	N105PU	N140(PU+CD)	N105(PU+Biofert)	N105 UDP
Boro 2021-22	2.30b*	6.01a	5.92a	5.47a	6.08a	5.65a	5.78a

*Different lower- case letters within the row denotes significant differences ($p<0.01$ in T. Aman; $p<0.05$ in Boro) between the treatments according to ANOVA and Duncan's Multiple Range Post-Hoc Test.

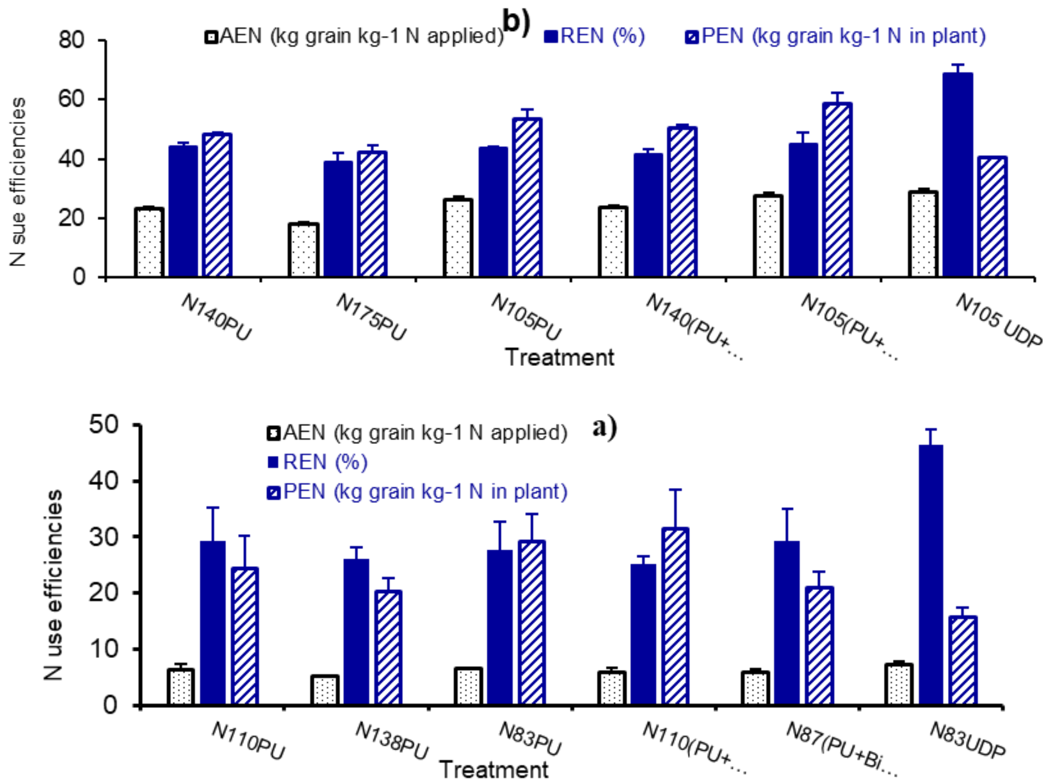


Fig. 6. Agronomic (AE_N), recovery (RE_N) and physiological (PE_N) N use efficiencies (mean ± SE, n=4) impacted by different N management options in T. Aman (a) and Boro (b) rice, 2021-22.

Time course of NH_3 emission fluxes after urea application in T. Aman season. Overall NH_3 emission was only detected from day 1 to day 5 in all N fertilizer applied plots after each split application of urea and no NH_3 emission was observed in the treatment with no N fertilizer application (N0) **(**Fig. 7**)**. The NH_3 emission peaks were usually observed on day 1 to 3 after all three split applications of urea **(**Fig. 7a and 7b**)**. The peak NH_3 emissions were greater in the treatment with higher rate of N application i.e. in the N138PU (T_3) after 1st and 2nd splits, while this was the case for N110PU after 3rd split **(**Fig. 7a**)**. In case of N83UDP, notable NH_3-N emission rates were only recorded on day 2 (4.2 mg $m^{-2}d^{-1}$) and day 3 (5.8 mg $m^{-2}d^{-1}$) after application of the whole amount of UDP at once during 1st split **(**Fig. 7b**)**. Among the N fertilizer applied treatments, the NH_3-N emission rate was lower in N83UDP followed by N110 (CD+ PU) and N87 (PU+Bio fert.) **(**Fig. 7a and 7b**)**.

This one -year experimental results revealed that considering yield, N use efficiencies and NH_3-N loss, N applied at the rate of 105 kg ha^{-1} from deep placed urea and PU + Bio-organic fertilizer in Boro season and N applied at 83 kg ha^{-1} from deep placed urea in T. Aman season could be the most suitable N management interventions to sustain rice production, reduce environmental harm from reactive N (Nr) and sustain soil health.

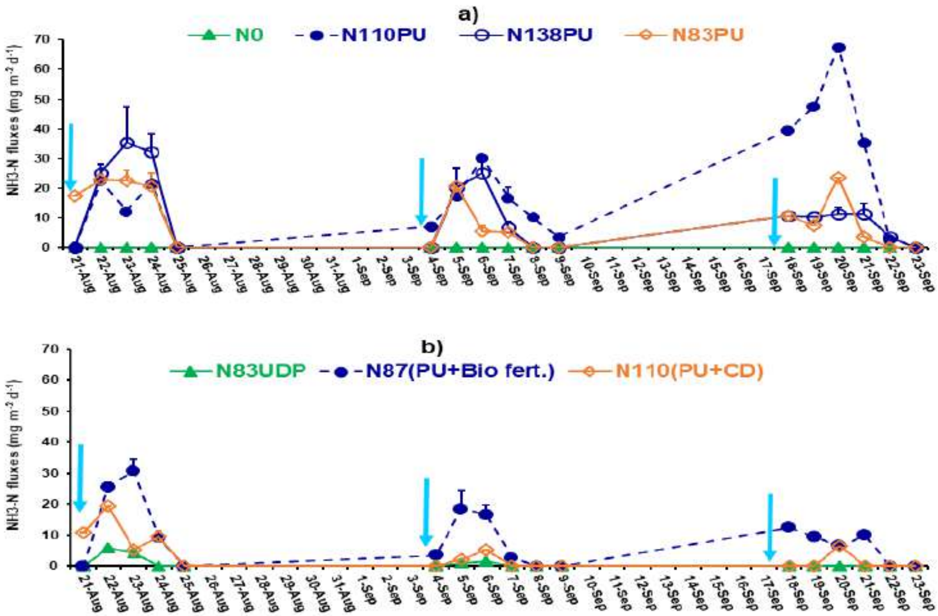


Fig. 7. Daily NH_3 emission fluxes (mean ± SE; n =2 or 3) (a, b) at different N managements in wet season rice, 2021; arrow shows the day of split application of prilled urea or deep placed urea.

Effect of biochar on rice yield in the charland. The study was conducted at BRRI RS, Sirajganj with the objective to determine the effect of biochar on rice growth and yield and soil health in problem soils. The experiment was initiated in Boro 2019-20 and consisted of four treatments: T_1= Control, T_2= recommended fertilizer (RF), T_3= RF + biochar @ 2 t ha^{-1} and T_4= RF + biochar @ 4 t ha^{-1}. The treatments were arranged in RCB design with three replications. The biochar was produced from *chita dhan* (unfilled grain). The recommended dose of N-P-K-S was 100-15-40-10 kg ha^{-1} in T. Aman and 138-21-75-18 kg ha^{-1} in Boro season. Biochar was applied only in Boro season and incorporated with soil before seven days of transplanting. In T. Aman season, 30 % fertilizer was reduced from the recommended dose in the biochar treated plots to observe the residual effect of biochar on rice yield. In T. Aman season, reduction of 30% fertilizer from the recommended dose in the biochar treated plots produced grain yields similar to full dose of recommended fertilizer (6.52 t ha^{-1}) which might be due to the residual effect of biochar. In Boro 2021-22 season, application of biochar @ 4 t/ha with recommended fertilizer resulted in the highest yield (7.30 t ha^{-1}) of BRRI dhan89 than the other treatments.

Effect of variety and fertilizer management on yield and greenhouse gas emissions from rice fields in the south-western coastal ecosystems. The field experiments were conducted in BRRI RS farm, Satkhira. Two rice varieties were tested including BRRI dhan67 (salt tolerant and shorter growth duration; ca. 140 days) and BRRI dhan92 (longer duration; growth duration ca. 160 days). Five fertilizer treatments were tested: (i) N control, broadcast prilled urea (PU) at 78 kg N ha^{-1}, (ii) urea deep placement at 78 kg N ha^{-1}, (iii) BRRI recommended dose at 120 kg N ha^{-1}, and (iv) integrated nutrient management at 78 kg N ha^{-1} with cow dung 2 t/ha and ash 1 t/ha. The experiment was laid out in a split-plot design, distributing the variety to the main plots and treatments to the sub-plots with three replications. Nutrients viz P, K, S and Zn were used as basal at the recommended rate to all plots as per National Fertilizer Recommendation Guide (FRG-2018) and the rates were 20 kg P/ha, 80 kg K/ha, 18 kg S/ha and 1 kg Zn/ha, respectively. Soil amendments (cow dung and ash) were applied three days prior of transplanting. Urea briquettes (UB) were placed at a depth of 10 cm at the center of four rice hills 10 days after transplanting (DAT). PU was applied in three equal splits except for the N control plot. The crop was harvested at full maturity of the crops. Grain yield was adjusted at 14% moisture and expressed in t ha^{-1}. The sundry weight of straw was also recorded plot-wise and expressed as t ha^{-1}. Notable, GHG data were not included in this report due to a lack of calculation and analysis.

Grain and straw yield. Application of N fertilizer significantly increased rice yield compared to the other treatments (Table 10). Integrated nutrient management (INM-N78 kg/ha) with two ton CD and one ton ash produced the highest grain yield of 5.87 t/ha in BRRI dhan67 and 5.15 t /ha in BRRI dha92 and it was statistically similar with UDP-N78 and PU-N120 treatment. Broadcast PU-N78 significantly reduced grain yield compared to other treatments. Similarly, BRRI recommended dose and INM treatment produced higher straw yield compared to broadcast PU. We could not get any additional advantage using a higher dose of N fertilizer (120 kg N ha^{-1}) as broadcast compared to UDP. However, BRRI dhan67 showed similar grain and straw yield with BRRI dhan92 in the Boro season (Table 10).

Table 10. Effects of variety and fertilizer management on grain and straw yield at BRRI farm, Satkhira during Boro season.

Treatment	Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
	BRRI dhan67	BRRI dhan92	Mean of 2 varieties	
N control	2.73c	3.00c	3.39c	
Prilled urea-N78	4.87b	4.18b	5.02b	
Urea deep placement-N78	5.52a	4.79a	5.65ab	
BRRI recommended dose N120	5.49a	4.99a	5.90a	
INM-N78 with 2 ton cow dung and 1 ton ash/ha	5.87a	5.15a	5.98a	
	BRRI dhan67	BRRI dhan92	BRRI dhan67	BRRI dhan92
Treatment mean	4.90A	4.42A	5.15A	5.22A

SOIL MICROBIOLOGICAL STUDIES

Field evaluation of BRRI bio-organic fertilizer. BRRI bio-organic fertilizer was developed with the objectives to reduce synthetic N and P fertilizer use in rice cultivation and improve soil health. To evaluate its field performance, one field experiment was conducted at BRRI HQ in both the season of T. Aman 2021, and Boro 2021-22. Bio-organic fertilizer (BoF) was used at 2 t ha^{-1}. The treatment combinations were NPKS (100%), BoF + 70% (N) +100% (KS), BoF +100% NPKS and fertilizer control. Recommendation rates of chemical fertilizers for T. Aman and Boro were (kg ha^{-1}) N-P-K-S @ 67-10-41-10 and 140-20-80-10, respectively. BRRI dhan87 at T. Aman and BRRI dhan89 was grown in the Boro season.

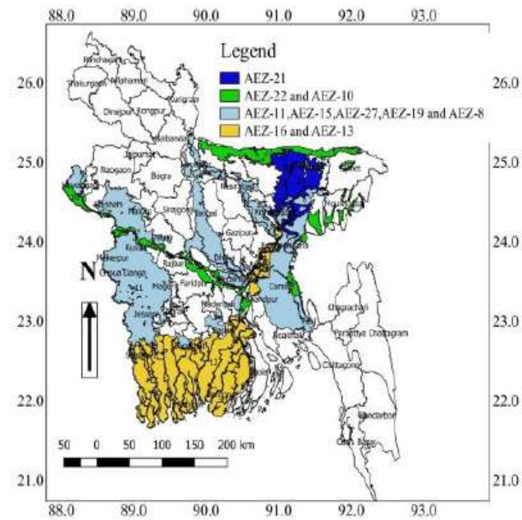
Grain yield. Study result proved bio-organic fertilizer (BoF_1@ 2t ha^{-1}) has potential to supplement 30% N and 100% P requirement for HYV rice without sacrificing yield. In the T. Aman, application of BoF with 70% (N) +100% (KS) produced the highest grain yield of 5.47 t ha^{-1}. Statistically similar grain yield was obtained in 100% NPKS (4.75 t ha^{-1}) and BoF +100% NPKS (4.85) treatment. However, in the Boro season, the highest grain yield was recorded (7.40 t ha^{-1}) in the BoF with 70% (N) +100% (KS) treatment and it was statistical by similar with BoF with 100% NPKS application. Significantly the lowest grain yield was found at the control treatment.

Microbial characterization of different AEZs soil. Soil biology dictates soil health. Studies were conducted with the aim to determine the soil microbial populations from eight AEZ's of Bangladesh and to characterize the potential free-living N_2 fixing, phosphate solubilizing, and indoleacetic acid producing bacteria and finally prepared a climate smart biofertilizer using the potential bacteria for higher rice productivity. Soil samples (0-15 cm depth) were collected using GPS recording from AEZ-10 (Faridpur), AEZ-11

(Jashore- Rajshahi), AEZ-13 (Satkhira), AEZ-15 (Munshiganj), AEZ-16 (Brahmanbaria-Munshiganj), AEZ-19 (Cumilla- Kishoreganj), AEZ-22 (Moulavibazar- Habiganj) and AEZ-27 (Rangpur- Bogura) and tested for microbial properties, texture, soil pH and organic matter.

Soil bio-physico-chemical properties of different AEZs. Microbial populations were enumerated on the selective media following 'total plate count' method. Study report showed that the range of total bacteria populations were significantly high in the Decreerchar union of AEZ-10 (2 x 10^6 to 2 x 10^9 cfu/g soil), Panisara union of AEZ-11 (2 x 10^7 to 2 x 10^9 cfu/g soil), and Deorghachi union of AEZ-22 (7 x 10^6 to 1 x 10^9 cfu/g soil) (Map). The lowest total bacteria range was found in AEZ-13. Total fungus population range was comparatively lower in the AEZ-10, AEZ-13, AEZ-15, AEZ-16 and AEZ-27. On average, Actinomycetes populations were low in all the tested AEZ's. The populations of free-living N_2 fixing bacteria were higher than the Rhizobium populations. However, populations of phosphate solubilizing bacteria were higher than free-living N_2 fixing bacteria. Aside soil microbial properties, soil physico-chemical properties such as soil texture, pH, total nitrogen and organic matter content were determined following standard protocol. Among the tested eight AEZs, the highest organic matter (3.90%) and total N (0.21%) was recorded in the Chadnighat union of Moulovibazar Sadar upazila in AEZ-22. In conclusion, among tested eight AEZs, the populations of beneficial bacteria (free-living N_2 fixing, Rhozobium and phosphate solubilizing bacteria), soil organic matter and total N were lower than any healthy agricultural soil. Application of organic matter and biofertilizer is crucial to replenish soil health and sustainable crop production.

Biomolecular characteristics of the isolated strains. The dominant potential bacteria from each AEZ were identified and tested for biomolecular characteristics. Among the strains, the highest N_2 fixation (28 ppm) NH_4) was recorded by *Bacillus thuringiensis* (B49) isolated from AEZ-27 and *Pseudomonas geniculata* (B61) isolated from AEZ-15. The highest 3,746 ppm P was solubilized by the *Stentrophomonas maltophilia* (B53), isolated from Shahjahnpur upazila of AEZ-27. The highest amount of indoleacetic acid (144 ppm) was produced by the *Bacillus sp.* (B59) isolated from Shyamshiddhi union of Sreenagar upazila (AEZ-15).



Map showing that highest population found in AEZ-21(10^9 cfu/g soil), AEZ-10 and AEZ-22 (10^8 cfu/g soil), AEZ-11, AEZ-15, AEZ-27, AEZ-19 and AEZ-8 (10^7 cfu/g soil) and AEZ-16 and AEZ-13 (10^6 cfu/g soil)

Formulation of biofertilizer for acid and saline soil. Isolated 15 potential strains were coated with TSP and urea fertilizer and named as 'Bio-coated urea' and 'Bio-coated TSP' biofertilizer, respectively. Nutrient mineralization form Bio-coated fertilizer and survival of the bacteria during the incubation study were in satisfactory level (Figs. 8a and b). In the glasshouse, pot experiments were conducted for testing the efficacy of the developed biofertilizer in the soil plant system. Study results showed that about 36% grain yield increased in BRRI dhan28 and saved 50% TSP fertilizer by the application of 'Bio-coated TSP' in acid soil compared to TSP fertilizer only (Table 11). Application of PGPR-coated urea improved grain yield 10.53% of BRRI dhan99 over chemical fertilizer in the saline soil (Table 12).

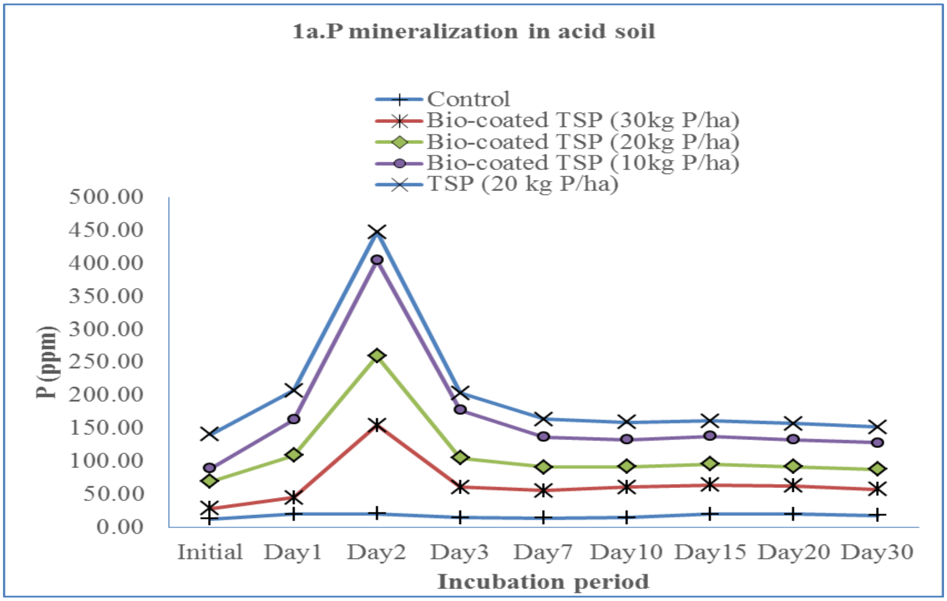


Fig. 8 a. Effect of Bio-coated TSP and TSP fertilizer on available P mineralization in Acid soil.

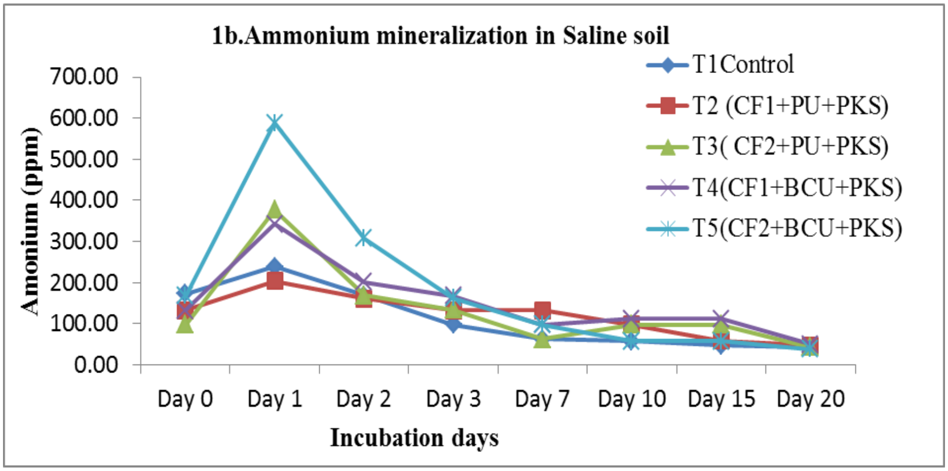


Fig. 8.b. Effect of Bio-coated urea and urea fertilizer on N mineralization in saline soil.

Here, CF1: NPKS (kg/ha) @ 120-20-50-10, and CF2: NPKS (kg/ha) @ 120-20-120-10, PU: Prilled urea and BCU: bio-coated urea.

Table 11. Effect of Bio-coated TSP and TSP fertilizer on growth and yield of BRRI dhan28 and PSB population after harvest.

Treatment	Plant height (cm)	Tiller /hill	Straw weight (g)	Panicle /hill	Yield/ plant (g)	PSB population (cfu/g soil)
Control	67.5 b	6.7	4.9b	5.0c	4.3c	$3x10^3$
Bio-coated-TSP (@30 kgP/ha)	68.3 b	7.2	6.7a	7.2a	7.0ab	$2x10^6$
Bio-coated-TSP (@20 kgP/ha)	73.0 ab	5.8	6.8a	5.8bc	7.0ab	$4x10^6$
Bio-coated-TSP (@10 kg P/ha)	69.0 ab	6.7	7.0a	6.7ab	7.6a	$5x10^6$
TSP (@20 kg P/ha)	75.2 b	5.0	5.3b	5.0 c	5.6bc	$3x10^4$
CV (%)	10.8	32.9	14.9	15.4	21.0	8

PSB; Phosphate solubilizing bacteria. In the colum, means followed by the letter were significant at the 5% level of significance.

Table 12. Effect of Bio-coated urea on growth and yield of BRRI dhan99.

Treatment	Plant height (cm)	Tiller /hill	Straw weight (g)	Yield/ plant (g)
Control	85.7 b	6 b	18.8 b	13.7 d
NPKS (kg/ha) @ 120-20-50-10, N as prilled urea	88.5 ab	10 a	26.8 ab	15.2 bc
NPKS (kg/ha) @ 120-20-120-10, N as prilled urea	92.7 a	11 a	29.6 a	15.0 c
NPKS (kg/ha) @ 120-20-50-10, N as Bio-coated urea	90.7 ab	11 a	31.7 a	16.6 a
NPKS (kg/ha) @ 120-20-120-10, N as Bio-coated urea	92.8 a	10 a	31.2 a	16.25 ab
CV (%)	25	11.8	27	5.97

In the column, means followed by the letter were significant at the 5% level of significance

Irrigation and Water Management

SUMMARY

During 2021-22, Irrigation and Water Management Division reported sixteen programmes of basic and applied research as well as two major programmes of technology validation and adaptation in different agroecological zones with a target to generate and extend water efficient technologies in rice water management for increasing land and water productivity which would lead to sustainable food security and improved livelihood. A soil physical property analysis indicated that at BRRI RS Kushtia farm, the average saturated water content was 31.4, average water content at field capacity was 25.6 and average water content at wilting point was 12.5 within the soil profile of 0-60 cm depth. At BRRI RS Sirajganj farm, the average saturated water contents varied between 31.4-28.4 average water contents at field capacity varied between 24-18.9 and average water contents at wilting point were 7.3-4.8 within the soil profile of 0-60 cm depth. At BRRI RS Rangpur farm, the average saturated water contents varied between 26.3-22.4 average water contents at field capacity varied between 19.8-17.8 and average water contents at wilting point were 3.4-2.8 within the soil profile of 0-60 cm depth. During Boro season, none of the ALART had stress tolerance capacity. ALART BR9930-2-3-3-1 produced higher yield (31.77 g/hill) with continuous standing water treatment. Performance evaluation of the proposed rice varieties under different water regimes during boro season showed that good yield could be achieved from BR11716-4R-105 and BRRI dhan92 under AWD practice. About 30% yield was increased by compaction over control followed by clay mixing during T. Aman and higher grain yield (7.54 t/ha) obtained from cowdung added at top soil layer followed by vermicompost added treatment during Boro season for improving soil-water availability for crop production in charland by amendment practices. Irrigation scheduling by CROPWAT model was found effective to save irrigation water in both Boro and T. Aman seasons. Irrigation water requirement and rainfall utilization for delayed transplanting during boro season showed that water productivity was higher with early transplanting on 15 and 31 January than delayed transplanting on 14 February and 1 March. In rainfed environment, considerable amount of yield increased (10.8-12.7%) due to drought mitigation by drought simulation model at reproductive and ripening stages compared to rainfed of T. Aman season in Kushtia. Overall water saved by following supplemental irrigation based on drought forecasting was 30.5 % compared to AWD system in the validation experiment in Kushtia. So, this model can give early warning to the farmers when to irrigate or not. This information will be helpful for farmers to save money and also to save them from probable yield loss during drought.The study revealed that the latest salt-tolerant rice variety like BRRI dhan97 and BRRI dhan67 can be grown with saline water irrigation up to 4 dS m^{-1} for getting higher yield potential during the dry season in the saline coastal zone. All the tested groundwater and surface water samples from different locations in the reporting year were safe to use in irrigation according to recommended quality indicator ranges. However, groundwater level depletion was about 42.94 m in last 24 years at BRRI HQ Gazipur farm, showing an alarming average declining rate of 1.65 m per year.There are suitable sources of surface water those can be used for irrigating crops by operating solar pumps in the Chattogram region. For the sustainable management of water resources, conjunctive use of municipal wastewater with fresh water would be a good irrigation option in Boro season. Based on the research findings in Dacope and Amtali upazilas, farmers expressed their willingness to continue the cultivation of BRRI dhan87 in medium high land and BRRI dhan76 in the medium-low to low land areas due to higher yield, short duration, and unique characters to cope with the environments. These varieties improve the land productivity, net income, and benefit cost ratio (BCR) and also facilitated the cropping intensification in the coastal areas. In haor region, AWD method successfully saved irrigation water which helped to mitigate water demand in the reproductive stage during Boro season. The study results indicated that huge yield loss occurred in the haor area due to water stress in the reproductive phase of Boro rice. Check valve installation in

Shallow Tubewell (STW) removed pump starting drudgery, and improved distribution system saved 18-20% irrigation water. Irrigation time was reduced by 20 percent due to use of polythene pipe compared to the earthen canal. Due to use of polythene pipe the irrigation time per unit area was reduced significantly. Fresh water resources development is one of the crucial issues for sustainable crop and soil salinity management in coastal areas. Surface fresh water was trapped in local canals within December for irrigation in dry season crops. Groundwater salinity was beyond the permissible limit of irrigation. Dacope area is more saline than that of Amtali areas. Therefore, special care needs to be adopted for dry season crop production. Groundwater abstraction is an important source of GHG emissions in Bangladesh. So, it is the time to harness the co-benefits of water and energy savings by adopting alternate wetting and drying practice for rice cultivation, by expansion of surface water irrigation facilities along with by selecting water use-efficient crop varieties having high yield potentials.

WATER USE EFFICIENCY IMPROVEMENT IN IRRIGATED AGRICULTURE

Determination of physical and hydraulic properties in different soil types

The study was conducted in BRRI RS, Kushtia, BRRI RS, Rangpur and BRRI RS, Sirajganj. Soil samples were collected from different soil profiles at 0-15, 15-30, 30-45, 45-60 cm using standard protocols from BRRI RS, Kushtia, BRRI RS, Rangpur and BRRI RS, Sirajganj. Soil textural classes were mostly clay, loam to silty loam, mostly loam for BRRI RS, Kushtia farm, BRRI RS, Sirajganj farm and BRRI RS, Rangpur farm, respectively. The average bulk density was from 1.30 to1.46 gm/cc. At BRRI RS, Kushtia farm, the average saturated water content was 31.4, average water content at field capacity was 25.6, and average water content at wilting point was 12.5 within the soil profile of 0-60 cm depth. At BRRI RS, Sirajganj farm, the average saturated water contents varied between 31.4-28.4, average water contents at field capacity varied between 24-18.9, and average water contents at wilting point were 7.3-4.8 within the soil profile of 0-60 cm depth. At BRRI RS, Rangpur farm, the average saturated water contents varied between 26.3-22.4, average water contents at field capacity varied between 19.8-17.8, and average water contents at wilting point were 3.4-2.8 within the soil profile of 0-60 cm depth. RETC programme was used to fit soil water release curve with measured water contents and metric potential data (Fig. 1). For fitting purpose, estimated soil parameters of clay soil was taken for BRRI RS, Kushtia soil, silt loam soil was taken for BRRI RS, Sirajganj soil, loam soil was taken for BRRI RS, Rangpur soil.

Problem and potentials for crop productivity improvement through water management in hilly areas

In 2020-21, the study was conducted in Sadar upazila of Khagrachari district. A field visit and detailed survey was conducted in that region. In the visited locations, the water resources were physically assessed, and several discussions were conducted with farmers, local stakeholders, inhabitants, local government bodies, NGO workers and obviously root level agricultural extension workers and researchers working in that area. The Sadar upazila of Khagrachari district has fourteen agricultural extension blocks. The cultivable available land in that upazila is 6,420 ha. The major corps of that area are mango, banana, malta, and rice. In the reporting year, Aus, Aman, and Boro rice was grown in 750 ha, 3,535 ha, and 1,505 ha, respectively. The total irrigated rice area in that upazila is only three percent. Sadar upazila has one river, 15 lakes, nine big canals, 12 creeks or fountains (Jiri or Chora) which are used as irrigation water sources. The small hill creeks or fountains are locally known as “Jiri” or, “Chora”. Usually, the water was conserved in the canal by constructing cross dams and applied to the agricultural field through gravity channel. The irrigated area covered by rivers, canals, and creeks are 1,279 ha, 55 ha, and 60 ha, respectively. During the study, it was also reported that irrigation water was crucial for seasonal fruit gardens established at the slope of the hills. If irrigation pumps along with pressurized irrigation distribution system could be installed, the prospect of fruit gardening in that region will be very bright. As irrigation energy source is also scarce or limited in that region, solar pump would be a solution to irrigate the crop lands. There is another constraint for agriculture and that was a proper distribution system of irrigation water. Due to bumpy land topography, it is not very easy to construct a good distribution system. If a pipe distribution network could be built in each command area of a water source, it might increase the potential utilization of water sources in agriculture. In Sadar upazila, 2,59 low lift pumps (LLP) are running to irrigate lands though they do not have any shallow tube-well or deep tube-well. The details about block-wise irrigation water sources, present irrigated area, and possible area extension of cultivable lands if irrigation pumps and distribution system is provided, (Table 1). The study in the respected area reveled that another 855 ha fallow area could be brought under cultivation with the help of irrigation facility in Sadar upazila. The possible options are: constructing rubber dams, installation of solar pump, modern water distribution systems along with high yielding crop varieties. This area is also a potential spot to spread agro-forestry technologies with the backup of irrigation equipment and power sources.

Study on water-stress tolerance for different advanced rice genotypes of BRRI

There were two ALART entries named BR9930-2-3-2-2 and BR9930-2-3-3-1 along with checks BRRI dhan50, BRRI dhan63 and BRRI dhan81under PQR supplied from Plant Breeding Division, BRRI during Boro season 2021-22 (Table 2). None of the ALART entries had stress tolerance capacity. ALART entry BR9930-2-3-2-2 produced higher yield (25.52 g/hill) with continuous standing water treatment. Yield was decreased by 12.1, 34.7 and 53.2% than that of continuous standing water with the water stress of -10, -30 and -60 kPa, respectively. Similarly, ALART entry BR9930-2-3-3-1 producrd higher yield (31.77 g/hill) with continuous standing water treatment. Yield was decreased by 10.1, 36.2 and 58.7% than that of continuous standing water with the water stress of -10, -30 and -60 kPa, respectively.

Performance evaluation of the proposed rice varieties under different water regimes

The study was conducted to find out suitable water regimes for rice varieties and proposed lines. The experiment was conducted during Boro season 2020-21 in a brick wall tank at BRRI HQ farm, Gazipur. Four long duration high yielding advanced lines of rice as- BR11715-4R-186, BR11723-4R-27, BR11723-4R-12 and BR11716-4R-105 were tested under four water management treatments as: T_1 = Maintaining continuous standing water (CSW) from 1 to 5 cm; T_2 = AWD irrigation practice (+5 to -15 cm); T_3 = Aerobic condition (AWD: 0–25 cm) up to booting stage; and T_4 = Aerobic condition (AWD: 0–25 cm) during the entire crop period. BRRI dhan92 was the check variety. Table 3 shows the amount of irrigation applied, rainfall occurred and total water use during the growth duration along with grain yield. The total number of irrigations in T_1, T_2, T_3, and T_4 are 14, 11, 20 and 19 respectively. The total amount of irrigations in T_1, T_2, T_3, and T_4 are 810 mm, 705 mm, 650 mm and 620 mm, respectively. The irrigation water saving under treatments T_2, T_3, and T_4 were 13, 20 and 23 per cent, respectively compared to treatment T_1. The amount of rainfall was 270 mm for BR11715-4R-186, BR11723-4R-27, BR11723-4R-12 and 151 mm for BR11716-4R-105 and BRRI dhan92 in all the treatments. Total rainfall recorded in January, February, March and April of 2022 were 3.6, 35.6, 17.6 mm and 58.4 mm, respectively. Only 20.6 mm rainfall was recorded during 5 February to 18 April 2022. It means that most of the vegetative phase and reproductive phase was about rainless. Sufficient rainfall was obtained after 18 April, so no irrigation was applied at the ripening phase. The experimental results show that good yield could be achieved from BR11715-4R-186, BR11723-4R-27, BR11723-4R-12 under CSW. The experimental results also show that good yield could be achieved from BR11716-4R-105 and BRRI dhan92 under AWD practice.

Improving soil-water availability for crop production in charland by amendment practices

The study has been carried out in BRRI RS farm, Sirajganj, during Aman 2021 and Boro 2021-22 to improve soil physical properties, soil water retention capacity of the root zone depth and to identify a suitable soil amendment practice to increase water use efficiency and the crop productivity of the charland. The study consists of five amendment practices as: T_1 = Compaction with clay soil at the layer of 20-30 cm, T_2 = Vermicompost added at the topsoil (0-10 cm) @ 5 t/ha, T_3 = topsoil (0-10 cm) mixed with 50% of clay soil, T_4 = Biochar added at the topsoil (0-10 cm) @5 t/ha, T_5 = Cow dung added at the topsoil (0-10 cm) @ 5 t/ha and T_6 = Control treatments in randomized complete block design with three replications. BRRI dhan100 was grown during T. Aman 2021. Among the grain yield and yield components, plant height and grain yield were statistically significant by different amendment practices (Table 4). Plant height were higher (135.85 cm) in compaction followed by cowdung added at top layer of soil (0-10 cm). Lower plant height (114.25 cm) were observed in clay mixing. Number of panicle per hill, number of grain per panicle and sterility percentages were not statistically different by amendment practices. Higher grain yield (5.73 t/ha) was found in compaction followed by clay mixing at top layer. Grain yield was increased over control by each amendment practices. About 30% yield was increased by compaction over control followed by clay mixing. BRRI dhan89 was grown during Boro 2021-22. Among the grain yield and yield components number of grain per panicle, grain yield and harvest index are statistically significant different by amendment practices (Table 5). Plant height, number of panicle per sq m area, sterility percentages and straw yield were not statistically significant different by amendment practices. However, plant height (112 cm) were higher in biocher added at the top layer of soil (0-10 cm) followed by vermicompost added at the top layer of soil. Higher panicle number per sqm area obtained from vermicompost added followed by control. Higher number of grain per panicle (184) obtained from compaction of lower soil layer (20-30cm) with clay soil followed by biocher added at the top layer of soil. Higher grain yield (7.54 t/ha) was obtained from cowdung added at the top soil layer followed by vermicompost added treatment. Harvest index was higher in vermicompost added amendment practices.

Determining minimum irrigation water requirement of rice at different regions of Bangladesh through water balance from on-farm demand and model simulation

The experiment was conducted for two seasons (T. Aman and Boro) in 2021-22 at the research field of BRRI RS, Rangpur. BRRI dhan87 and BRRI dhan58 were transplanted in T. Aman 2021 and Boro 2021-22 seasons, respectively. In Rangpur, during T. Aman season, drought occurred at the later part of the season as rain ceased. The control treatment (i.e., continuous standing water in the field) received the highest amount while CROPWAT treatments required comparatively less irrigation. Both AWD and CROPWAT treatment saved irrigation compared to continuous standing water treatment. Yields the similar in AWD and CROPWAT treatments and yield of control treatment was different than other two treatments (Table 6). During Boro 2021-22 season, the total growth span of BRRI dhan58 was 150 days, however, 105 days after transplanting (vegetative, reproductive, and ripening stage) was taken into consideration in this study. The actual water requirement was calculated using the total measured evapotranspiration (ET) during this time (105 days). Predicted water requirement was simulated by CROPWAT model. Presumably, treatment T1 received the highest amount of irrigation water in response to total irrigation requirement (Table 1), because the field was kept almost saturated all the time during the experiment. The AWD treatment (T2) received comparatively lower irrigation than continuous standing water treatment. Generally, received amounts of irrigation in T2 and T3 were closer. In Rangpur, AWD treatment had the highest yield among the treatments, but irrigation application and yields of AWD and CROPWAT treatments did not have any major difference in Rangpur. Irrigation scheduling by CROPWAT model might be a potential approach to save irrigation water, but still needed in depth evaluation in terms of irrigation demand, irrigation received and yields.

Optimization of Water Use Efficiency Through Subirrigation and Mini-sprinkler Irrigation System in Fine (light) Textured Soils of Bangladesh

Subirrigation is a water table management method (reverse process of subsurface drainage). This is the artificial addition of water to the soil profile to moisten the crop root zone. In this system, water applied through perforated drain-pipe from beneath the soil surface. Water is allowed to stand for lateral and upward movement by capillarity. Subirrigation system regulates the shallow ground water table, makes the upper layer of soil remained dry while lower layer soil moisture content remained unchanged. The advantages of subirrigation system are: (a) optimum water supply to manage crop water requirement, (b) reduce evaporation, seepage, and percolation losses, (c) increase irrigation water-use efficiency, and (d) can be used for soil having low water holding capacity and high infiltration rate. However, the system has some limitations like: (a) high initial cost and expensive to setup, (b) chance of occurring saline and alkali condition, (c) chance of N-nutrient loss through drain water, (d) soil should have high hydraulic conductivity. The design and installation of subsurface irrigation system covered a piece of land in IWM research plot at BRRI farm in Boro 2021-22. The length of the installed system area was 10 m and the width of the system was 6 m. Total area of the installed subirrigation system was 60 sq. m. For design purpose, the soil physical and hydraulic properties of the selected fields were considered. Then, the lateral (drain) spacing and lateral and main (drain) size were determined using available equation and models (Hooghoudt equation, DRAIN CALCULATOR, etc.). The design spacing was found 1.2 m and design depth was found 30 cm from ground surface. For both lateral and main pipe size, 4 in diameter PVC pipe was selected for the subirrigation system. For subsurface irrigation, an overhead tank (1000 L) was installed to supply adequate irrigation water to crop root zone of the field. A flowmeter (4 in diameter) was set up at the inlet of the system to measure the amount of water supplied to the field. Basically, in the first season of the subirrigation system installation, the system was observed carefully so that the system could run successfully. Any major constraint was not marked during the whole season except some technical faults of the system. The troubleshooting was done immediately when found at the field. Figure 2 shown the detailed design of the installed subirrigation system. A high yield rice variety, BRRI dhan89 was grown in the research field. The average yield was found 6.13 t/ha.

Irrigation water requirement and rainfall utilization for delayed transplanting of Boro rice in different locations of Bangladesh

The experiment was conducted at BRRI HQ farm, Gazipur in 2021-22 season to find out the variation of irrigation water requirement in relation to the delayed transplanting. BRRI dhan81 was tested with four transplanting dates (T1 = 15 January, T2 = 31 January, T3 = 1 February, T4 = 1 March). The plot was arranged with randomized complete block design (RCBD) and four replications. Forty-day-old seedlings were transplanted in conventional puddled plots with 20 x 20 cm spacing. The fertilizers urea, TSP, MOP, gypsum and zinc sulphate rate were 300, 100,160,112 and 10 kg/ha, respectively. Irrigation water was applied according to AWD practice. Throughout the growing season, total water requirement and irrigation water varied with transplanting date. Plant water requirement was higher in January transplanting than February and March transplanting (Table 7). Transplanting on 14 February (T3) and 1 March (T4) had 63 and 129 mm lower water requirement than transplanting on 15 January (T1). Similarly, applied irrigation water was around 15 and 19% lower in transplanting on 14 February (T3) and 1 March (T4) compared to transplanting on 15 January (T1). Although, irrigation water requirement decreased with delayed transplanting, the utilization of rainfall was increased. Transplanting on 14 February (T3) and 1 March (T4) received about 71 and 119 mm more rainfall relative to transplanting on 15 January (T1). Among the treatments, there was little variation of total water used due to the variation of rainfall. Growth duration was varied with transplanting dates (Table 8). Growth duration reduced by 12 and 21 days for transplanting on 14 February (T3) and 1 March (T4) than transplanting on 15 January. Transplanting on 15 and 31 January gave the highest yield about 6.6 and 6.3 t/ha, respectively. The delayed transplanting on 14 February and 1 March had around 20 and 40% lower yield than transplanting on 15 January. Water productivity was also higher with early transplanting on 15 and 31 January than delayed transplanting on 14 February and 1 March.

UTILIZATION OF WATER RESOURCES IN RAINFED ENVIRONMENT

Validation of agricultural drought forecasting for mitigating drought in T. Aman rice at Kushtia region

The experiment has been conducted at BRRI regional station Kushtia in T. Aman 2021 to validate the excel based drought simulation model (DSM). BRRI dhan87 was used as test variety. Forecasted rainfall, evapotranspiration and existing soil moisture were used as input of DSM model. Seven days daily minimum and maximum temperature, average relative humidity (%), wind speed was collected from BRRI agromet lab. Three treatments, rainfed (I_0), supplemental irrigation based on drought forecasting (I_1) and supplemental irrigation based on AWD system (I_2) were used to mitigate drought. Sufficient amount of rainfall occurred during T. Aman 2021 in BRRI rs farm, Kushtia. But early part of ripening stage received low rainfall when BRRI dhan87 transplanted on 15 August. Average agricultural drought measured in rainfed plot (I_0) was 10.5 mm under reproductive stage on 29 October and 25.6, 19.4 and 26.4 mm on 5th, 12th and 19 November of the growth duration under ripening stage (Table 9). In this week sufficient rainfall did not meet the evaporative demand of the BRRI dhan87 and encountered a drought stress when crop was transplanted on 15 August. But during the 30 August transplanting, two consecutive droughts 4.4 mm and 15.6 mm were observed at 31 October and 7 November of the growth duration, respectively at reproductive stage. Due to delayed transplanting, the crop faced a higher amount of drought at the reproductive stage compared to early transplanting in rainfed treatment. Early transplanting crop was able to escape a prolong drought. Quantification of average agricultural drought forecasting by drought simulation model (DSM) as well as soil water demand according to I_1 treatment plot was 5.9 mm in the reproductive stage at 29 October and 21.6, 18.9, 25.9 mm at 5, 12 and 19 November of the growing period, respectively in the ripening stage. So, four supplemental irrigations were applied when BRRI dhan87 transplanted on 15 August. On the other hand, observed average agricultural drought based on AWD system according to I_2 treatment plot was 18.7, 13.8 and 21.4 mm on the same date of the growing period of I_1 treatment in the ripening stage only. So, 4 and 3 supplemental irrigations were applied under I_1 and I_2 treatments, respectively when BRRI dhan87 was transplanted on 15 August. During 30 August transplanting of BRRI dhan87, quantification of drought forecasting according to I_1 treatment plot was 13.1 mm on 7th November in the reproductive stage and four consecutive droughts 19.8, 20.8, 25.1 and 18.6 mm at 14, 21, 28 November and 5 December in the ripening stage of the growing period, respectively (Table 9). Furthermore, observed average drought based on AWD system according to I_2 treatment plot was 16.8, 17.3, 21.3 and 16.0 mm on the same date of the I_1 treatment in the ripening stage. So, 5 and 4 supplemental irrigations were applied during the 30 August transplanting in the I_1 and I_2 plots, respectively. DSM model forecasted drought at reproductive and ripening stages of T. Aman rice satisfactory in Kushtia region. The model underestimated drought with overall prediction error was 20.23% compared to observed drought. Overall water saved by following supplemental irrigation based on drought forecasting was 30.5 % compared to AWD system. Considerable amount of yield increased (10.8-12.7%) due to drought mitigation (I_1 and I_2) at reproductive and ripening stages compared to rainfed (I_0) during T. Aman season (Table 10). Overall water saved by following supplemental irrigation based on drought forecasting was 30.5 % compared to AWD system. So, this model can provide early warning to the farmers when to irrigate or not. This information will be helpful for farmers to save money and also to save them from probable yield loss during drought.

Irrigation scheduling of rice (oryza sativa l.) based on weather forecasting in Gazipur

Better use of weather forecasting data is a vital strategy to save irrigation water for paddy rice. Medium range weather forecasting data following the water balance simulation model can save unnecessary irrigation applications to the field. In this study, reference evapotranspiration and rainfall events mainly focused on the input data of the water balance simulation model to estimate irrigation water for paddy rice cultivation. Based on that, 7-days medium-range weather forecasting can improve decision-making plan for applying irrigation. The results indicate that, WRF model signifies quite accurate forecasting of the mentioned weather parameters based on NRMSE and relBias. Comparing to the conventional and AWD irrigation, the newly proposed irrigation scheduling method can further save irrigation water about 22.0 and 10.5% compared to conventional and AWD irrigation system, respectively without significant yield loss. The results also showed that, weather forecasting based irrigation scheduling can increase water productivity than conventional and AWD irrigation. Nevertheless, the newly proposed irrigation scheduling method incorporated with weather forecast is suggested to apply in irrigation practice for its simplicity and effectiveness.

LAND PRODUTIVITY IMPROVEMENT IN THE COSTAL ENVIRONMENT

Saline water irrigation strategies for Boro rice cultivation in the coastal saline area

A field experiment was conducted at Dacope upazila in Khulna district of Bangladesh to understand the soil salinity dynamics and to assess the effect of saline water irrigation on plant growth and yield of Boro rice in 2021-22 growing season. The treatments were irrigating two salt-tolerant rice varieties (BRRI dhan67 and BRRI dhan97) with saline water having five salinity levels (water salinity < 1 dS m^{-1}, 4 dS m^{-1}, 6 dS m^{-1}, 8 dS m^{-1} and 10 dS m^{-1}). Strip plot design was followed with three replications. The plot size was 5 m x 4 m.rty-two-day-old seedlings were transplanted on 17 January 2022 with 20 x 20 cm spacing. Fertilizer and other cultural activities were followed according to BRRI guidelines. Freshwater was used from pond and the different levels of saline water were prepared using canal saline (varied from 2-4 dS/m) water and table salt in a 1000 litre capacity tank. The prepared water was applied in each plot through a plastic pipe. Figure 3 presented the dynamics of soil salinity with saline water irrigation. In all irrigation treatments, soil salinity was below 4 dS/m upto 28 February. Soil salinity increased gradually in all irrigation treatments with progress of the growing season. At the harvesting time, soil salinity was 6.7, 8.7, 11.2, 12.8 and 14.4 dS/m for irrigation water salinity less than 1 dS/m, 4 dS/m, 6 dS/m, 8 dS/m and 10 dS/m. Irrigation water salinity affected rice yield and yield components (Table 11). There was significant difference of rice yield with irrigation treatments but no difference with varieties. Rice yield was satisfactory (6.0 and 6.3 t/ha) in saline water irrigation <1 dS/m and 4 dS/m. Whereas, rice yield significantly reduced with increasing salinity level of irrigation water. The grain yield reductions were 9.7, 29.8, 44.3, and 58.5 % for BRRI dhan67 and 5.4, 17.3, 28.6, and 46.0% for BRRI dhan97 for saline water irrigation of 4 dS m^{-1}, 6 dS m^{-1}, 8 dS m^{-1} and 10 dS m^{-1}, respectively, compared to saline water irrigation less than 1 dS m^{-1} (recommended salinity level of irrigation water). BRRI dhan97 had a lower yield reduction than BRRI dhan67, indicating that BRRI dhan97 was more salt tolerant than BRRI dhan67. Increasing salinity level of irrigation water also increased unfilled grain and reduced plant height. The study revealed that the latest salt-tolerant rice variety like BRRI dhan97 and BRRI dhan67 can be grown with saline water irrigation up to 4 dS m^{-1} for getting higher yield potential during the dry season in the saline coastal zone.

SUSTAINABLE MANAGEMENT OF WATER RESOURCES

Monitoring of groundwater fluctuation and safe utilization in different geo-hydrological regions

In this study, available water level recorder was used for measuring groundwater fluctuation in BRRI HQ Gazipur and all the regional stations. Data were recorded weekly. Collected weekly records were calculated to obtain monthly average. In Gazipur, during 2021-22 period, maximum lowering of groundwater (-48.17 m) was observed in June and minimum (-46.55 m)) in August (Fig. 4). The fluctuation was more than 1.6 m. The fluctuation was higher than the previous year. In 1998, the minimum groundwater level was about 5.23 m below the ground surface which was 48.17 m in 2022 (Fig. 5). Therefore, the lowering was about 42.94 m in 24 years. During the initial five years (1998-2002) the lowering (3.8 m) was not so high, but during the last five years (2018-2022) the lowering was about 6.23 m. Figure 6 presented monthly groundwater levels of BRRI regional stations. Among 10 regional stations, the groundwater level was below the suction limit (> 8 m) during Boro season in Cumilla, Rajshahi and Habiganj.

Conjunctive use of wastewater and freshwater for irrigation in Boro rice cultivation

For determining the suitability of different wastewater treatments, a pot experiment was conducted with five irrigation treatments namely T1= Irrigation with freshwater(control), T2= Irrigation with municipal wastewater (MWW), T3= Irrigation with industrial wastewater (IWW), T4= Irrigation with fresh water and industrial wastewater (50% FW and 50% IWW) and T5= Irrigation with fresh water and municipal wastewater (50% FW and 50% MWW). Thirty-eight-day-old seedling of BRRI dhan89 was transplanted with RCBD and three replications. In total 16 irrigations were applied in every pot throughout the growth stages. Yield and yield contributing parameters were recorded. Irrigation with freshwater(control) produced the highest yield (76.61g/pot) followed by irrigation with fresh water and municipal wastewater (50% FW and 50% MWW) (71.01g/pot). So, along with freshwater, municipal wastewater with freshwater is a good option for irrigation practices in boro season.

Assessment of surface and groundwater quality for irrigation in selected locations of Bangladesh

The experiment was conducted in six regional stations namely Gazipur, Rajshahi, Rangpur, Barishal, Habiganj of BRRI in 2021-22. The water samples were collected from different source of ground water and surface water. The quality of water for location was assessed for its irrigational purposes. In the present study all the samples had KR less than 1.0 except Barishal. So, Kelly's ratio showed full satisfaction in using for irrigation. Soluble sodium percentage values were found in satisfactory level. Magnesium absorption ratio was found satisfactory (desired range <50) for irrigation.

Assessing On-farm Water-use Efficiency of BRRI Research Farm, Gazipur

For computing water use efficiency of BRRI west byde farm, one pump was chosen for this study and the command area was also quantified. After transplanting, operating time of pump and discharge rate was monitored and calculated. Seepage and percolation and the evapotranspiration was also measured. Required and supplied amount of water was found 68,202.6 m3 and 102,189.96 m3 respectively. The WUE was rated 66.74 %. So, 34% of applied water was not used by crop and being wasted by different ways.

RENEWABLE ENERGY

Feasibility Assessment of Solar Pump Utilization for Irrigation Purpose in Chattogram Region

In 2021-22, the study was conducted in Dagon Bhuiyan of Feni district and Fotikchhori and Mirershorai of Chattogram district. Field visit and detailed survey was conducted in that region. In the visited locations, the water resources were physically assessed and several discussions were conducted with farmers, local stakeholders, inhabitants, local government bodies, NGO workers and root level agricultural extension workers as well as researchers working in that area. Field data were also collected from solar pump suppliers, service providers and users. Solar pumps are in operation in different locations of Chattogram region. Therefore, field-level data were collected from the relevant traders, service providers and users associated with the selected pumps. Secondary data were gathered from books, journal articles, research reports, internet, etc. We have visited three solar pump fields which were controlled by DAE. There is available solar radiation observed in Chattogram region which is very suitable to operate a solar pump (Fig. 7). Maximum radiation is obtained in April and that the minimum is found in July. January to April is the maximum water required during Boro season and those times maximum solar radiation is observed in Chattogram region. Source of water of all the pumps was surface water. River, canal, creeks or fountains (Jiri or Chora) which are used as irrigation water sources. Water levels from the field surface to water bodies of the river or canals varied from 2-6 m. Special type of single phase vertical multistage centrifugal pump is used in the visited locations. This pump is 4 kw and winding by three types of coils such as high, medium and low resistance which protected the pump from low to high voltage due to variability of solar radiations during operation. Figure 8 shown some selected fields. So, there are suitable sources of water those can be used for irrigation by operating solar pumps in the Chattogram region.

TECHNOLOGY VALIDATION IN THE FARMERS' FIELD

Mass demonstration of suitable Aman rice varieties for facilitating Rabi/Boro crops intensification

A group of farmers were selected to cultivate the same variety in a block based on the land suitability within the study locations of Dacope and Amtali. The individual farmers' plot treated as disperse replications for the same variety within the block. The tested variety were BRRI dhan87, BRRI dhan76 and BRRI dhan77 along with the farmers' popular variety BR23. In Dacope area, the tested varieties BRRI dhan87 and BRRI dhan76 covered about 12.0 and 18.8 ha with the farmers' participation of 97 and 54 farmers, respectively during Aman season 2021 along with the farmers adopted high yielding variety of BR23. Whereas, in Amtali area those varieties (BRRI dhan87 and BRRI dhan76) covered about 7.4 and 12.5 ha with the farmers' participation of 24 and 47 farmers, respectively during the same season. Mass or block demonstration of the same variety in a location creates an advantage to control the insect-pest and crop harvest. All the tested rice varieties performed well in the coastal region during Aman season 2021. Though the fluctuation of BRRI dhan87 was higher because of some pest infestation, but the average yield was comparatively higher with other tested varieties. BRRI dhan76 produced a consistent yield in both the locations. Farmers were highly interested to cultivate those varieties based on the land suitability. The yield of BRRI dhan87 in Dacope area varied from 3.39 to 6.62 t/ha with an average of 4.59 t/ha and BRRI dhan76 varied from 3.93 to 5.32 t/ha with an average of 4.63 t/ha, whereas in Amtali area BRRI dhan87 varied from 3.97 to 6.30 t/ha with an average of 4.86 t/ha and BRRI dhan76 varied from 4.03 to 5.67 t/ha with an average of 4.74 t/ha. Gross and net income per hectare of Aman rice at average yield (4.59 - 4.86 t/ha) were in the range between BDT 44,050 - 48,582 and BDT 11,783 - 14,894 in Dacope and Amtali (Table 12). Farmers are satisfied with the biophysical performance of wet season (WS) rice over the last couple of years. The yield performance of the promising T. Aman varieties (BRRI dhan87 and BRRI dhan76) were good in both Dacope and Amtali areas. Based on the research findings in both the locations, farmers expressed their willingness to continue the cultivation of BRRI dhan87 in medium high land and BRRI dhan76 in the medium-low to low land areas due to higher yield, short duration, and unique characters to cope with the environments. These varieties improve the land productivity, net income, and benefit cost ratio (BCR) and also facilitated the cropping intensification in the coastal areas.

Growing vegetable crops with rice under waterlogged lowland condition

The experiment was conducted in Dacope, Khulna during wet season of 2021. Previously we introduced plastic bags and bamboo sticks, but it damaged within two years. For considering the durability, we reused plastic drum, concrete pillar, and galvanized iron wire in this purpose. To avoid the shading effect from the vegetable crops, we synchronized the vegetable crops with T. Aman rice. This year we placed bags on the bank of Gher and planted on gher boundary (Fig.9). Among the tested fruits and vegetables, watermelon and sweet gourd produced comparatively higher yield than the other vegetables. However, yield loss was found in T. Aman rice field in integrated condition over farmers' practice (sole rice). This was the integrated effect of shading effect and land occupied by bag placement in the rice land. The mean return from integrated rice was found Tk 96,462 whereas, sole rice return was found Tk 1,02,497 resulted 6% higher return in sole rice field (Table 13). Among the integrated vegetables watermelon with sweet gourd showed the best performance among the other vegetables due to their higher productivity. Though other creeping vegetables yielded comparatively lower, it has higher unit price than sweet gourd. Besides, farmers showed interest on creeping vegetables since it met their home consumption, and these were locally unavailable during the monsoon period. Compared to the previous year's findings production costs in integrated vegetables was very minimum due to reuse of previous materials. It was found that the average vegetable production cost was Tk 1,20,882. Plastic drum, concrete pillar, iron rope etc have long durability and it can be reused in further years. Gross margin from sole rice (Tk 15,918) was Tk 4,034 higher from the integrated rice (Tk 11,884) during 2021 at Dacope, Khulna (Fig. 10). However, average of Tk 98,236 gross margin was obtained from vegetable production in the area which was significantly higher than the previous year's findings (Tk 20,361 to Tk 30,961) in the same location. Thus, the findings showed the higher profitability of integrated rice and vegetable cultivation over traditional rice cultivation in water stagnant coastal environment in Bangladesh. The integrated rice/vegetable system was not economically attractive under the initial method (plastic sac with bamboo). But after some modification by introducing durable plastic drum and concrete pillar and galvanized iron wire and synchronizing vegetable production with T. Aman rice, then two to three times vegetable production was possible. Now the farmers were interested to cultivate high value off-season watermelon and get more return compared to the other vegetables.

Water resources management for Boro/Rabi crops by canal blocking

There are plenty of freshwater resources in wet season with a huge amount of rainfall (about 2000 mm) but less in dry season. To protect the crops and habitats in the coastal zones of Bangladesh from tidal water pressure about 139 polders were made. Polders are prone to flooding and poor drainage due to lower ground level of polders than sea level at high tide. Therefore, they require carefully managed drainage, usually through sluice gates at low tide. Improper management of sluice gate sometimes creates drainage congestions and water-logged situation in wet and late monsoon season. There are several rivers and equals crisscross the coastal area, which acts as a source of water supply and drainage. But in dry season, most of the river and canal water goes beyond the permissible limit of irrigation for crops and thus a vast area remains fallow in dry season. To conserve freshwater resources and to facilitate and increase the cropping intensity and to improve the land productivity, fresh water was trapped in the existing canals of Dacope and Amtali areas (Fig.11). By using this freshwater Boro/Rabi field crops were grown.

Salinity dynamics of water and soil in coastal areas of Bangladesh

To monitor river and trapped canal water salinity, three spots were selected at a certain distance in both the locations of Dacope, Khulna and Amtali, Barguna and measured water salinity of the selected points by EC meter. An observation well was installed in one corner of the experimental field within the weather station boundary at Pankhali village of Dacope, Khulna and very near to the experimental field at Sekandarkhali village of Amtali, Barguna to measure groundwater level and salinity. Soil salinity from rice field was measured weekly and non-rice field was measured at 15 days intervals after transplanting at 0-15, 15-30, 30-45 and 45-60 cm soil depth. The collected samples were meshed after oven drying and sieved to remove derides. Then the soil samples were mixed with distilled water at the rate of soil and water in 1:5. After shaking 30 minutes with 5 minute intervals and settling for minimum 30 minutes and measured the electrical conductivity by standard EC meter. Salinity of the river Jabjapia, Dacope, Khulna remained below 1.0 dS/m up to December (Fig. 12) and is considered highly suitable for irrigating crops. Even river water remained suitable (<4.0 dS/m) for irrigation up to end of December. After that the river water salinity gradually increased and at the end of Rabi/Boro cropping season it reached about 32 dS/m in May. The canal water was trapped within December at the period of high tide making canal water salinity of about 1.0 dS/m. Its salinity increased in a slower rate and reached up to 3 dS/m in May due to evaporation and influence of groundwater flow (Fig. 13). In Amtali area, salinity of the river Andharmanik started to increase after November and reached its peak in May (Fig 12). After the onset of rainfall in June the salinity level of river water sharply decreased and from July to November the river water became fresh and after that its salinity starts to increase. The canal water was trapped on before November and canal water average salinity was 1.3 dS/m. Groundwater level and salinity in the experimental field at Pankhali, Dacope varied between 0.21-1.21 m below the field surface and 0.31-2.26 dS/m, respectively (Figs.14 and 15) In Dacope, groundwater salinity remained less than 4.0 dS/m during the study period and is considered suitable for irrigation development. But withdrawal of groundwater from the upper low saline aquifer is a risky venture for increasing salinity by intrusion of river high saline water in dry season. Whereas, average groundwater level at Sekandarkhali, Amtali varied between 0.93 to 1.8 m from ground surface and groundwater salinity at 2.75 to 10.32 dS/m (Figs.14 and 15). The year-round soil salinity varied from 2.0 to 8.0 dS/m in Dacope and that was 1.8 to 6.0 dS/m in Amtali areas. In dry season, the soil salinity goes to its peak in April and after the onset of monsoon rainfall it reduces. However, the Amtali area is less saline compared to Dacope area. Fresh water resources development is one of the crucial issues for sustainable crop and soil salinity management in coastal areas. Surface fresh water was trapped in local canals within December for irrigation in dry season crops. Groundwater salinity was beyond the permissible limit of irrigation. Dacope area is more saline than that of Amtali areas (Fig. 16). Therefore, special care needs to be adopted for dry season crop production.

Block demonstration of Boro rice by using stored surface water in coastal areas for cropping intensification

The experiment was conducted at Dacope and Batiaghata in Khulna district, Amtali and Taltali in Barguna district and Kalapara, Patuakhali in Barishal region with the tested salt tolerant rice variety of BRRI dhan67 and the high yielding varieties of BRRI dhan74, BRRI dhan97, BRRI dhan99 and BRRI dhan89. In Khulna area, the tested varieties covered about 20.4, 2.9 and 1.2 ha with the farmers' participation of 168, 40 and 12 farmers during the 2021-22 Boro seasons. Whereas, in Barishal area it covered about 15, 10 and 3 ha with the farmers' participation of 46, 37 and 11 during the same season. All the tested rice varieties performed well in the coastal region during Boro 2021-22. In Dacope, Khulna area, BRRI dhan99 produced comparatively higher grain yield followed by BRRI dhan67. BRRI dhan97 produced the lowest yield among the three tested varieties. BRRI dhan67 produced better yield performance over BRRI dhan97. BRRI dhan74 performed the best in Taltoli whereas, similar yield performance was observed among the tested variety in Amtali, Barguna and Kalapara, Patuakhali. A large yield variation was observed for each varieties in the tested locations. This is because of the seedling age, transplanting time and intercultural practices variation among the farmers. Gross margin and net income per hectare of Boro rice based on the average yield (4.95- 6.20 t/ha) were in the range between BDT 86,036 – 107,025 and BDT 45,379-64,822 in Khulna and Barishal region (Table 14). Farmers are satisfied with the biophysical performance and successful production of dry season (DS) rice with BCR ranged from 1.41 to 1.57 over the last couple of years. All the tested varieties performed well in both the sites over the tested years. But, freshwater availability is the main constraints for cultivation of Boro rice. However, farmers are highly interested to grow Boro rice by conserving fresh water by trapped canal, because the production is less risky compared to other Rabi crops, which were more vulnerable for uncertain rainfall and cyclonic damage. Cultivation of Boro rice become profitable for its safe and higher production.

Upscaling of Improved Water Management Practices for Sustainable Productivity in the Haor areas

Boro is the main and only crop in the haor areas. Cultivated popular high yielding varieties are BRRI dhan28 and BRRI dhan29. Cultivated popular hybrid varieties are Janakraj, Chokka and Jhalak. Popular local varieties are Gochi, Lakhai, Tepi boro and Rata boro. Short duration varieties like BRRI dhan28 are popular in Matian haor due to late recession of flood water and early inundation. Long duration varieties like BRRI dhan29 are popular in the Shanir haor due to early recession and late inundation by flood water. Main source of irrigation is the surface water from river, canals, ponds, ditches and beels. Except river, other sources of irrigation water dries up during later part of February. As a result, crops suffer from severe water stress if sufficient rainfall does not occur in March. Due to water stress at the reproductive phase yield of Boro rice is very low (2-3 t/ha) though land is fertile compared to other regions of Bangladesh. In the farmers' opinion main problem for sustainable production are the irrigation water scarcity and early flash flood at the maturity stage. Other problems inciude labour scarcity during transplanting and harvesting, high labour wage, lack of technological knowledge etc. A total of 12 demonstrations were conducted in the haor areas. Out of the 12 demonstrations 10 were conducted in Shanir haor and two were in the Matian haor. Varieties used were- BRRI dhan29, BRRI dhan84, BRRI dhan89, Chokka, Jhalak and Janokraj. The last three were hybrid varieties. Amount of irrigation was measured each time. Crop-cut was done to measure the yield. The irrigation and yield data were compared with farmers practice plots. The yield of the AWD plots was 3.13-6.36 t/ha. The highest yield (6.36 t/ha) was obtained from BRRI dhan29. Out of 12 plots, seven produced yield of more than 5.0 ton/ha. Lower yield (<4.5 ton/ha) in some plots were due to damage by hailstorm (15 April 2022). The average yield obtained in the AWD plots was similar to the farmers practice plots. Generally, 2-3 irrigations were saved in AWD irrigation practice than the farmers practice (maintaining saturation to standing water). Polythene pipes were supplied to 3 LLP and 1 DTW irrigation systems. Two LLPs were at Sreepur and Borodol of the Matian haor. One LLP and one DTW were at Moddho Tahirpur and Ujan Tahirpur of the Shanir haor. A low lift pump was installed at the Bank of Boulai river to cultivate a portion of fallow land in Shanir haor. The distance was more than 1000 ft out of which 600 ft was settlements. So, 600 ft PVC pipe was used to carry the water through the settlements. As the construction of earthen canal was very difficult due to undulation of land, about 800 ft Polythene pipe was supplied to carry water to the plots. Around five hectares of lands were brought under cultivation with the irrigation water. Around 500 ft polythene pipe was provided to a newly installed DTW of Ujan Tahirpur to carry water to remote places. Pumping time was higher in the earthen canal due to leaching loss. A comparison between earthen canal and polythene pipe was made to assess the performance. Two adjacent plots at a distant place were irrigated by earthen canal and polythene pipe. Area of each plot and time required for irrigation were recorded. Irrigation time was reduced by 20 percent due to use of polythene pipe compared to earthen canal. Due to use of polythene pipe the irrigation time per unit area was reduced significantly. Check valve was installed in 3 STWs. Among the shallow tubewells two were used for supplementary irrigation in Boro rice. The discharge of the pump was measured before and after installation of the check valve. No significant difference was found in discharge. The pump operation became very easier after installation of the check valve. It takes 2-3 persons to start the pump any time before installation of the check valve. Only one person could easily start the pump after installation of the check valve. A total of 21 plots were monitored in Both Matian and Shanir haor. Plots were categorized as- no stress, less stress, moderate stress, severe stress and very severe stress. Perforated PVC (AWD) pipes with 50 cm depths were installed in the plots to monitor the parched water table. Pipes having 50 cm depth were installed in the plots to assess the water stress. Based on the continuous stress period below the specified stress limit, an indicator was developed to assign the stress category. The yield was compared to assess the impact of water stress. A total of 3 and 6 plots were under no stress and less stress group, respectively. Four plots were under each of moderate stress, severe stress, and very severe stress groups. Highest yield was obtained in no stress plots and the lowest in very severe stress plots. The average yield of the plots under no stress, less stress, moderate stress, severe stress, and very severe stress groups were 6.23, 5.43, 4.55. 3.90 and 3.16 t/ha, respectively. The average yield reduction in less stress, moderate stress, severe stress, and very severe stress plots were 12.9%, 27.0 %, 37.5% and 49.3%, respectively compared to the no stressed plots. The study results indicate that huge yield loss occurred in the haor area due to water stress in the reproductive phase of Boro rice.

Mass block demonstration of Aus, Aman and Boro rice by using high yielding varieties, improved agricultural practices in the coastal areas to cropping intensification

The demonstrations were setup in farmers' field at Barishal, Khulna and Satkhira district. During Aus season, BRRI dhan48 covered 29 hectares with 10 demonstrations. The average yield was 4.0 – 5.5 t/ha. During Aman season, the new and high yielding varieties BRRI dhan76, BRRI dhan75 and BRRI dhan87 along with the farmers' popular varieties BR10, BR11 and BR23 were tested in the selected area. The area covered with these improved varieties was 83 ha by 70 demonstrations. The highest yield was from BRRI dhan87 in all locations which varied from 4.1 to 6.0, 5.6 to 6.4 and 5.8 to 6.2 t/ha with an average of 5.4, 6.1 and 6.0 t/ha in Khulna, Barishal and Satkhira, respectively. The average yield of BRRI dhan76 was 4.6 to 5.3 t/ha. BR23 and BR11 also had satisfactory yield which varied from 3.8 to 5.6 t/ha. In Boro season, high yielding rice varieties BRRI dhan74, BRRI dhan81, BRRI dhan89, BRRI hybriddhan5 and salt tolerant rice varieties BRRI dhan67, BRRI dhan97 and BRRI dhan99 were demonstrated in a block with a range of 10-80 Bigha area in low saline areas of Barishal and high saline areas in Khulna and Satkhira region. In all the locations, total area was 430 ha with 100 demonstrations. In Batiaghata, Khulna, the range of yield was 7.2 t/ha to 8.8 t/ha and 6.5 t/ha to 7.7 t/ha for BRRI hybrid dhan5 and BRRI dhan89. On the other hand, in Dacope Khulna, BRRI dhan67 had higher yield than BRRI dhan97 and BRRI dhan99. The yield range was 5.2 t/ha to 6.6 t/ha and 5.0 to 6 t/ha for BRRI dhan67, BRRI dhan97 and BRRI dhan99, respectively. In Barishal region, the highest yield was from BRRI dhan89 and BRRI hybrid dhan5 which ranged from 6.8-8.4 t/ha and 6.5-9.0 t/ha. Whereas BRRI dhan74 performed well than BRRI dhan67. The range of yield was 6.2-7.8 t/ha and 5.4-6.7 t/ha for BRRI dhan74 and BRRI dhan67. In Satkhira region, BRRI dhan67 and BRRI dhan81 had higher yield ranged from 6.0 to 7.2 t/ha than BRRI dhan50 and BRRI dhan63.

Assessment of improved agricultural practices to maximize rice yield in the coastal area during T. Aman season

The experiment was conducted in farmer's field at Dacope upazila in Khulna and Patuakhali sadar upazilla in Patuakhali in 2021 season. Four Aman rice varieties viz BRRI dhan76, BRRI dhan87, BR23 and local cultivars Jatibalam and Sadamota were tested with improved agricultural practices (optimum seedling age, timely transplanting, spacing, recommended fertilizer, supplemental irrigation) and farmer practices. In both the locations, improved practices increased 12-22% rice yield than the farmers' practice.

Impact of alternate wetting and drying irrigation for Boro rice cultivation in the coastal saline area

Ten demonstrations were implemented in Barishal and Khulna to assess the AWD practices on rice yield and irrigation water. In Barishal, AWD practice saved three irrigations than continuous irrigations without any yield sacrificed. Whereas, in Khulna region, AWD practices saved two irrigations than continuous irrigations without any yield loss. The results indicate that the adoption of AWD irrigation practice in the coastal areas can save irrigation water and increase Boro rice cultivation.

Greenhouse gas emissions from irrigated agriculture in Bangladesh and reduction policies/strategies

Water demands in Bangladesh for agricultural and non-agricultural uses are mostly met from groundwater sources. As a result, groundwater table is declining in different parts of the country which necessitate pumping water from deeper layers. It is a great concern not only for sustainable uses of groundwater resources but also for increasing pumping cost. Pumping of water for irrigation is one of the most energy-consuming processes, which is also related with greenhouse gas (GHG) emissions. This issue has not been addressed yet in Bangladesh. We have considered surface and groundwater irrigation devices and area coverage during 2019-2020 for GHG estimation (Table 15). Based on water lifting heads, area coverage and fuel used, GHG emissions varied among locations and sources of irrigation water (Fig.17). Total GHG emission for crop fields irrigation was about 2.82 million tons (Mt) CO2-e (which is about 5% of the emission of agricultural sector) of which 0.26 Mt CO2-e for surface and 2.56 Mt CO2-e for groundwater irrigations. The hotspots of GHG emissions were Rajshahi region followed by Rangpur and Mymensingh regions (Table 16). Area coverage by shallow tube wells (STWs), deep tube wells (DTWs) and low lift pump (LLPs) were 56.8%, 19.2% and 24.0% of cultivated areas; but GHG emissions were 35.4%, 55.5% and 9.2%, respectively. The present findings showe that groundwater abstraction is an important source of GHG emissions in Bangladesh. So, it is the time to harness the co-benefits of water and energy savings by adopting alternate wetting and drying practice for rice cultivation, by expansion of surface water irrigation facilities along with selecting water use-efficient crop varieties having high yield potentials.

Intervention in surface water utilization through integrated minor irrigation schemes for escalating water and land productivity in coastal region

Agricultural land use and crop productivity in the Barishal region are decreasing day by day. The main constraint that affecting the productivity of this region is lack of good quality irrigation water. However, all river waters or canal waters are not saline according to water salinity monitoring conducted during the past 15 years by Irrigation and Water Management Division of BRRI. Based on the findings, water from the river Tentulia, Buriswar, Bishkhali, and Boleswar was less than 1.0 dS/m round the year. The results suggest that water from the selected rivers is suitable for irrigation when the water is applied from the upstream of the saline-sweet water interface of the river which is located about 20 to 30 km north from the estuaries. The fallow, or single cropped agricultural lands in the coastal region of Barishal is a potential target for expansion of Boro rice cultivation and thus to increase the cropping intensity. For this purpose, less saline surface water, particularly water from Burishwar and Bishkhali river water, can be used through integrated minor irrigation schemes. Therefore, the project's primary research is to increase water and land productivity through efficient water diversion, modern distribution systems, and judicious water management practices. Other research initiatives include identifying the most water-efficient cropping pattern in the project area. Six experiments have been established in Patuakhali Sadar and Taltoli upazila under the project. The close monitoring of water salinity under multiple sampling locations, the range of suitable water sources is wider in terms of distances in the polder. Boro rice cultivation, that is dependent on the irrigation with fresh or less saline water, can be done in the areas that are located at the closer vicinity of the river Burishwar. The cultivable area can be extended to even more southern part of the polder using less saline water not from the river but from the canals, the water source of which is from the upstream side of the saline sweet water interface. Thousands of fallow lands can be brought under Rabi crops coalition using the surface water available in all canals in Polder number 44. However as discussed in the first experiment, all canals do not store or flow fresh of less saline water, instead the canals alongside the Burishwar river, which connects the salinity monitoring points 2B, 2A, 1, 12,13 15, 16A, 16B, 17 contains fresh or less saline water during the Rabi season. Therefore, the dead canals (length about 35 km) that represents these non-saline points are recommended for re-excavation. In Patuakhali Sadar upazila of Patuakhali district, about 41 hectares (300 bigha) of fallow area have been brought under Boro cultivation establishing 12 block trials. The minimum size of a block is about 25 bigha, whereas the maximum size is 100 bigha. In total 165 farmers cultivated modern high yielding BRRI varieties such as BRRI dhan67, BRRI dhan74, and BRRI dhan89. In Taltoli upazila of Barguna district, about 27 hectares (200 bigha) of fallow area have been brought under Boro cultivation establishing eight block trials. The minimum size of a block is about 25 bigha, whereas the maximum size is 50 bigha. In total 100, farmers cultivated modern high yielding BRRI varieties such as BRRI dhan67, BRRI dhan74, and BRRI dhan89. All Boro trial fields have been irrigated with less saline river/canal water that the salinity of water is being continuously monitored.

Table 1. Irrigation water sources, present irrigated area, and possible area extension of cultivable lands in Sadar, Khagrachari.

Irrigation resource	Block	Present irrigated Area coverage (ha)	Extendable irrigated Area coverage in future (ha)
Creek	Bhai Bon Chora	45	45
Creek	Bahi Bon Chora	52	30
Canal	Dur Chori	10	60
Canal	Dur Chori	20	30
River (Chengi)	Gamari Dhala	80	60
River (Chengi)	Muni Gram	100	300
Creek	Kuki Chora	50	100
River (Chengi)	Pourashova	80	120
Creek	Pourashova	20	30
Creek	Pourashova	50	80

Table 2. Rice yield of premium quality rice (PQR), ALART-1, 2 and check variety along with irrigation treatment at BRRI HQ farm, Gazipur during Boro 2022.

ALART and check variety	Grain yield (g/hill)				Tolerance capacity
	CS	**-10 kPa**	**-30 kPa**	**-60 kPa**	
BR9930-2-3-2-2	25.52	22.43(-12.1%)	16.67 (-34.7%)	11.95 (-53.2%)	CS
BR9930-2-3-3-1	31.77	28.55 (-10.1%)	20.26 (-36.2%)	13.13 (-58.7%)	CS
BRRI dhan50 (ck)	33.79	28.06 (-17.0%)	13.39 (-60.4%)	13.13 (-61.1%)	CS
BRRI dhan63 (ck)	27.34	21.16 (-22.6%)	14.97 (-45.2%)	12.86 (-53.0%)	CS
BRRI dhan81 (ch)	36.51	27.52 (-24.6%)	16.91 (-53.7%)	15.75 (-56.9%)	CS
$lsd_{0.05}$					ns (6.802)
cv%					4.3

Table 3: Irrigation, rainfall and grain yield of the selected Advanced lines under different water management treatments during Boro season 2021-22 at BRRI HQ farm, Gazipur.

Variety	Treat	Number of irrigation	Irrigation applied (mm)	Rainfall (mm)	Total water use (mm)	Average yield (kg/ha)	Irrigation water saving than T1 (%)	Change in yield than T1 (%)
BR11715-4R-186	T1	14	810	270	1080	7195		
	T2	11	705	270	975	6930	-13.0	-3.7
	T3	20	650	270	920	6163	-19.8	-14.3
	T4	19	620	270	890	5844	-23.5	-18.8
BR11723-4R-27	T1	14	810	270	1080	7624		
	T2	11	705	270	975	7152	-13.0	-6.2
	T3	20	650	270	920	6786	-19.8	-11.0
	T4	19	620	270	890	6206	-23.5	-18.6
BR11723-4R-12	T1	14	810	270	1080	6744		
	T2	11	705	270	975	6582	-13.0	-2.4
	T3	20	650	270	920	6507	-19.8	-3.5
	T4	19	620	270	890	6119	-23.5	-9.3
BR11716-4R-105	T1	14	810	151	961	6270		
	T2	11	705	151	856	6482	-13.0	3.4
	T3	20	650	151	801	6072	-19.8	-3.2
	T4	19	620	151	771	5925	-23.5	-5.5
BRRI dhan92	T1	14	810	151	961	7154		
	T2	11	705	151	856	7210	-13.0	0.8
	T3	20	650	151	801	6782	-19.8	-5.2
	T4	19	620	151	771	6647	-23.5	-7.1

Table 4: Effects of amendment practices in charland on Yield and yield components of BRRI dhan100 during T. Aman, 2021.

Treatments	Plant height (cm)	Panicle/hill (no.)	Grain per panicle (no.)	Sterility (%)	Grain yield (t/ha)	Yield increased over control
T_1	135.85	10.47	114.5	13.35	5.73	30.5
T_2	114.25	11.13	112.8	12.27	4.72	15.7
T_3	117..63	11.6	115.7	18.21	4.69	15.1
T_4	117.99	10.33	114.9	15.82	4.13	3.6
T_5	122.16	10.73	118.5	11.82	4.55	12.5
T_6 (Control)	118.34	10.13	112.7	14.33	3.98	--
$lsd_{0.05}$	6.68	ns	ns	ns	0.99	
cv%	2.4				4.3	

Table 5: Effects of amendment practices in charland on Yield and yield components of BRRI dhan89 during boro 2021-22.

Treatment	Plant height (cm)	Panicle/m^2 (no.)	Grain per panicle (no.)	Sterility (%)	Straw yield (t/ha)	Grain yield (t/ha)	HI
T_1	109	233.3	184	10.41	6.07	6.98	0.54
T_2	106	268.3	176	12.58	6.73	6.87	0.51
T_3	110	285.0	154	12.92	6.11	7.30	0.55
T_4	112	261.7	180	12.32	7.13	6.86	0.49
T_5	106	241.7	179	10.86	6.54	7.54	0.54
T_6 (Control)	108	271.7	176	10.33	6.31	6.91	0.52
$lsd_{0.05}$	ns	ns	9.12	ns	ns	0.35	0.027
cv%			2.9			2.7	2.8

Table 6. Treatment-wise irrigation applied and average yield in T. Aman 2021 and Boro 2021-22, Rangpur.

Treatment	Irrigation (mm)		Avg. yield (t/ha)	
	T. Aman	Boro	T. Aman	Boro
Control (T1)	**260**	**1150**	**4.45**	**6.76**
AWD (T2)	232	963	5.20	7.71
CROPWAT (T3)	145	790	5.43	7.50

Table 7: Water requirement and water applied for Boro rice in Gazipur in 2021-22.

Treat-ment	Water requirement (mm)			Water applied (mm)				
	Evapo-transpiration (ET)	Seepage and Percolation (S&P)	Total water required (mm)	Number of irrigation	Water applied in land preparation	Applied irrigation	Rainfall	Total amount of water sed (mm)
T_1	406	400	806	13	200	780	115	1095
T_2	407	390	796	12	200	720	145	1065
T_3	387	357	743	10	200	660	186	1046
T_4	358	320	677	9	200	630	234	1064

Table 8: Yield and water productivity of different transplanting dates of Boro rice in Gazipur in 2021-22.

Treatment	Growth duration (days)	Total water use including rainfall (mm)	Yield (t/ha)	Water productivity (kg/ha-mm)
T1	139	1095	6.6a	6.0
T2	135	1065	6.3a	5.9
T3	127	1046	5.3b	5.0
T4	118	1064	3.7c	3.5

Table 9: Amount of average agricultural drought (mm) quantified in different growth stages under different treatments of BRRI dhan87 at Kushtia during T. Aman 2021

Growth duration (Week)	Growth phase	15 Aug DoT (I$_0$)	(I$_1$)	(I$_2$)	Growth duration (Week)	Growth phase	30 Aug DoT (I$_0$)	(I$_1$)	(I$_2$)
15-Aug	Vegetative	0	0	0	30-Aug	Vegetative	0	0	0
21-Aug		0	0	0	05-Sep		0	0	0
28-Aug		0	0	0	12-Sep		0	0	0
04-Sep		0	0	0	19-Sep		0	0	0
11-Sep		0	0	0	26-Sep		0	0	0
18-Sep		0	0	0	03-Oct		0	0	0
25-Sep	Reproductive	0	0	0	10-Oct	Reproductive	0	0	0
02-Oct		0	0	0	17-Oct		0	0	0
09-Oct		0	0	0	24-Oct		0	0	0
16-Oct		0	0	0	31-Oct		4.4	0	0
22-Oct		0	0	0	07-Nov		15.6	13.1	0
29-Oct		10.5	5.9	0	14-Nov	Ripening	25.6	19.8	16.8
05-Nov	Ripening	25.6	21.6	18.7	21-Nov		27.4	20.8	17.3
12-Nov		19.4	16.4	13.8	28-Nov		30.4	25.1	21.3
19-Nov		26.4	23.4	21.4	05-Dec		22.5	18.6	16.0
26-Nov		0	0	0	12-Dec		0	0	0
03-Dec		0	0	0	15-Dec		0	0	0
05-Dec		0	0	0		Total	125.9	97.4	71.4
	Total	**81.9**	**67.3**	**53.9**					

Table 10. Yield increased due to drought mitigation during T. Aman 2021 in Kushtia.

Treatment	Yield on 15 Aug transplanting (t/ha)	% yield increased than I$_0$	Yield on 30 Aug transplanting (t/ha)	% yield increased than I$_0$	% yield loss due to delay transplanting
I$_0$	6.5	-	5.5	-	18.2
I$_1$	7.2	10.8	6.1	10.9	18.0
I$_2$	7.3	12.3	6.2	12.7	17.7

Table 11. Effect of different level of irrigation water salinities on yield and yield contributing parameters.

Saline water Irrigation	Variety	Yield (t ha^{-1})	Number of filled grain per panicle	Number of unfilled grain per panicle	Plant height (cm)
I1	V1	6.7	152	6	122
I2		6.1	148	17	110
I3		4.7	122	16	104
I4		3.8	109	33	102
I5		2.7	106	35	105
I1	V2	6.0	149	11	112
I2		5.8	145	18	110
I3		4.9	134	24	106
I4		4.3	117	30	101
I5		3.2	112	35	106
		Treatment means			
I1		6.3	151	9	117
I2		6.0	147	17	110
I3		4.8	128	21	105
I4		4.0	113	32	102
I5		2.9	109	35	100
V1		4.9	128	22	109
V2		4.8	139	26	107
P-values					
Irrigation		0.001	0.05	0.001	0.01
Variety		NS	NS	NS	NS
Irrigation x variety		0.001	NS	NS	NS
$LSD_{0.05}$					
Irrigation		0.28	19.8	7.0	7
Variety		-	-	NS	NS
Irrigation x variety		0.39	-	-	-

Table 12. Cost and return of Aman rice at Dacope and Amtali during 2021.

	Costs and returns (BDT/ha)	
Item	Dacope	Amtali
Total paid-out cost (VC) (cost of inputs including fertilizer, pesticides, irrigation, herbicides and hired labour)	52,700	51,968
Total imputed cost (opportunity cost of land and family labour and interest on operating capital)	32,267	33,688
Total cost (TC)	84,967	85,656
Mean grain yield (t/ha):	4.61	4.80
Market value of grain (BDT/ha)	92200	96000
Market value of straw (BDT/ha)	4,550	4,550
Gross benefit (BDT/ha)	96,750	100,550
Gross income (BDT/ha)	44,050	48,582
Net income (BDT/ha)	11,783	14,894
Benefit over cost (full cost basis)	1.14	1.17

Farm gate price of paddy is BDT 20.00/kg

Table 13. Cost and returns from vegetables with T. Aman rice at Dacope, Khulna during 2021.

Sl. #	Gross return (Tk ha^{-1})				Total variable cost (Tk ha^{-1})			
	Vegetable	Integrated rice	Total (Rice with vegetable)	Sole rice	Vegetable	Integrated rice	Total (Rice with vegetable)	Sole rice
F1	240340	96696	337036	102900	108051	84779	192830	86779
F2	233020	96300	329320	101380	114899	83779	198678	85779
F3	154770	94360	249130	100564	175386	85779	261165	87779
F4	257448	96372	353820	102820	102287	83527	185814	85527
F5	210016	98584	308600	104820	103787	85027	187314	87027
Mean	**219119**	**96462**	**315581**	**102497**	**120882**	**84578**	**205160**	**86578**

F1= Okhil Halder, F2= Pobitra Mistre F3= Md. Sain gazi, F4= Gofinat Boiragi, F5= Refatul Gazi

Table 14. Cost and return of Boro rice at Dacope and Amtali during 2021-22.

Item	Costs and returns (BDT/ha)				
	Dacope	Amtali	Kalapara	Taltali	Batiaghata
Total variable cost (Cost of inputs including fertilizer, pesticides, irrigation, herbicides and hired labour)	69,224	70,214	70,654	71,555	72,111
Total imputed/ fixed cost (Land rent, family labour and interest on operating capital)	41,067	40,657	40,107	42,203	41,067
Total cost	110,291	110,871	110,761	113,758	113,178
Grain yield (t/ha)	5.62	5.25	5.74	6.02	5.81
Selling price (BDT/t)	25,000	25000	25,000	25,000	25,000
Market value of grain (BDT/ha)	140,500	131,250	143,500	150,500	145,250
Market value of straw (BDT/ha)	26,480	25,000	26,960	28,080	27,240
Gross income (BDT/ha)	166,980	156,250	170,460	178,580	172,490
Gross margin (BDT/ha)	97,756	86,036	99,806	107,025	100,379
Net return (BDT/ha)	56,689	45,379	59,699	64,822	59,312
Benefit over cost (full cost basis)	1.51	1.41	1.54	1.57	1.52

Table 15. Region-wise pumping lifts of different irrigation devices and water use for *Boro* rice production in Bangladesh.

Region/Division	Pumping lifts (m)*			Water use (m^3 ha^{-1})
	DTW	STW	LLP	
Rangpur	10.75-16.47	5.57-7.60	5.50-5.70	7236 - 7835
Rajshahi	14.39-40.08	7.68-8.00	4.50-5.50	6835 - 7636
Khulna	8.50-18.00	4.57-8.00	4.57-5.50	6237 - 7637
Mymensingh	14.80-25.50	7.90-8.00	4.40-5.50	6037 - 7337
Dhaka	10.20-20.40	5.07-8.00	5.07-5.66	6236 - 7737
Barishal	3.50-8.50	3.83-5.00	2.62-4.25	6235 - 7236
Sylhet	8.50-15.05	5.73-7.91	5.50-5.89	6136 - 5636
Chattogram	8.50-20.10	3.94-7.80	3.94-5.91	6235 - 7537

* Considering all agricultural use and excluding all city areas.

Table 16. Region-wise total GHG emission (Kt CO_2-e) of different irrigation devices in Bangladesh.

Region/Division	Ground water			LLP/SW	Total GHG
	DTW	STW	Total		
Rangpur	257.35	255.48	512.83	4.93	517.76
Rajshahi	768.14	228.53	996.68	17.00	1013.68
Khulna	75.02	188.87	263.88	26.67	290.55
Mymensingh	293.70	115.10	408.80	23.63	432.43
Dhaka	91.19	129.57	220.76	47.48	268.24
Barishal	NA	0.04	0.04	28.12	28.16
Sylhet	6.59	21.16	27.75	45.23	72.98
Chattogram	74.24	59.32	133.56	65.77	199.33
Bangladesh	**1566.23**	**998.07**	**2564.30**	**258.82**	**2823.12**

NA = Data not available

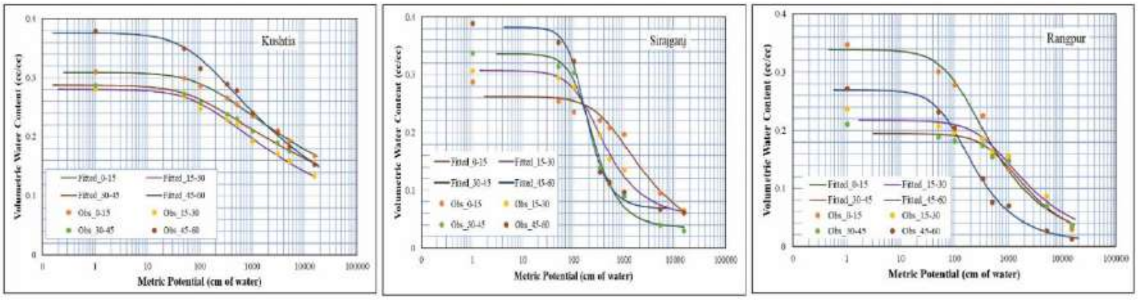


Fig. 1. Fitted soil water release curves at different depths of soil profile for Kushtia, Sirajganj and Rangpur.

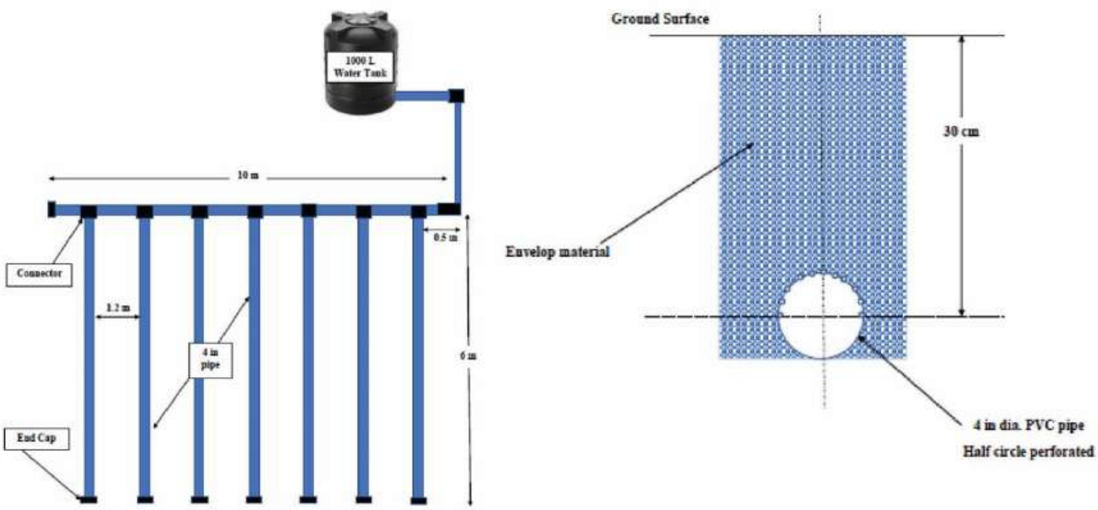


Fig. 2. Subirrigation system detail design.

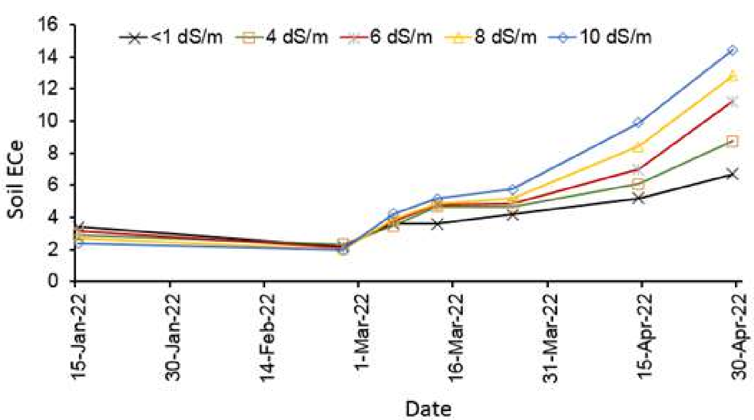
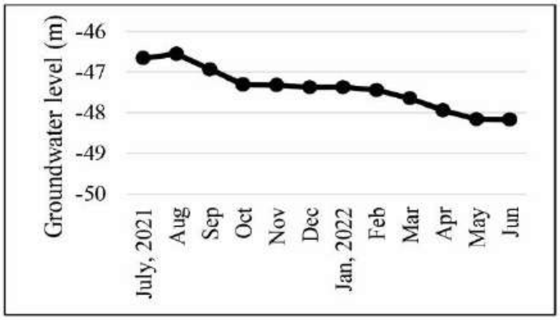


Fig. 3. Soil salinity dynamics at 0-10 cm soil depth with saline water irrigation during the growing season of Boro rice in Dacope, Khulna in 2021-22.



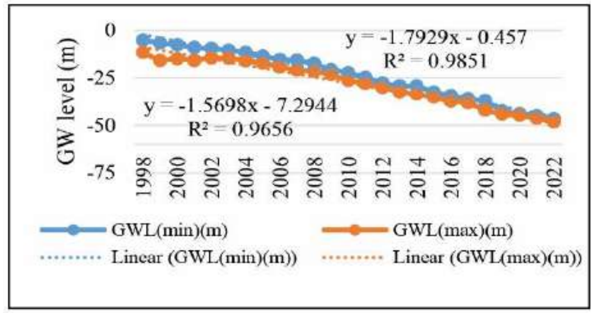


Fig. 4. GW fluctuation (2021-22) at BRRI HQ farm Gazipur.

Fig. 5. Long-term GW declination (1998-2022) at BRRI HQ farm, Gazipur.

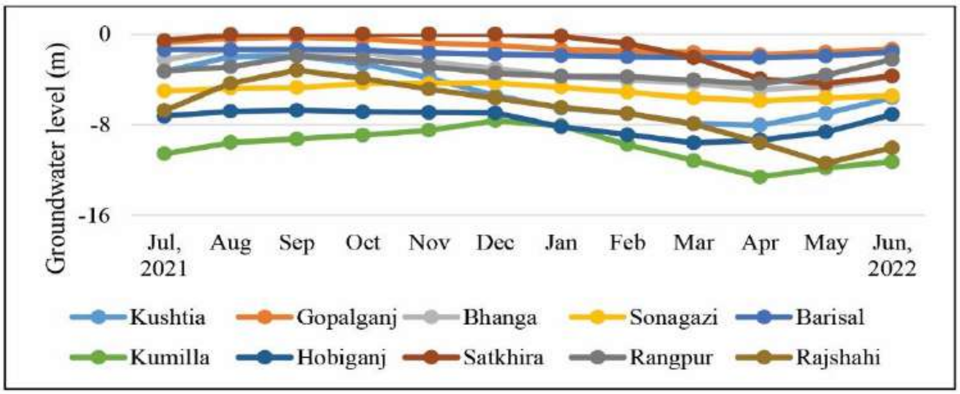


Fig. 6. Yearly GW level fluctuation at different BRRI RS during 2021-22.

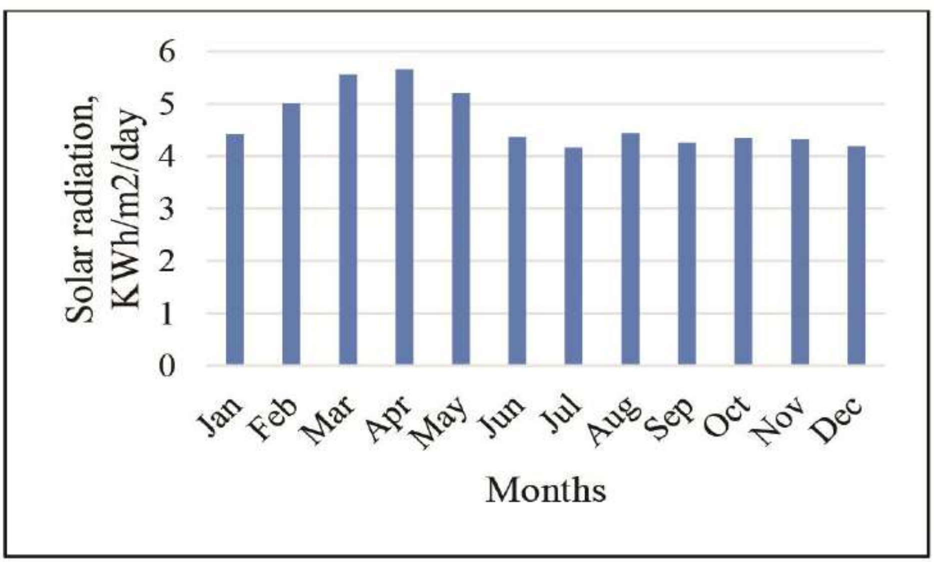


Fig. 7. Monthly solar radiation distribution in Chattogram region.

Village-Khushipur, Union-Joylaskar, Upazilla-Dagon bhuiyan, District-Feni

Village-Hapania, Union-3 no Narayanhat, Upazilla-Fotikchhori, District-Chattogram

Village-North Durgapur, Union-8 no Durgapur, Upazilla-Mirershorai, District-Chattogram

Fig.8. Some selected locations of solar pumps in Chattogram region.

Fig. 9. Off-season watermelon with T. Aman rice at Dacope, Khulna, 2021.

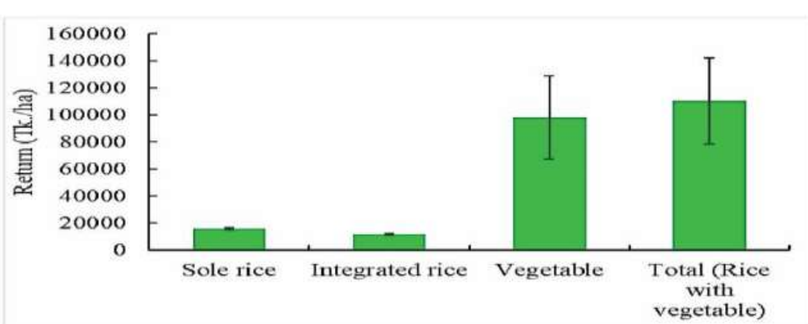


Fig. 10. Gross margin of sole rice and integrated rice-vegetables at Dacope, Khulna during 202.

Fig. 11. Trapped fresh water by earthen embankment, Dacope, Khulna, Rab, 2021-22.

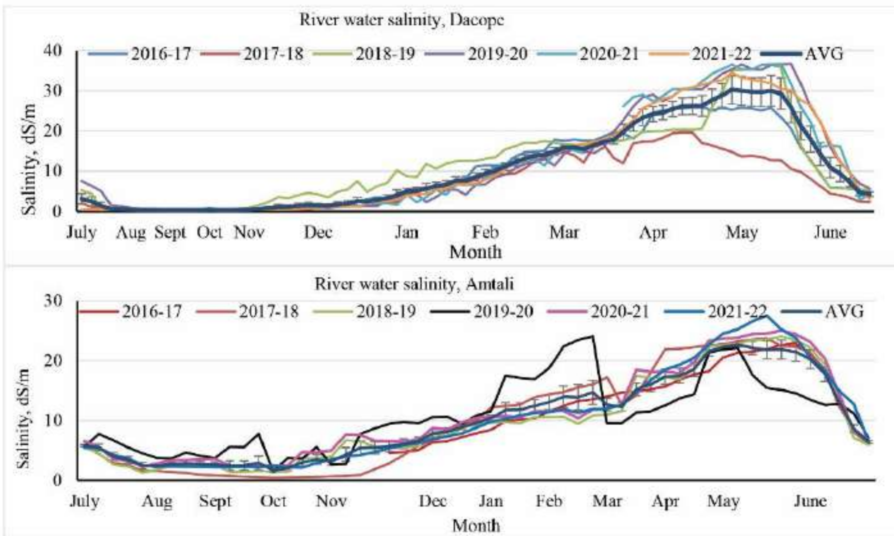


Fig. 12. River water salinity at Dacope and Amtali during 2016-22

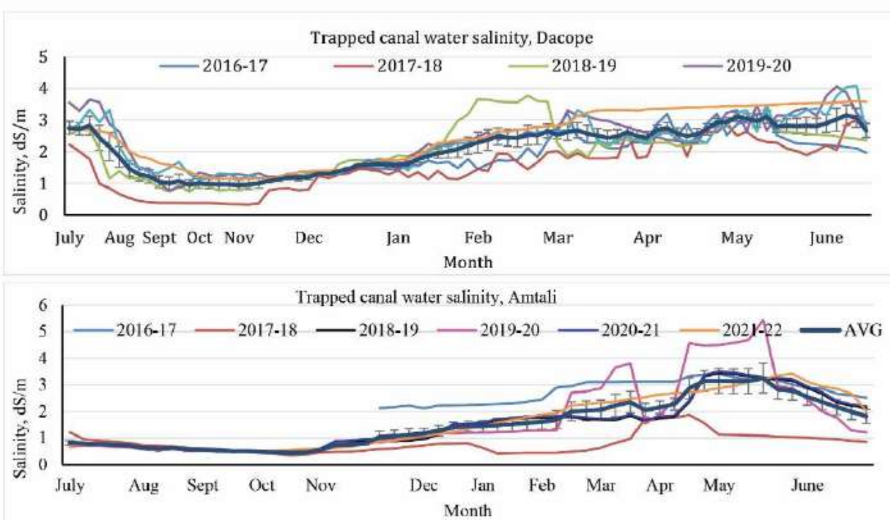


Fig. 13. Trapped canal water salinity at Dacope and Amtali during 2016-22.

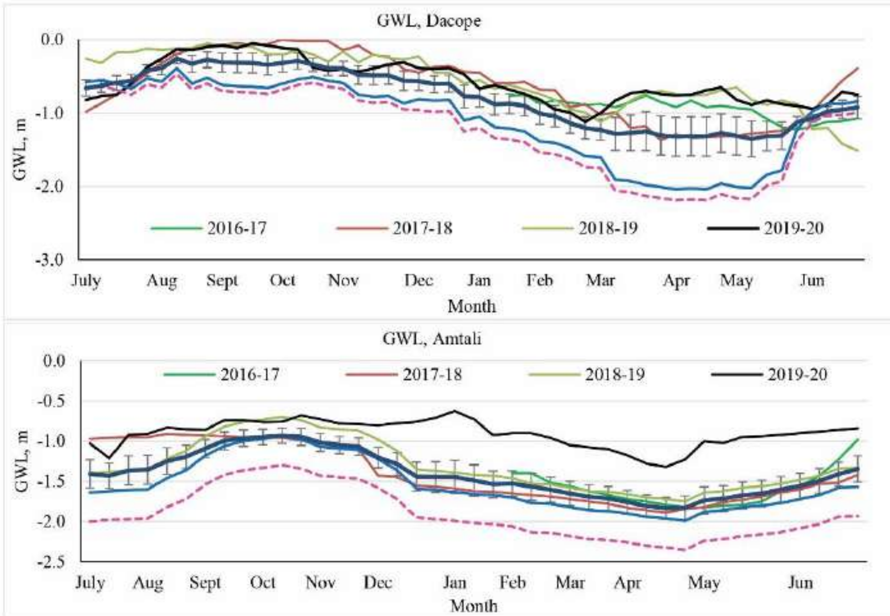


Fig. 14. Groundwater level at Dacope and Amtali during 2016-22.

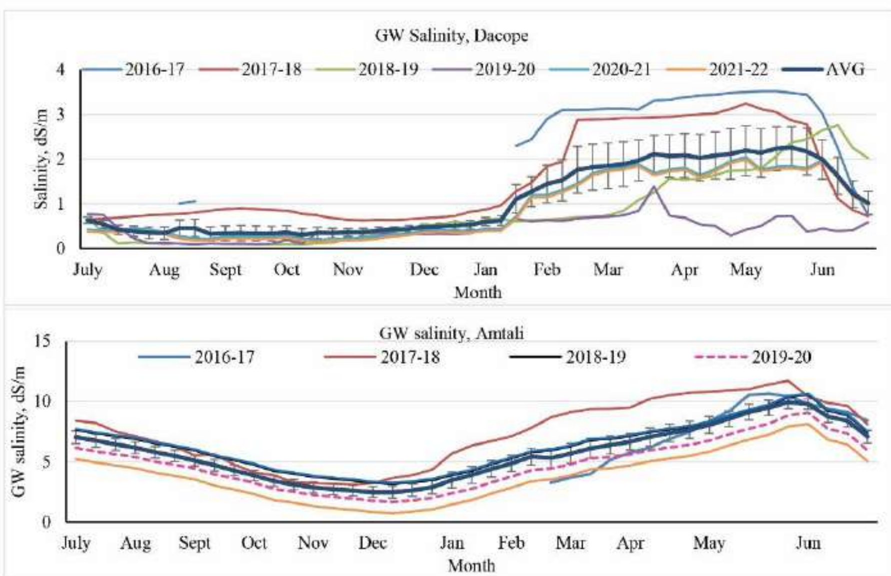


Fig. 15. Groundwater salinity at Dacope and Amtali during 2016-22.

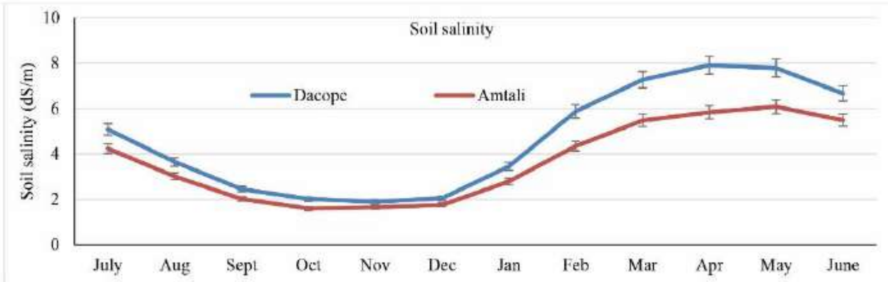


Fig. 16. The average year round soil salinity in Dacope and Amtali areas, 2016-22.

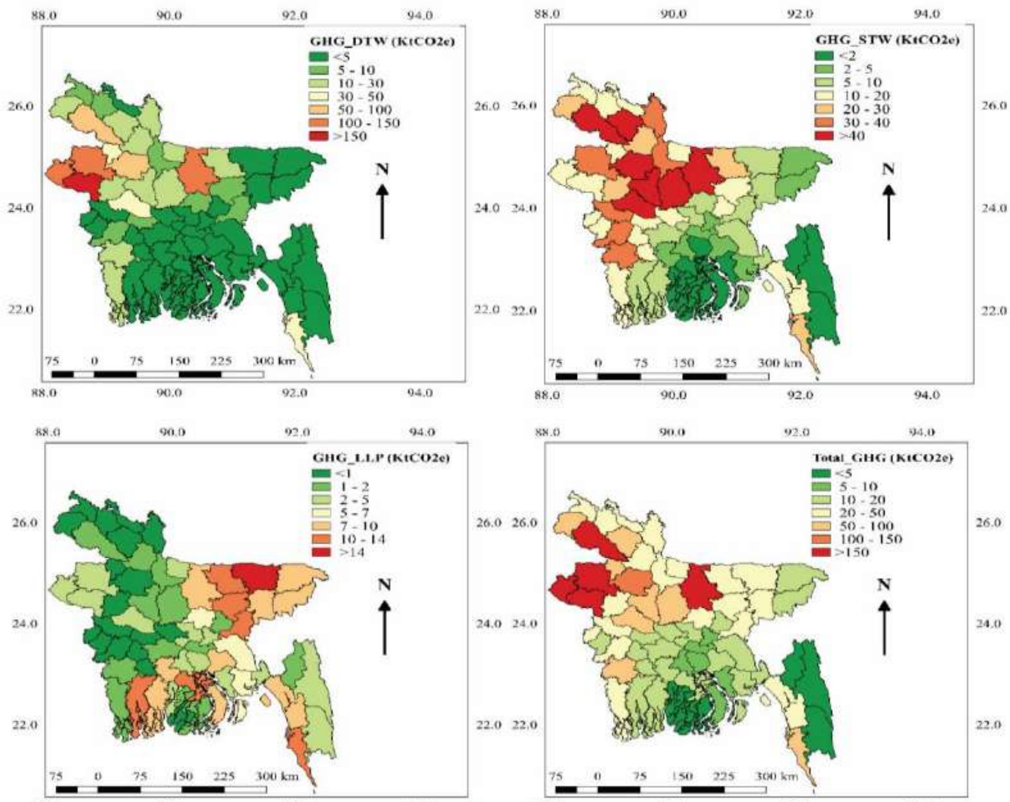


Fig. 17. GHG emission from different irrigation devices and water sources.

Plant Physiology Division

SUMMARY

A total of 31 experiments under seven different projects have been carried out during 2021-22 in Plant Physiology Division of BRRI. In salinity stress, around 400 germplasm and 300 advanced breeding lines were characterized of which 39 genotypes were found tolerant to moderately tolerant at seedling stage. Salinity resistance at reproductive stage, BRRI dhan47 and BRRI dhan99 showed the lowest reduction (6-48% and 22-48% respectively) in grain per panicle followed by BRRI dhan97 (11-56%) under different salinity stress. The yield reduction of tolerant and susceptible check was 27-35% and 35-61% respectively. At 8 dS/m salinity level, the highest yield reduction was observed in PN191 (~59%) followed by CN6 (~52%) and the lowest in BRRI dhan67 (~3%). Increasing salinity level to 10 dS/m, yield reduction ranged from ~51 to ~78% for all the tested lines excluding BRRI dhan67 which was ~42%. Days to heading were also earlier for PN151, BRRI dhan67 and IR58443-6B-10-3 than the other tested genotypes at all salinity levels. For improving salinity tolerance of rice through CRISPR/cas9 system, guide sequence of *OsRR22* gene was properly cloned into the binary vector pC1300-Cas9. Plants were regenerated through *Agrobacterium*-mediated transformation. Genomic DNA was extracted from the leaves of transformed plants using the sodium dodecyl sulfate (SDS) method. Hygromycin phosphotransferase positive plants were identified using HPT primer pair designed from Hygromycin phosphotransferase resistant zone of the Cas9 vector. Some 114 germplasm and 13 advanced breeding lines were screened for two weeks of complete submergence where one germplasm (Acc. no. 1710) were found moderately tolerant. Elongation ability of BRRI dhan91 was evaluated under deep flooding condition. The plant height of the tested varieties ranged from 104.06 cm in BRRI dhan52 to 242.22 cm in Hbj AII and tillering ability ranged from 2.5/hill in Higol digha to 7/hill in Lal digha under 1.5 m deep water condition. The plant height of the attempted variety BRRI dha n91 was found 161.87 cm with poor tillering ability (3.3/hill). In drought tolerance, 343 germplasm and four advanced breeding lines were tested of which 46 germplasms were selected for further evaluation and seven germplasms were selected for donor parent. Two advanced breeding lines BR10540-4-1-2-4-1 and BR10538-2-1-2-3-2 were performed better which were selected for ALART. Selection of new high temperature tolerant breeding lines, an experiment having eight spikelet fertility QTL introgression lines were evaluated with high temperature (35±3 ^{0}C) and high humidity (75±5%) condition during flowering. Out of eight lines, four lines scored 5 and classified as moderately heat tolerant. The rest four lines scored 7 and classified as moderately sensitive to heat stress. Two tolerant donor, N22 and Kachalath scored 3 and 5 respectively. High temperature induced spikelet fertility QTL introgression advanced lines in the background of BRRI dhan28 was tested for observation yield evaluation. A total of 81+52 = 133 lines of BRRI dhan28 and BRRI dhan29 were evaluated in the field condition along with parents for yield potential. Out of the 133 lines, 4 and 21 lines in the background of BRRI dhan28 and BRRI dhan29 respectively, having >0.5 t/ha yield advantage were selected for further evaluation. A marker-assisted introgression of high temperature induced spikelet fertility QTL (qHTSF4.1) for the T. Aus and T. Aman seasons was carried out for BRRI dhan48, BRRI dhan62 and BRRI dhan71 respectively. A total of 60 BC_1F_1 of BRRI dhan48, BRRI dhan62 and BRRI dhan71were planted and after genotyping with R4M30 markers the selected progenies were backcrossed with respective parents and 110 BC_2F_1 seeds were produced. Some 250 rice germplasms and 1,411 advanced breeding lines were screened for seedling stage cold tolerance of which 65 germplasm and 269 advanced breeding lines were selected as moderately cold tolerant at seedling stage. Some 28 advanced breeding lines were characterized in natural field condition where BR11894-R-329 and BR10717-5R-82 was found as moderately cold tolerant at reproductive phase. Three advanced breeding lines (BR8781-16-1-3-P2, BR9829-78-1-2 and BR9830-5-2-2-3) along with two check varieties namely BRRI dhan27 and BRRI dhan48 were evaluated for lodging tolerance.

Advanced breeding lines BR8781-16-1-3-P2 showed lodging tolerance due to their shorter 4th internode length, better wrapping score and higher stem density (51.17 mg/ cm), although they had longer plant height (126.81 cm) and higher moment (1321.67 g.cm). The lodging characters of five BRRI varieties viz. BRRI dhan49, BRRI dhan87, BRRI dhan93, BRRI dhan94 and BRRI dhan95 along with lodging tolerant check variety BR11 were determined. Stem thickness of tested varieties was similar to the check variet BR11. Flag leaf angle was 2-4 degree more in tested varieties than BR11 except BRRI dhan95 which had it 2 degree less. Total wrapping score of BRRI dhan95 was similar to BR11 but other varieties had less score. Panicle weight of tested varieties was 0.16 to 0.2 g higher than check variety BR11 except BRRI dhan95 which had 0.24 g less. Less panicle weight and well wrapped stem of BRRI dhan95 might be the main reason of its lodging tolerance. Five different types of polythene covering on Boro rice seedbed along with control were evaluated. The highest seedling strength was recorded from seedbed having polythene covering during cold wave followed by covering for all the time with opening at both ends and covering for whole night. The lowest seedling mortality rate after transplanting in the main field was recorded from covering during cold wave which was statistically similar to the control. Seedling mortality after transplanting was comparable between covering for all the time with opening at both ends, covering for whole night and covering from 11.0 am to sun set although it was slightly higher than control the treatment. Polythene covering for all time at seedbed had lower seedling strength but higher seedling mortality. Some 246 advanced breeding lines along with Nazirsail, BR22 and BR11 as check varieties were tested to measure the level of photosensitivity at net house of Plant Physiology Division. Two breeding lines (BR11032-4R-31 and BR11046-4R-95) showed strong response in flowering with an increase in photoperiod similar to BR22. On the other hand one local deep-water genotype (Khoiamotor) and one shallow-deep water line (BR10230-7-19-B) showed fairly strong sensitive having RPS (~80%). On the basis of germination percentage BRRI dhan50, BRRI dhan60, BRRI dhan69, BRRI dhan86 and BRRI dhan89 was found highly susceptible to pre-harvest sprouting and BR19, BR16, BRRI dhan63, BRRI dhan45, BRRI dhan36, BR27, BRRI dhan55, BRRI dhan48, BRRI dhan88, BRRI dhan82, BRRI dhan67, BRRI dhan84, BRRI dhan42 and BRRI dhan28 found moderately tolerant to pre-harvest sprouting which had less than 5% pre-harvest sprouting spikelet. Investigation of anatomical differences in the leaves, in comparison to rice, Uri dhan has a greater number of veins and a denser vascular bundle. The mesophyll cells and vascular bundle in the Uri dhan were both well-organized and highly composed compared to rice. The chlorophyll fluorescence-based imaging to characterize the salinity tolerance of rice at seedling stage, IR58443 (standard tolerant check) and IRRI154 (standard sensitive check) were evaluated under soil-based salinity stress for 0, 6 and 12 dS/m stress. Chlorophyll fluorescence image was taken 24 (Day 1), 48 (Day 2) and 72 hrs. (Day 3) after stress application. Initial Fv/Fm values (Day1) were noticeably low, but they progressively increased and were kept very near to normal for the tolerant genotype (IR58443), whereas the pattern was exactly the opposite for the sensitive genotype (IRRI154). For developing male sterile line through CRISPR/cas9 system, guide sequence of TMS5 gene was properly cloned into the binary vector pC1300-Cas9. Plants were regenerated through Agrobacterium-mediated transformation. Genomic DNA was extracted from the leaves of transformed plants using the sodium dodecyl sulfate (SDS) method. Hygromycin phosphotransferase positive plants were identified using HPT primer pair designed from Hygromycin phosphotransferase resistant zone of the Cas9 vector.

SALINITY TOLERANCE

Screening of rice germplasm for salinity tolerance

About 400 rice germplasm along with tolerant check IR58443 and susceptible check IR154 were screened to find out saline tolerant germpaslm at seedling stage at 12 dS/m. Among them only 20 germplasm (namely Genebank Acc. No. 3291, 3141, 3142, 3155, 3157, 3163, 3195, 3196, 3197, 3201, 3204, 3218, 3306, 3346, 3347, 3393, 3397, 3406, 3431 and 3603) were found moderately saline tolerant with SES score 3. The SES score of tolerant and susceptible check was 3 and 9 respectively.

Screening of rice advanced breeding lines for salinity tolerance at Aman 2021

About 100 rice advanced breeding lines along with tolerant check IR58443 and susceptible check IR154 were screened for salinity tolerant at 12dS/m at seedling stage. Among the breeding lines nine genotypes (namely SV1154, SV1155, SV0525, SV0529, SV1176, MTU1010, IR93354:34-B-5-1-23-1RGA-2RGA, M202 and Sahel134) were found moderately tolerant to salinity with SES score 3. The SES score of tolerant and susceptible check was 3 and 9 respectively.

Screening of rice advanced breeding lines for salinity tolerance at Boro 2021-22

About 200 rice advanced breeding lines were screened for salinity tolerance at 12dS/m at seedling stage where tolerant and susceptible check was IR58443 and IR154 respectively. Standard susceptible and tolerant check was used as BRRI dhan89 and BRRI dhan67, BRRI dhan97 respectively. Among the breeding lines 10 genotypes (namely BR11712-4R-333, BR11722-4R-73, BR11722-4R-398, TP24493, IR18T1073, IR15T1319, BR11714-4R-69, BR11714-4R-74, IR 108604-2-1-AJY 3-B-1 and IR16T1661) were found moderately tolerant to salinity with SES score 3. The SES score of tolerant and susceptible check was 3 and 9 respectively and all the standard check had SES score 7.

Characterization of salt tolerant varieties in artificial saline condition for whole growth period during Aman season

An experiment was conducted to know the of salinity tolerance level of newly released saline tolerant BRRI varieties. BRRI dhan47, BRRI dhan67, BRRI dhan97 and BRRI dhan99 was used as saline tolerant variety where IR58443 and IR154 used as tolerant and susceptible check. Soil-based methods described by Gregorio et al. (1997) were followed. Salinity label was maintained as 0, 3, 6, 9 and 12 dS/m. Here it is observed that, BRRI dhan47 and BRRI dhan99 Showed the lowest reduction (6-48% and 22-48% respectively) in grain per panicle followed by BRRI dhan97 (11-56%) under different salinity stresses. The yield reduction of tolerant and susceptible check was 27-35% and 35-61% respectively **(Fig. 1).**

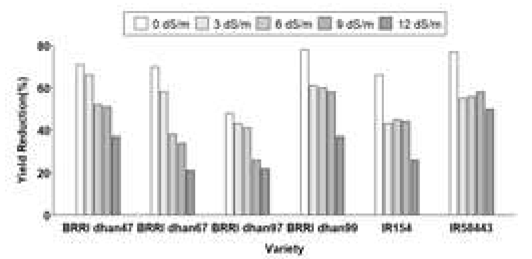


Fig. 1 Percent yield reduction under different levels of salinity stress.

Characterization of advanced breeding lines for salinity tolerance at reproductive stage

The experiment was conducted to evaluate the performance of one PVT and three advanced breeding lines at different salinity levels in the net house condition during Boro 2021-22. Plants were grown in the perforated plastic pots (drilled and lined with canvas) filled with grinded soil. The soil was fertilized with NPKS @ 100, 25, 40 and 25 mg/kg soil. The pots were placed inside a bucket serving as water bath. Three to four pre-germinated seeds were sown at the soil surface of each pot. Seedlings were thinned to two plants per pot two weeks after sowing. Salt stress was applied 50 days after sowing; stress was made by adding NaCl in the bucket at 6, 8 and 10 dS/m. One set of plants were used as control. The experiment was laid out in RCB design with three replications. Different morphological and yield related traits were measured to evaluate the tested genotypes. In this study, genotypes × salinity interaction showed significant results for all the tested parameters except total dry matter per plant. Yield potentiality is the most important indicator for selecting a genotype as future tolerant variety at stress condition. Yield of tested genotypes was decreased gradually with the increasing level of salinity. But with the increase of salinity to 8 dS/m, genotypes BRRI dhan67 produced the highest yield followed by PN232. Increasing salinity level to 10 dS/m, genotypes BRRI dhan67, PN151, PN232 and IR58443 performed better than the other genotypes (**Fig. 2**). All the tested genotypes and checks had shown increasing trends of yield reduction with increasing salinity level (**Fig. 3**). But the reduction was very minimum which was below 50% for all the tested genotypes upto 6 dS/m salinity stress. At 8 dS/m salinity level the highest reduction was observed in PN191 (~59%) followed by CN6 (~52%) and the lowest in BRRI dhan67 (~3%). Increasing salinity level to 10 dS/m, yield reduction ranged from ~51 to ~78% for all the tested lines excluding BRRI dhan67 which was ~42% (**Fig. 3**). Growth duration is another criterion for selecting a variety at salt stressed condition. Days to heading were also earlier for PN151, BRRI dhan67 and IR58443-6B-10-3 than the other tested genotypes at all salinity levels (**Fig. 4**).

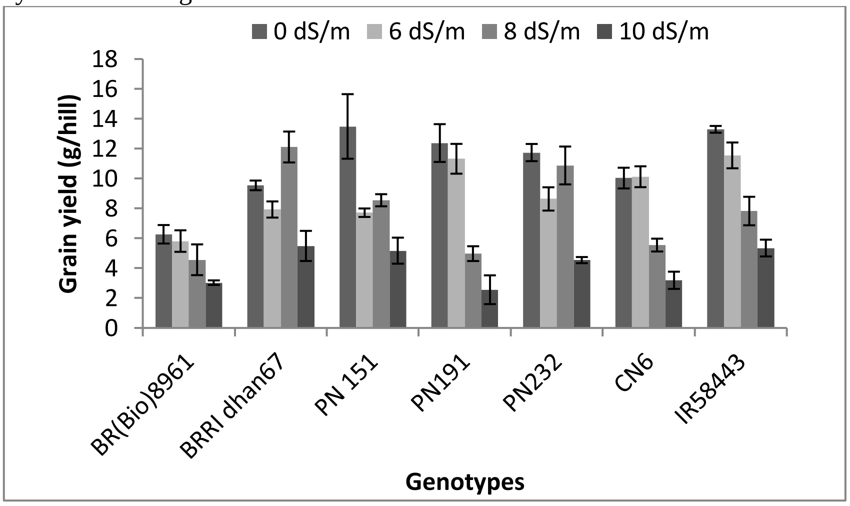


Fig. 2. Yield potential of tested genotypes in varying salinity level. Error bar represents ±SE.

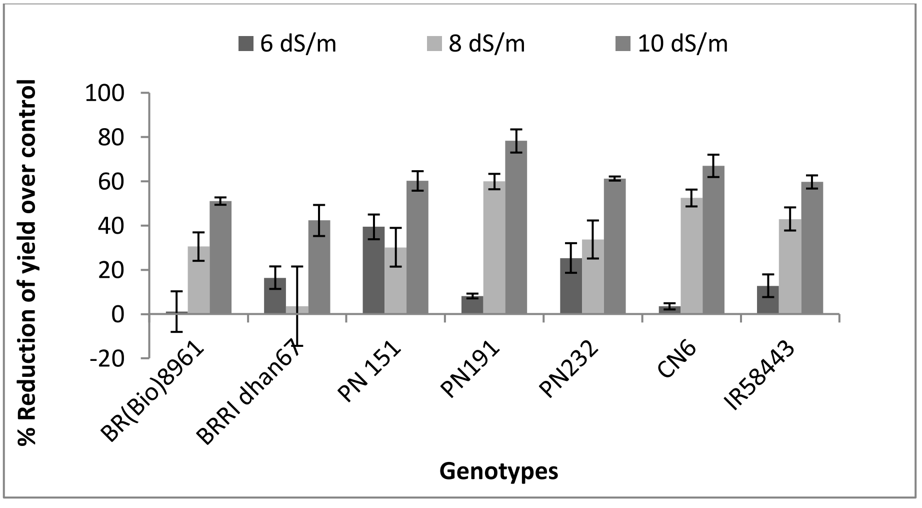


Fig. 3. Reduction of yield over control (%) among the tested genotypes at saline condition. Error bar represents ±SE.

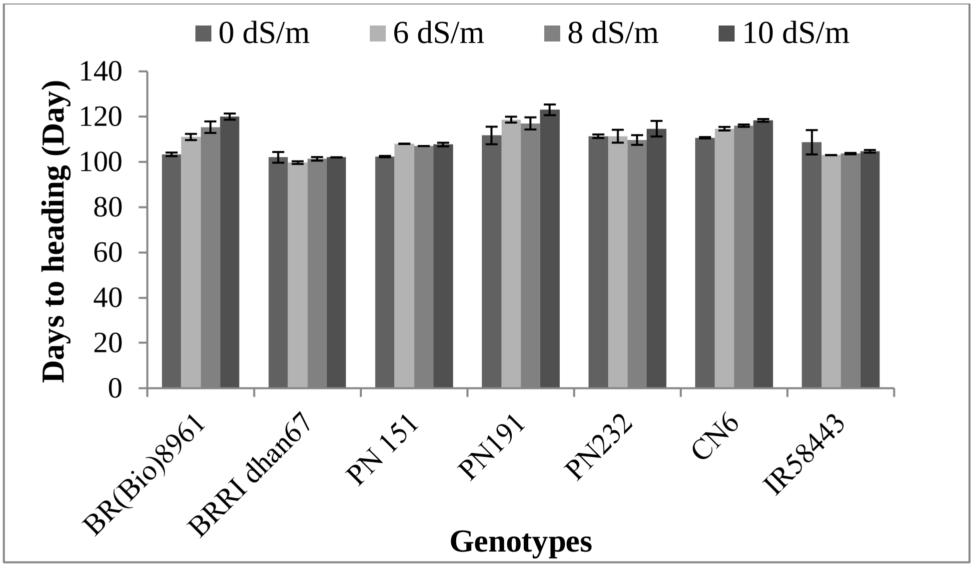


Fig. 4. Days to heading of tested lines and checks in varying salinity levels. Error bar represents ±SE.

CRISPR-Cas9 mutagenesis of the *OsRR22* gene for improving salinity tolerance of rice

Salinity is one of the most important abiotic stress affecting the world rice production. Numerous salt tolerance quantitative trait loci were identified and few of them had been transferred into popular rice varieties via marker-assisted selection (MAS) but none of them showed greater promise. The *OsRR22* gene encodes a 696–amino acid B-type response regulator transcription factor that is involved in both cytokinin signal transduction and metabolism; its loss of function has been reported to significantly increase salt tolerance. To design a CRISPR/Cas9 targeting the *OsRR22* gene in rice, a 19bp guide sequence (5′-AGAGGGATCAATTCCCCGT-3′) was a protospacer adjacent motif lying within the *OsRR22* coding sequence (*LOC_Os06g08440*). The guide sequence was properly cloned into the binary vector pC1300-Cas9 (**Fig. 5**). The binary vector pC1300-Cas9 harboring Cas9/*OsRR22* sgRNA was mobilized into *Agrobacterium tumefaciens* LBA4404 by freeze-thaw method and confirmed through PCR-gel electrophoresis (**Fig. 6**). Plants were regenerated through *Agrobacterium*-mediated transformation. Genomic DNA was extracted from the leaves of transformed plants using the sodium dodecyl sulfate (SDS) method. Hygromycin phosphotransferase positive plants were identified using HPT primer pair designed from Hygromycin phosphotransferase resistant zone of the Cas9 vector (**Fig. 7**). PCRs amplifications are being performed using primer pairs, which generated an amplicon harboring the target site, and the resulting amplicons are being sequenced using the Sanger method.

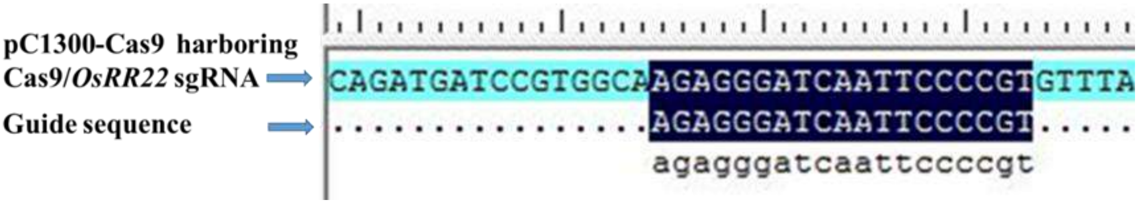


Fig. 5. Confirmation of vector constructs alignment by of recombinant pC1300-Cas9 harboring Cas9/*OsRR22* sgRNA with guide sequence.

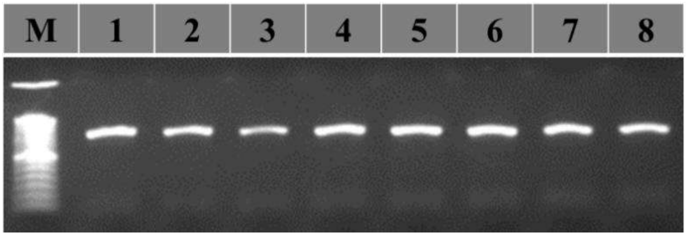


Fig. 6. Confirmation of *Agrobacterium* transformation through PCR-gel electrophoresis. *Agrobacterium tumefaciens* LBA4404 with recombinant pC1300-Cas9 harboring Cas9/*OsRR22 sgRNA* **(Lane 1-8)**. **M**: marker (50 bp DNA ladder).

Fig. 7. Hygromycin phosphotransferase positive plants for salinity tolerance.

SUBMERGENCE TOLERANCE

Identification of rice germplasm and advanced breeding line for two weeks flash flood submergence tolerance

A total of 114 local germplasm, 13 advanced breeding lines were tested along with tolerant checks (FR13A and BRRI dhan79) and sensitive checks (IR42 and BR5) to identify the tolerant germlasm for two weeks under complete submerged condition at the vegetative phase. Eighteen seedlings (6 hills x 3 rows) with 20 cm x 20 cm spacing of 20 day-old for each germplasm were transplanted in a concrete submergence tank. Two weeks after transplanting plants were submerged completely at 1 meter water level and kept submerged condition for 14 days. During submergence period the water of the tank was made turbid twice daily, and the water pH, temperature, dissolved O_2 and turbidity were measured. After 21 days of drain out of water, recovery or survivability score was taken. Survival scoring was done by following standard evaluation system (SES) (IRRI, 2014). The results showed that most of the germplasms were elongating type i.e. plant height exceeds the 1m water level during submerged condition and survivability was very poor. Out of 114 germplasm only one germplasm (Acc. 1710) was found tolerant (SES score 1) having survivability 100 percent but elongating type. The rest of the germplasms were found less tolerant (SES score 9) having survivability 0-38.9 percent with elongating type. Survivability of the tolerant check varieties FR13A and BRRI dhan79 had 100% and 84.9%, respectively whereas susceptible check varieties survived 0%. The average water pH, temperature and dissolved O_2 of the submergence tank were 8.01, 30.48 ℃ and 12.08 mg/L, respectively. The average turbidity of the water tank was 68.15 and 136.95 FNU (Formazin Nephelometric Units) before and after made turbid, respectively during submergence.

Screening of advanced breeding lines for Anaerobic tillering ability under water stagnant condition at T. Aman season

A total of 220 advanced breeding lines along with two BRRI varieties BR10 and BRRI dhan30 were tested to observe the anaerobic tillering ability of the advanced breeding lines under water stagnant conditions. Six seedlings (6 hills x 1 row) with 20 cm x 20 cm spacing of 20 day-old for each line were transplanted in a concrete tank. The water pressure @ 5 cm/week was started from seven days after transplanting and was continued up to 60 cm. The stagnant water was maintained up to maturity. The experiment was conducted to observe the anaerobic tillering ability under medium stagnant (60 cm water pressure) conditions. The plant height, tiller number/hill and survivability were found to ranges from 88-158 cm, 2-8 tillers/hill and 50-100% respectively. Out of 220 advanced breeding lines, 44 lines produced higher tiller/hill (>5) compared to the check varieties BR10 and BRRI dhan30 under water stagnant conditions. Among the 44 higher tiller producing lines, BR11921-4R-356, BR11925-4R-162 and BR11920-4R-521 produced the highest number of tiller/hill under water stagnant conditions. Further validation could be done to confirm the above mentioned lines for anaerobic tillering ability with other agronomic and phenotypic characters.

Evaluation for elongation ability of BRRI dhan91 under deep flooding condition

An experiment was conducted to see the elongation ability of BRRI dhan91 under deep flooding condition. BRRI dhan91 along with FR13A, BRRI dhan79, BRRI dhan51, BRRI dhan52, BR5, BR10260-7-19, Lal khama, Lal digha, Hbj AII, Higol digha, Laxmi digha, Hbj AIV, Hbj AVIII and Koiamotor were tested in this study. Twenty-day-old seedlings were transplanted and two weeks after transplanting water level was increased @ 2 cm per day and stopped when the water level was up to 1.5 m. Data on plant height and tillering was recorded after reaching the water level 1.5 m. The plant height of the tested varieties ranged from 104.1 cm in BRRI dhan52 to 242.2 cm in Hbj AII and tillering ability ranged from 2.5/hill in Higol digha to 7/hill in Lal digha under 1.5 m deep water condition. The plant height of the attempted variety BRRI dhan91 was found 161.9 cm with poor tillering ability (3.3/hill).

DROUGHT TOLERANCE

Screening of rice germplasm for drought tolerance at reproductive phase, T. Aman 2021

Three hundred rice germplasm collected from BRRI genebank along with the check varieties BRRI dhan56, BRRI dhan71 and IR64 were tested during T. Aman season 2021 at farmer’s field in Alimganj, Paba, Rajshahi following Field-managed screening protocol (IRRI, 2008). Thirty-day-old seedlings were transplanted at a spacing of 20 cm x 20 cm. The experiment was laid out in Alpha lattice design with two replications. Standard agronomic management practices were followed. Irrigation was withheld four weeks after transplanting and the field drained out properly for not allowing any standing water until maturity. Out of 300 germplasm, 46 genotypes showed better performance in relation to yield under rainfed condition at reproductive phase, which were selected for further confirmation under control condition in rainout shelter.

Confirmation of performance for advanced breeding lines under control drought condition at reproductive phase

Four advanced breeding lines along with the check varieties BRRI dhan56, BRRI dhan71 and IR64 were evaluated in Plant Physiology net house shaded by polythene sheet at BRRI HQ, Gazipur during T. Aman season 2021. Twenty-five-day-old seedlings were transplanted in drum (56 cm x 43 cm) containing 110 kg puddled soil in two sets where the 1st set was grown in well-watered conditions and 2nd set under stress condition. At panicle initiation stage water was drained out from the 2nd set so that the plants experiences drought stress from the reduction division stage. The water table depth and soil moisture was recorded. At severe drought stress some life saving water was applied and calculated as follows: $= \Pi r^2 h$

Where, r = 56/2 = 28 cm (The radius of the circumference of pot at the base of the hill.)

h = 0.5 cm/day (the approximate evapotranspiration at the period of November December.

Out of four advanced breeding lines BR10540-4-1-2-4-1 performed better followed by BR10538-2-1-2-3-2 **(Table 1.)**

Table 1. Grain yield, filled grain no. and % sterility of four tested genotypes as affected by water stress at reproductive phase.

Designation	Grain yield (g/plant)			Filled grain no./plant		%Sterility	
	Control	Stress	% Reduction	Control	Stress	Control	Stress
BR10538-2-1-2-3-2	39.00	19.87	49.1	1802	1080	27.1	39.5
BR10539-8-1-3-2-2	34.40	10.39	69.8	1579	613	29.7	62.9
BR10539-43-1-1-1-1	30.86	11.29	63.4	1412	656	38.8	67.9
BR10540-4-1-2-4-1	45.94	25.78	43.9	2068	1342	27.4	30.6
BRRI dhan56	35.78	21.7	39.4	1619	1234	24.5	32.9
BRRI dhan71	43.25	25.09	42.0	1878	1270	25.9	28.4
IR64	33.67	10.23	69.6	1475	512	29.4	65.8
LSD (5%)	7.9		-	390.5		9.5	
CV (%)	20.0		-	20.7		17.5	

Evaluation of previously selected germplasm under drought stress at reproductive phase in the rain-out shelter

This experiment was conducted in the rain-out shelter, Plant Physiology Division at BRRI HQ, Gazipur during T. Aman season, 2021 to evaluate previously selected 43 germplasm with the check varieties BRRI dhan71 and IR64. Thirty-day-old seedlings were transplanted in puddled soil at a spacing of 20 cm x 20 cm. Standard agronomic management practices were followed. Weeds were controlled when needed. Four weeks after transplanting, the plots were drained out for inducing drought stress at reproductive phase. The water table depth was below 1 m and soil moisture was around 20%. Under control drought condition in the rainout shelter, out of 43 germplasm BRRI Genebank Acc. no. 1934 yielded the highest followed by Acc. no. 1996, 2022, 2288, 2290, 2292 and 2420. The sterility percentage of these genotypes was less than 50 (**Table 2**).

Table 2. Observed growth characteristics, yield and yield components of tested 43 genotypes.

BRRI Gene bank Acc. no.	Filled grain no./plant	Sterility (%)	Grain wt. (g)/plant
1934	580.2	28.5	11.53
1939	379.2	57.7	5.86
1942	145.2	82.3	2.59
1946	247.8	58.1	4.67
1947	240.0	49.0	4.02
1950	164.0	64.3	3.56
1953	196.3	58.7	4.28
1955	438.7	44.3	8.60
1996	641.3	34.6	9.58
1998	592.3	39.3	5.89
2004	654.2	27.9	6.22
2022	672.3	30.6	10.13
2036	315.5	33.3	5.69
2134	496.7	35.9	7.79
2285	273.0	55.7	4.11
2286	597.3	42.7	5.92
2288	440.8	45.3	9.17
2290	495.0	25.3	9.10
2291	392.8	22.8	6.79
2292	520.2	31.4	9.45
2293	458.0	17.2	8.46
2294	417.7	31.9	8.02
2298	441.8	34.1	8.75

2364	405.7	35.9	8.99
2390	269.2	60.4	5.96
2400	268.8	49.5	5.57
2402	316.3	37.8	6.14
2405	412.8	34.4	4.70
2409	524.7	41.8	7.99
2415	156.5	54.5	3.41
2416	368.7	41.2	7.28
2420	423.2	32.3	9.50
2425	207.0	50.8	4.15
1995	253.5	50.3	5.30
1997	312.2	60.7	3.89
2010	222.8	52.4	5.48
2027	210.8	35.6	4.04
2297	271.0	42.1	5.18
2327	277.2	51.6	4.87
2385	466.5	43.2	8.12
2389	255.7	58.6	4.59
2401	298.5	43.7	5.84
2410	371.5	56.3	7.30
BRRI dhan71	926.9	18.8	18.95
IR64	237.3	54.8	4.35
--	306.3	26.7	5.2

High temperature tolerance of spikelet fertility QTL introgression lines under controlled high temperature condition

Global warming has become a serious threat to the productivity of rice in the tropical and sub-tropical regions like South-Asia including Bangladesh. It was estimated and reported that, every 1℃ increase in global mean temperature will reduce global rice yields by 3.2%. Considering the role of rice in Bangladesh food security and the negative effect of global warming on rice productivity, there is an urgent need to breed thermotolerant rice. Selection of tolerant breeding lines from current breeding materials is necessary for the development of new high temperature tolerant variety with high yield potential. To facilitate breeding for heat tolerance, an experiment having eight spikelet fertility QTL introgression lines were evaluated with high temperature (35±3 ^{0}C) and high humidity (75±5%) condition during flowering. Out of eight lines, four lines scored 5 classified as moderately heat tolerant. However the rest four lines scored 7 classified as moderately sensitive to heat stress (**Table 3**). Two tolerant donor, N22 and Kachalath scored 3 and 5 respectively.

Table 3. Spikelet fertility (%) under controlled high temperature (35±3^{0}C) and high humidity (75±5%) condition during flowering of 8 *qHTSF4.1* introgression lines along with parents and checks. Values are the mean±SE (n=9).

Line/Parent	Spikelet fertility under control condition	Spikelet fertility under HT* stress condition	SES# based on spikelet fertility under HT stress
Line-2	68.94±4.49	48.99±3.60	5
Line-3	75.59±4.94	46.45±7.70	5
Line-4	73.46±2.18	29.01±5.15	7
Line-5	68.20±3.90	58.02±5.70	5
Line-6	60.48±4.73	46.83±5.62	5
Line-7	63.38±6.96	27.34±2.93	7
Line-8	70.95±2.65	28.11±1.23	7
Line-9	52.09±4.23	29.99±6.39	7
BRRI dhan28	61.92±6.52	33.14±4.37	7
BRRI dhan29	76.92±5.55	37.00±6.40	7
N22	76.39±6.56	65.61±60.00	3
Kachalath	66.01±9.04	47.9±11.71	5

*HT = High temperature, #SES = Standard evaluation system.

Observational trial of high temperature induced spikelet fertility introgression lines in the background of BRRI dhan28 and BRRI dhan29

High temperature induced spikelet fertility QTL introgression advanced lines in the background of BRRI dhan28 was tested for observation yield evaluation during Boro 2021-22. A total of 81+52 = 133 lines of BRRI dhan28 and BRRI dhan29 were evaluated in the field condition along with parents for yield potential. A total of 100 plants per line were planted in rows of 25 plants x 4 rows per line during 29 November 2021 sowing and 9 January 2022 planting. Out of the 133 lines, 4 and 21 lines in the background of BRRI dhan28 and BRRI dhan29 respectively, having >0.5 t/ha yield advantage were selected for further evaluation.

Marker assisted introgression of high temperature induced spikelet fertility QTL (qHTSF4.1) in the background of BRRI dhan48 and BRRI dhan62

Bangladesh already faces increasingly extreme weather including droughts, floods and storms, but high temperatures/heat waves/heat shock have become a serious danger to rice production in recent years. During the anthesis/flowering stage, rice is susceptible to high temperatures (generally seven days before and after heading). Previously, high temperature stress was thought to be a problem only for Aus rice; later, it was thought to be a problem for long duration Boro and late Boro (Boro rice grown after potato harvest) during April to May, and sometimes extended to June/July when rainfall becomes very low or non-existent. However, due to the introduction of short-season T. Aman varieties, the issue has been extended to T. Aman rice as well. If rainfall is low during September-October, the short-duration T. Aman cultivars are at risk of high temperature-induced spikelet sterility. In light of this, a marker-assisted introgression of high temperature induced spikelet fertility QTL (qHTSF4.1) for the T. Aus and T. Aman seasons was carried out for BRRI dhan48, BRRI dhan62 and BRRI dhan71 respectively. A total of 60 BC_1F_1 of BRRI dhan48, BRRI dhan62 and BRRI dhan71were planted and after genotyping with R4M30 markers the selected progenies were backcrossed with respective parents and 110 BC_2F_1 seeds were produced.

COLD TOLERANCE

Screening of rice genotypes for seedling stage cold tolerance

Some 250 BRRI genebank germplasm and 1411 advanced breeding lines along with four check varieties namely BRRI dhan28, BRRI dhan36, Vhutan and HbjB-VI were tested for seedling stage cold tolerance in cold water tanks at artificial condition. Seeds were sown in plastic trays (60 cm length x 30 cm breadth x 2.5 cm height) filled with gravels and crop residue free granular soil and allowed to grow until 3-leaf stage. The plastic trays were then placed into cold water tanks adjusted to constant temperature at 13°C. Out of 250 Genebank germplasm, 38 accessions (Genebank Acc. no. 2556, 2558, 2559, 2560, 2561, 2563, 2564, 2565, 2566, 2575, 2576, 2577, 2578, 2579, 2588, 2589, 2618, 2635, 2637, 2639, 2646, 2656, 2657, 2658, 2659, 2660, 2661, 2663, 2664, 2667, 2670, 2671, 2674, 2684, 2685, 2686, 2688, 2691) showed moderately cold tolerant at seedling stage. Out of 1411 advanced breeding lines 334 lines were selected of which 65 and 269 lines were found cold tolerant and moderately cold tolerant at seedling stage, respectively. Rest of the genotypes were susceptible to highly susceptible.

Evaluation of advanced breeding lines for reproductive stage cold tolerance

Some 15 advanced breeding lines along with the check varieties namely BRRI dhan28, BRRI dhan67, BRRI dhan88, BRRI dhan89, BRRI dhan92 and BRRI dhan96 were evaluated for reproductive stage cold tolerance at natural field condition. There were two seeding times 21 October and 25 November (control). Thirty-five-day-old seedlings were transplanted in the main field. Early planting was done with a view to falling rice reproductive phase at cold stress. Cold tolerance of rice genotypes were measured visually based on vegetative growth and leaf discoloration score at vegetative phase. We mainly focused on spikelet sterility for reproductive phase cold tolerance. However, data on date of flowering and maturity, plant height, panicle per hill, panicle length, last internode length, last leaf sheath length, panicle degeneration and exertion, filled and unfilled grain per panicle, grain yield and yield components were recorded for better understanding of cold tolerance of specific rice genotypes. An advanced breeding line BR11894-R-329 showed cold tolerance at vegetative phase as it had very little or no leaf discoloration with better vegetative growth. While, BR11894-R-169 was found the most cold susceptible at vegetative phase although it had sufficient growth but leaf discolored greatly. Growth duration increased by natural cold in early planting of BR11894-R-134, BR10715-5R-1, BR11894-R-110, BR10715-5R-9, BR11894-R-309 was less than BRRI dhan67. In early sowing/planting, grain yield of BR11894-R-110 and BR11894-R-134 was significantly higher than BRRI dhan28, BRRI dhan67, BRRI dhan96 and BRRI dhan88 but statistically similar to BRRI dhan89 and BRRI dhan92. Another three lines BR11894-R-3099, BR11894-R-169 and BR11894-R-299 had comparable yield to BRRI dhan67. Two long duration breeding lines BR10715-5R-1 and BR10715-5R-9 had statistically similar yield to BRRI dhan89 and BRRI dhan92 (**Table 4**).

In 25 November sowing, none of the tested rice genotypes out yielded BRRI dhan89 and BRRI dhan92. However, nine advanced lines BR10715-5R-1, BR11894-R-134, BR11894-R-110,

BR10715-5R-9, BR11894-R-329, BR11894-R-230, BR11894-R-233, BR11894-R-105 and BR11894-R-169 had significantly higher yield than BRRI dhan88 but statistically similar to BRRI dhan67, BRRI dhan89 and BRRI dhan92 (**Table 4**).

Percent sterility was increased significantly in early planting over usual planting time. In 21 October sowing, percent sterility of BR10715-5R-9, BR10715-5R-1, BR11894-R-134, BR11894-R-110, BR11894-R-169, and BR11894-R-309 were statistically similar to BRRI dhan67.

Table 4. Growth duration, yield and sterility of tested rice genotypes.

Genotypes	Growth duration (day)		Yield (t/ha)		Sterility (%)	
	21Oct	25Nov	21Oct	25Nov	21Oct	25Nov
BR11894-R-105	177.0	154.6	3.25	6.71	42.05	20.28
BR11894-R-169	178.0	150.0	3.98	6.67	31.82	15.64
BR11894-R-230	178.0	149.0	3.64	6.72	39.42	18.93
BR11894-R-233	177.0	150.3	3.63	6.72	37.52	15.34
BR11894-R-270	177.6	150.0	3.33	6.48	37.76	16.10
BR11894-R-329	176.0	150.6	3.68	6.79	39.79	16.60
BR11894-R-110	172.5	155.0	5.34	6.83	31.76	17.54
BR11894-R-134	172.3	155.3	5.21	6.84	31.27	15.76
BR11894-R-165	178.3	150.6	2.85	6.15	43.20	18.64
BR11894-R-299	172.6	152.0	3.90	6.10	39.58	21.32
BR11894-R-304	177.0	148.3	2.86	5.56	39.80	16.81
BR11894-R-309	173.0	154.0	4.16	6.56	32.54	18.83
BR11894-R-80	179.3	149.6	2.87	6.40	39.63	19.53
BR10715-5R-1	180.3	163.0	5.56	6.84	30.00	20.22
BR10715-5R-9	178.3	160.3	5.62	6.81	29.01	16.43
BRRI dhan28 (ck)	173.6	148.6	3.61	6.01	40.65	14.92
BRRI dhan67 (ck)	170.0	150.3	4.14	6.84	29.16	13.26
BRRI dhan96 (ck)	175.6	150.0	3.60	6.59	40.49	12.41
BRRI dhan89 (ck)	179.0	163.0	5.53	7.07	28.50	16.61
BRRI dhan92 (ck)	180.0	163.3	5.62	7.08	27.94	18.13
BRRI dhan88 (ck)	177.6	149.6	2.58	6.02	43.00	15.87
$LSD_{5\%}$ Genotype (G)	3.07		0.41		3.37	
$LSD_{5\%}$ Sowing time (S)	0.94		0.24		1.01	
$LSD_{5\%}$ for G*S	4.34		0.62		4.63	

Considering all these parameters five short to medium duration advanced breeding lines (BR11894-R-110, BR11894-R-134, BR11894-R-169, BR11894-R-299 and BR11894-R-309) and two long duration lines (BR10715-5R-9 and BR10715-5R-1) were selected as moderately cold tolerant (**Table 4**).

Characterization and evaluation of some selected rice genotypes for cold tolerance

Some 11 advanced breeding lines, two exotic varieties along with five check varieties namely BRRI dhan28, BRRI dhan67, Minasahi and HbjB-VI were characterized and evaluated in natural field condition. There were three seeding times 15 October, 1 November and 15 November (control). Thirty five-day-old seedlings were transplanted in the main field. Early planting (15 October and 1 November) was done with a view to falling rice reproductive phase at cold stress. Changes in different parameters of rice after natural cold treatment were compared with control treatment. In early planting, all rice genotypes experienced cold stress at reproductive phase. Cold stress caused longer growth duration, shorter last internode length as well as plant height, poor panicle exertion and higher percentage of sterility over control treatment in all rice genotypes. Considering above parameters previously selected advanced rice genotypes BR10717-5R-82 was selected as moderately cold tolerant line which was similar to BRRI dhan67. Other four rice genotypes such as Black rice (Phil), GB-34, BR11001-5R-37 and BR11000-5R-27 were found moderately cold susceptible lines at reproductive phase. However, rest of the rice genotypes viz BR11001-5R-2, TP30753, BR11662-11-5-3, BR11663 (132A3)-6-2, BR11000-5R-4, BR11894-R-R-R-345, BR11338-5R-39 and BR11338-5R-12) were susceptible at reproductive stage.

Evaluation of lodging tolerance of some advanced breeding lines, T Aus 2021

Three advanced breeding lines (BR8781-16-1-3-P2, BR9829-78-1-2 and BR9830-5-2-2-3) along with two check varieties namely BRRI dhan27 and BRRI dhan48 were evaluated for lodging tolerance in Aus 2021 season in BRRI HQ farm, Gazipur. Just after heading, 10 randomly selected plants were cut at culm base. Visible internode length (1st to 5th internode) and total internode length/culm length were measured using meter scale. Forth internode diameter and thickness were measured by slide calipers and micrometer respectively. Wrapping score were done by visual observation. Flag leaf angle was measured using 180 degree angle ruler. Stem density were measured in terms of dry weight per unit length of total stem length. Bending moment (gm cm) was calculated using total fresh weight of plant above ground (gm) and culm length (cm). Visual lodging rate of a variety was calculated as percent logged area. Panicle exertion, panicle length and panicle weight were measured at maturity.

Forth internode length of BR8781-16-1-3-P2, BR9829-78-1-2 and BR9830-5-2-2-3 were lower than BRRI dhan27 but comparable with BRRI dhan48. However, BR8781-16-1-3-P2 had the shortest forth internode length. Forth internode diameter of BR8781-16-1-3-P2 and BR9829-78-1-2 were significantly higher than BRRI dhan48 but similar to BRRI dhan27. Stem thickness of tested varieties were similar to check varieties. Wrapping score of BR9829-78-1-2 was statistically similar to BRRI dhan48 but BR8781-16-1-3-P2 had significantly higher wrapping score than the check varieties. Flag leaf angle of BR8781-16-1-3-P2 was about five degree less than the check varieties. On the other hand it had significantly higher stem density. Bending moment of BR8781-16-1-3-P2 and BR9829-78-1-2 were significantly higher than the check variety BRRI dhan48. BR9830-5-2-2-3 had similar moment to BRRI dhan48. Both panicle length and weight of tested varieties were significantly higher than the check varieties. Panicle exertion of BR8781-16-1-3-P2 and BR9830-5-2-2-3 were similar to BRRI dhan48 but lower than BRRI dhan27. Visual lodging rate of BR8781-16-1-3-P2 (3.33%) was significantly lower than both the check varieties. However, visual lodging rate of BR9829-78-1-2 and BR9830-5-2-2-3 was statistically similar to BRRI dhan48 but lower than BRRI dhan27. Advanced breeding lines BR8781-16-1-3-P2 showed lodging tolerance due to its shorter fourth internode length, better wrapping score and higher stem density (51.17 mg/cm), although it had longer plant height (126.81 cm) and higher bending moment (1321.67 g.cm)

Studies on lodging tolerance of T. Aman rice varieties at reproductive phase

An experiment was conducted in T Aman 2021 season in BRRI HQ farm, Gazipur to determine the lodging characters of five BRRI varieties viz. BRRI dhan49, BRRI dhan87, BRRI dhan93, BRRI dhan94 and BRRI dhan95 along with lodging tolerant check variety BR11. Four sets of seeds were sown on 20 June, 5 July, 20 July and 5 August 2021 at 15 days interval. Twenty-five-day-old seedlings were transplanted in the main field. Just after heading, data were recorded on visible internode length (1st to 5th internode), total internode length/culm length, internode diameter and thickness, wrapping score, flag leaf angle, stem density, bending moment and visual lodging rate. Data on panicle exertion, panicle length, panicle weight, grain yield and yield components were recorded at maturity.

When seeds sown before 15 July in first and second sets, BRRI dhan87, BRRI dhan93, BRRI dhan94 were lodged completely, while BRRI dhan49 lodged partially. BRRI dhan95 did not lodge in these two sets which was comparable to lodging tolerant check variety BR11. However, none of the varieties were lodged if seeds were sown after 15 July in third and forth set. Forth internode length was the longest in BRRI dhan87 followed by BRRI dhan93 and BRRI dhan94 which was higher than BR11. It was comparable between BRRI dhan49 and BRRI dhan95 but higher than BR11. Stem thickness of tested varieties was similar to check varieties BR11. Flag leaf angle was 2-4 degree more in tested varieties than BR11 except BRRI dhan95 which had 2 degree less. Total wrapping score of BRRI dhan95 was similar to BR11 but other varieties had less score. Panicle weight of tested varieties was 0.16 to 0.2 g higher than the check variety BR11 except BRRI dhan95 which had 0.24 g less. Less panicle weight and well wrapped stem of BRRI dhan95 might be the main reason of its lodging tolerance.

Effect of polythene covering on seedling raising in Boro season

Sprouted seeds of BRRI dhan88 were shown in puddle seedbeds on 22 December 2021. It was covered by transparent polythene sheet. Five different types of polythene covering treatment at seedbed viz. covering for all time, covering for 24 hrs during cold wave, covering from 11.0 am to sun set, covering for whole night and covering for all time with opening at both end of the seedbed cover along with control were used. The longest seedling was recorded from covering for all time followed by covering from 11.0 am to sun set and covering for all time with opening at both ends of the seedbed cover. Fresh weight of seedling was significantly higher in covering for all time with opening at both end than all other treatments. However, highest seedling strength was recorded from seedbed having polythene covering during cold wave followed by covering for all time with opening at both end and covering for whole night. The lowest seedling mortality rate after transplanting in the main field was recorded from covering during cold wave, which was statistically similar to the control. Seedling mortality after transplanting was comparable between covering for all time with opening at both ends, covering for whole night and covering from 11.0 am to sun set although it was slightly higher than control treatment. Polythene covering for all time at seedbed had lower seedling strength but higher seedling mortality.

GROWTH STUDIES

Effect of sowing time on growth and yield of newly released Aman varieties

Newly released three BRRI developed Aman varieties (BRRI dhan93, BRRI dhan94 and BRRI dhan95) along with BR11 and BRRI dhan49 were evaluated to observe the yield and growth under different seeding time during Aman 2021. The seeding was done in four different splits of set (1st set = 20 June, 2nd set=5 July, 3rd set=20 July and 4th set=5 August) highest yield of the BRRI dhan93 was observed at the 3rd set (4.34 t/ha) with 128 days growth duration followed by 4th set (4.21 t/ha but which were statistically similar. Statistical similar highest yield was observed in casesaf 3rd and 4th set for BRRI dhan94 (around 4.54 t/ha) with 122 to 128 days of growth duration. BRRI dhan95 produced maximum yield (5.84 t/ha) at 2nd set of experiment with 124 days of growth duration. On the other hand the highest yield (4.92 t/ha) of BR11 was found at the 1st set but which was statistically similar to 2nd and 3rd set with 122-133 days of growth duration. BRRI dhan49 had no significant variation in yield among the different sowing time and maximum yield (5.0 t/ha) was found at the 3rd set (**Fig. 8**). The range of growth duration of BRRI dhan49 was 119 to 133 days.

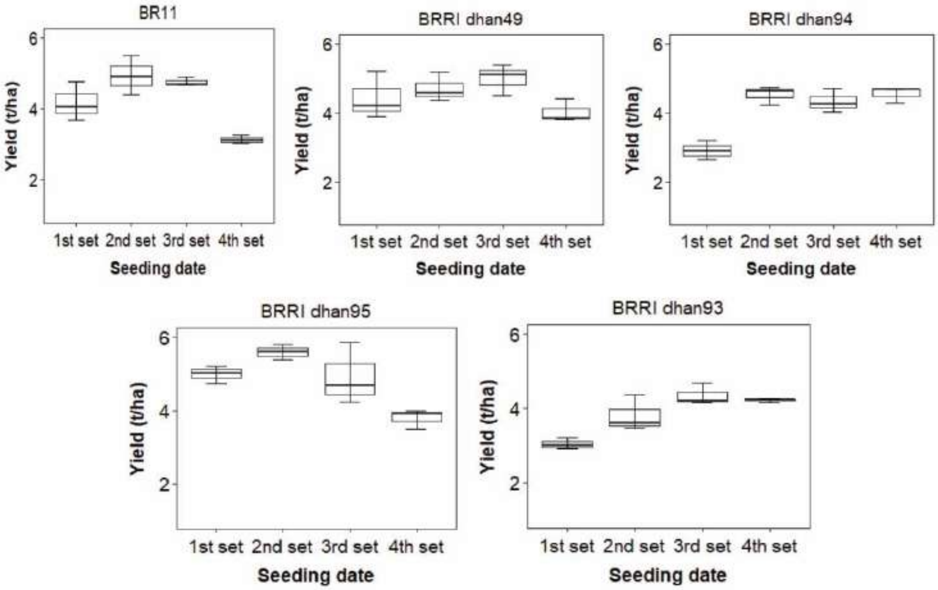


Fig. 8 Yield of the selected varieties under different seeding dates.

Effect of sowing time on growth and yield of newly released Boro varieties

Four newly released Boro varieties (BRRI dhan96, BRRI dhan97, BRRI dhan99 and Bangabandhu dhan100 were seeded at four different set between 15th November to 30 December at 15 days interval to observe the growth and yield. Among the four varieties BRRI dhan96 produced the highest yield at 2nd (6.5 t/ha) followed by 1st set (5.9 t/ha) which was statistically similar. The highest growth duration was observed at 1st set followed by 2nd, 3rd and 4th set (154-130 days). There was no significant yield difference found among 1st to 3rd set for BRRI dhan97 and Bangabandhu dhan100 the yield range was 5.3 to 5.8 t/ha and 4.6 to 5.7 t/ha respectively with 145-163 days and 145-159 days of growth duration respectively. BRRI dhan99 produced the highest yield at 2nd set of experiment. (6.3 t/ha) with 149 days of growth duration (**Fig. 9**).

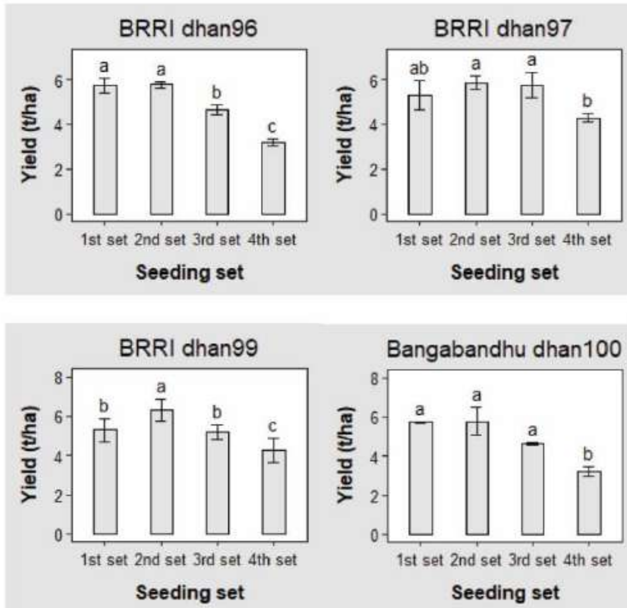


Fig. 9. Yield of four new Boro varieties under different seeding time.

Screening of Pre-harvest sprouting of some BRRI varieties

Thirty-six BRRI varieties were used to evaluate pre harvest sprouting (PHS) of spikelet. At research field artificial condition were created to sprout the seed by wrapping the selected panicle with wet cloth at 50 and 80% maturity stage for seven days. After seven days the panicles were harvested and counted the germinated spikelet. On the basis of germination percentage BRRI dhan50, BRRI dhan60, BRRI dhan69, BRRI dhan86 and BRRI dhan89 was found highly susceptible to pre-harvest sprouting and BR19, BR16, BRRI dhan63, BRRI dhan45, BRRI dhan36, BR27, BRRI dhan55, BRRI dhan48, BRRI dhan88, BRRI dhan82, BRRI dhan67, BRRI dhan84, BRRI dhan42 and BRRI dhan28 were found moderately tolerant to PHS which had less than 5% PHS spikelet (**Fig. 10**).

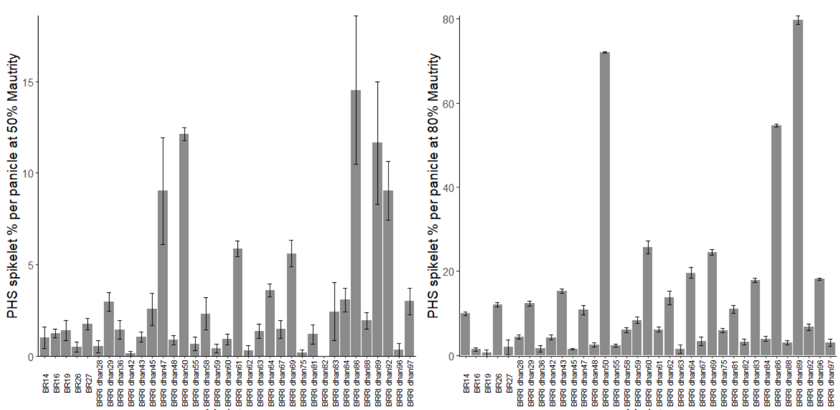


Fig. 10**.** Pre-harvest sprouting spikelet percentage at 50% and 80% maturity.

Identification of regeneration ability of Aus rice varieties

BRRI dhan42, BRRI dhan65, BRRI dhan83, Morichboti, Hasikalmi, DA dhan31 were used to observe the regeneration ability at the vegetative stage. Thirty-day after sowing plant were bending by mowing to break the apical dominance. None of the genotypes performed better in terms of tillering ability than the control condition.

Determination of growth phase of short duration (60 days in India) Aus rice varieties

Pande dhan and BRRI dhan42 were direct seeded to determine the duration of the different growth phases and yield of short duration Aus variety of india. Pande dhan was found higher growth duration (2 weeks more than the check BRRI dhan42).

Phenological development of two newly released BRRI varieties

Crop phenology is important for choosing cultivars with an appropriate growth period and for determining the timing of management practices such as planting, fertilizer application and harvesting. The accurate rice phenological development stages estimation is also important for rice yield estimation in different climatic conditions. The evaluation of phenology plays a pivotal role in assessment of the effects of climate change and the development of adaptation practices. BRRI developed two modern Boro rice varieties BRRI dhan88, BRRI dhan92 and IR64 were selected to execute the experiment on three different sowing dates. Three different sowing dates were 3 April, 18 April, and 3 May. Seedlings were grown in seedbed. Twenty five-day-old seedlings were transplanted in the field using single seedling per hill at 20×20 cm spacing. The plot size was 3×6 m^2. The study was laid out in RCBD with three replications

Fertilizers were applied as urea, triple superphosphate, muriate of potash, and gypsum at the rate of 165-60-105-67 $kgha^{-1}$ for urea, TSP, MoP, and Gypsum, respectively. Full doses of triple superphosphate, muriate of potash, and gypsum were incorporated at the final land preparation time. Urea was applied in the three equal splits at 10, 25 days after transplanting and 3rd dose seven days before PI. All the fertilizers were applied as per BRRI recommendation. The crop was kept weed free throughout the growth period. Adequate measures were taken to keep the insect infestation to a minimal.

The results of different parameters at Aus season indicated that there was significant difference among the varieties and seeding dates of. Plant height was found the highest at 3rd seeding. Number of panicle per m^2 varied from 197 to 302. The percent sterility was maximum in IR64 in 1st seeding and minimum in BRRI dhan88 in 2nd seeding. The highest 1000-grain weight was observed in IR64 grown at set 1 and the lowest in BRRI dhan88 grown at set 3. Grain yield drastically reduced irrespective of variety and seeding time due to high sterility. It is the number of filled spikelets and the spikelet size that govern grain yield of rice (Yoshida, 1981). Number of panicles and number of filled spikelets per unit area and (TGW) (grain size) are the major determinants of grain yield. Figure 11 shows the graphical representation of maximum. temperature of flowering period (5 days before and after 50% flowering) of the varieties shown in **fig.11**. The emerged panicle exposed to temperature higher than the critical threshold of 33°C might increase spikelet sterility in natural condition of the modern variety. The growth duration was higher in 2nd seeding irrespective of varieties (**Table 5**).

Table 5. Interaction effects between variety and date of seeding on yield and yield components.

Variety × date of seeding	Plant height (cm)	Panicle per m^2	Sterility (%)	1000-grain weight (gm)	Yield (t/ha)	Duration (from seeding to maturity) (days)
BRRI dhan88 ×Set 1	92.22	280.56	58.41	20.46	2.88	105
BRRI dhan88 ×Set 2	87.78	255.56	45.54	20.29	1.93	106
BRRI dhan88 × Set 3	99.67	255.56	45.62	19.05	2.51	100

Variety × date of seeding	Plant height (cm)	Panicle per m^2	Sterility (%)	1000-grain weight (gm)	Yield (t/ha)	Duration (from seeding to maturity) (days)
BRRI dhan92 × Set 1	118.44	197.22	66.47	22.49	1.52	133
BRRI dhan92 × Set 2	116.00	222.22	62.15	22.19	1.31	139
BRRI dhan92 × Set 3	134.67	227.78	67.54	21.66	1.89	132
IR64 × Set 1	107.67	211.11	71.51	24.01	1.22	126
IR64 × Set 2	108.78	302.78	70.29	23.06	1.42	132
IR64 × Set 3	110.11	213.89	65.98	21.71	1.49	127
LSD at 5% level	9.23	39.95	15.99	1.38	1.02	0.00

Seed sowing: Set 1: 4 April 2021, Set 2:18 April 2021, Set 3: 3 May 2021

PI and flowering stage

Irrespecty of varieties there was an increase in the duration of the sprouting to panicle initiation stage in 2nd sowing and then decreased in third sowing. It took 85 days when seed was sown at the beginning of April and 91 days for mid-April sowing and then decreased to 84 days for the variety BRRI dhan92. Similar trend was observed for the variety IR64. For BRRI dhan88, the days required for PI almost similar in 1st and 2nd sowing but it was decreased when sowing was done at the beginning of May. The days required from PI to 50% flowering was taken in consideration for flowering stage. The time required for 50% flowering (from PI to 50% flowering) and maturity (from 50% flowering to maturity) more or less similar irrespective of varieties and sowing time (**Table 6.**)

Growing degree days (GDD)

Degree days expresses the influence of mean temperature on the developmental rate (the reciprocal of the duration of any phase). It can be used for phenological forecasting of a rice crop. The tested varieties varied in growing degree days (°Cd) requirements both for panicle initiation and flowering (**Table 7**). The degree days (°Cd) requirements for panicle initiation were 1229.67±53.63, 1808.84±48.08, 1689.68±43.98, while for flowering 472.74±12.58, 516.83±0.507, 504.16±6.27 for BRRI dhan88, BRRI dhan92 and IR64 respectively.

Table 6. Growth stage of rice varieties as affected by sowing time in Aus season 2021, Plant Physiology Division, BRRI.

Sprouting date	Variety	Day to PI (from prouting sprouting)	Day to 50% flowering (from PI)	Day to Maturity (from 50% flowering)	Day to Maturity (from sprouting)
2 Apr 2021	BRRI dhan88	60	23	23	106
	BRRI dhan92	85	25	24	134
	IR64	80	24	23	127
17 Apr 2021	BRRI dhan88	61	23	23	107
	BRRI dhan92	91	25	24	140
	IR64	85	24	24	133
2 May 2021	BRRI dhan88	54	24	23	101
	BRRI dhan92	84	25	23	133
	IR64	78	25	25	128

Table 7. Degree days of rice varieties as affected by sowing time in Aus season 2021, Plant Physiology Division, BRRI.

Variety	Required DD (°Cd)			
	from sprouting to PI	from PI to 50% flowering)	from 50% flowering to maturity)	from sprouting to maturity)
BRRI dhan88	1229.67 (±53.63)	472.74 (±12.58)	329.37 (±149.876)	2179.92 (±42.942)
BRRI dhan92	1808.84 (±48.08)	516.83 (±0.507)	340.67 (±155.342)	2823.92 (±45.257)
IR64	1689.68 (±43.98)	504.16 (±6.274)	333.96 (±152.186)	2689.59 (±37.023)

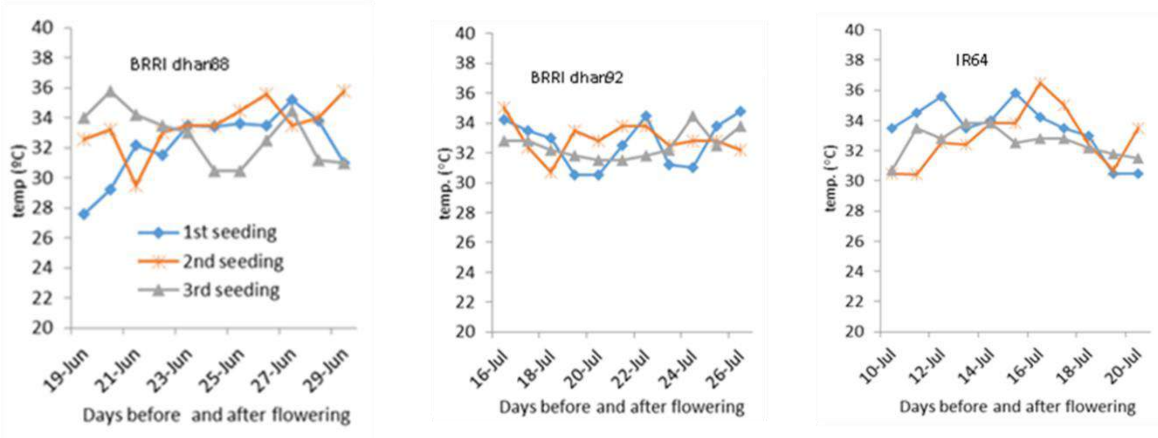


Fig. 11. Maximum temperature during flowering.

Response to photoperiod of some advanced breeding lines under controlled photoperiod condition

A study was conducted to find out the photoperiod sensitivity of some promising breeding lines. on total 230 advanced breeding lines developed for RLR ecosystem (salinity and insect resistance) were tested along with BR22, Nizersail (strong photoperiod sensitive) and BR10, BR11, BRRI dhan30 (moderate photoperiod sensitive) as standard checks. Seeds of all the tested and check varieties were directly sown to the well-prepared field beds during 11 April 2021. Ten-hour photoperiodic treatment (7.00 AM to 5.00 PM) was started from seed sowing by using black cloth cover. One set were grown at natural day length. Observations were made on date of seeding and date of heading to determine the Basic Vegetative Phase (BVP), Photoperiod Sensitive Phase (PSP) and Relative Photoperiod Sensitivity (RPS). On the basis of RPS, 2 breeding lines (BR11032-4R-31 and BR11046-4R-95) showed strong response in flowering with an increase in photoperiod similar to BR22 (**Table 8**). But rest of breeding lines showed nearly insensitive to moderately sensitive to photoperiod. The relative photoperiod sensitivity of BR10, BR11 and BRRI dhan30 was ranged from 36% to 39% compared to Nizersail, which are considered as moderately sensitive variety.

Table 8. Photoperiod sensitivity of selected promising advance breeding lines during T. Aman 2021. Each value is the mean of 5 samples (sowing date: 11 April 2021).

Designation	Basic Vegetative Phase (day)	Photoperiod Sensitive Phase (day)	Relative Photoperiod Sensitivity (%)	Remarks
BR11032-4R-31	**13±0.31**	**167±1.76**	**116**	**SPPS**
BR11046-4R-95	**13±0.38**	**166±1.15**	**115**	**SPPS**
BR10 (ck.)	38±3.03	57±3.33	39	MPPS
BR11 (ck.)	42±0.58	52±1.30	36	MPPS
BR22 (ck.)	**11±0.31**	**168±0.63**	**116**	**SPPS**
BRRI dhan30 (ck.)	36±0.59	57±1.00	39	MPPS
Nizersail (ck.)	**9±1.84**	**144±2.38**	**100**	**SPPS**

Note: BVP and PSP values are the Mean±SE (n=10), MPPS = Moderate photoperiod sensitive, SPPS = Strong photoperiod sensitive

Photosensitivity test of deep-water, shallow-deep water and stagnant shallow water lines

Another study was conducted to find out the photoperiod sensitivity of some advanced breeding lines developed for deep-water, shallow-deep water and stagnant shallow water condition. Sixteen (16) advanced breeding lines were tested along with BR22, Nizersail (strong photoperiod sensitive) and BR11 (moderate photoperiod sensitive) as standard checks. Seeds of all the tested and check varieties were directly sown to the well-prepared soil bed under control net house condition on 16 May 2021. Ten-hour photoperiodic treatment (7.00 AM to 5.00 PM) was started from seed sowing by using black cloth cover. One set were grown at natural day length. Observations were made on date of seeding and date of heading to determine the basic vegetative phase (BVP), Photoperiod Sensitive Phase (PSP) and Relative Photoperiod Sensitivity (RPS). On the basis of RPS, one deep-water line (BR9390-6-2-1B) showed strong response in flowering with an increase in photoperiod similar to BR22 (**Table 9**). However, one local deep-water genotype (Khoiamotor) and one shallow-deep water line the (BR10230-7-19-B) showed fairly strong sensitive having RPS (~80%) (**Table 9**). But rest of breeding lines showed weakly to moderately sensitive to photoperiod.

Table 9. Photoperiod sensitivity of deep-water, shallow-deep water and stagnant shallow water lines during T. Aman 2021. Each value is the mean of 5 samples (sowing date: 16 May 2021).

Designation	BVP	PSP	%RPS	Remarks
BR11	29.83	54.13	47.51	Moderately sensitive
BR22	17.25	119.25	104.68	Strong sensitive
Nizer sail	30.71	113.92	100.00	Strong sensitive
Deep water line				
BR9390-6-2-2B		Segregating line		
BR9376-6-2-2B	33.60	60.80	53.37	Moderately sensitive
BR10260-5-15-21-6B	30.67	79.93	70.17	Moderately sensitive
BR9390-6-2-1B	10.50	116.50	102.27	Strong sensitive
Dudlaki		No one survived		
Khoia Motor	27.50	90.50	79.44	Fairly strong*
Shallow water				
BR10230-7-19-B	19.50	91.25	80.10	Fairly strong*
BR10230-7-19-2B	37.67	50.13	44.01	Moderately sensitive
BR10247-14-18-7-3-3B	41.67	41.50	36.43	Moderately sensitive
BR102385-1-9-3B	37.00	51.20	44.95	Moderately sensitive
BRRI dhan91	36.40	64.20	56.36	Moderately sensitive
Stagnant shallow deep				
BR9377-21-3B	12.60	77.15	67.72	Moderately sensitive
BR9892-6-2-2B	36.50	50.50	44.33	Moderately sensitive
BR10247-14-18-4	35.50	50.67	44.48	Moderately sensitive
BR10247-4-7-4-B	20.50	40.83	35.84	Moderately sensitive
BR9392-6-2-3B	17.00	39.17	34.38	Weakly sensitive

Investigation of anatomical differences in the leaves of C3 and C4 species

Leaf structure strongly controls leaf photosynthesis and plays a key role in every step starting from light interception up to the biochemical fixation of carbon dioxide. However, there has been growing interest in the characterization of rice leaf anatomical differences between C3 (rice) and C4 species such as maize, sorghum, green foxtail millets etc. Engineering the leaf structure of cultivated rice could, therefore, be of direct interest to current research efforts that aim to increase photosynthetic efficiency and thereby achieve improved yields. Recently, Chowrasia and Mondal (2020) have claimed that Uri dhan (*Oryza coarctata*) should possess C4 photosynthesis based on anatomical, cell ultra-structural, and molecular evidences. Based on these information, anatomical differences between the leaves of Uri dhan and rice were investigated. In comparison to rice, Uri dhan has a greater number of veins and a denser vascular bundle. The mesophyll cells and vascular bundle in the Uri dhan were both well-organized and highly composed compared to rice (**Figs.12 and 13**).

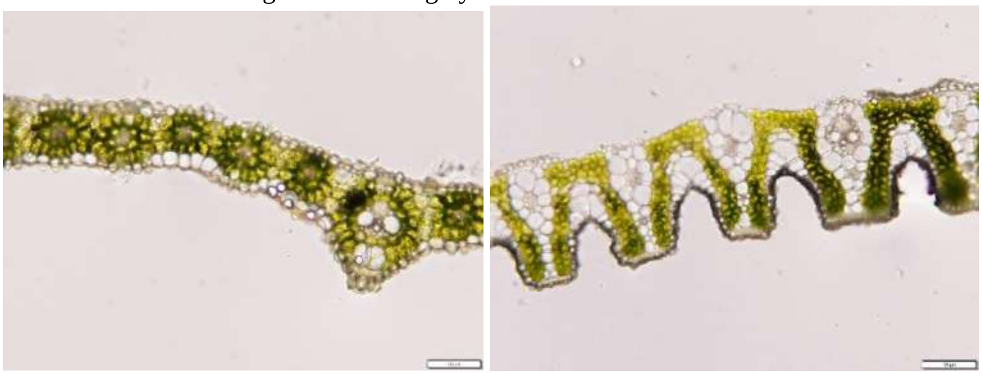


Fig. 12. Veins and vascular bundles in the leaves of rice (left) and Uri dhan (right) (20×).

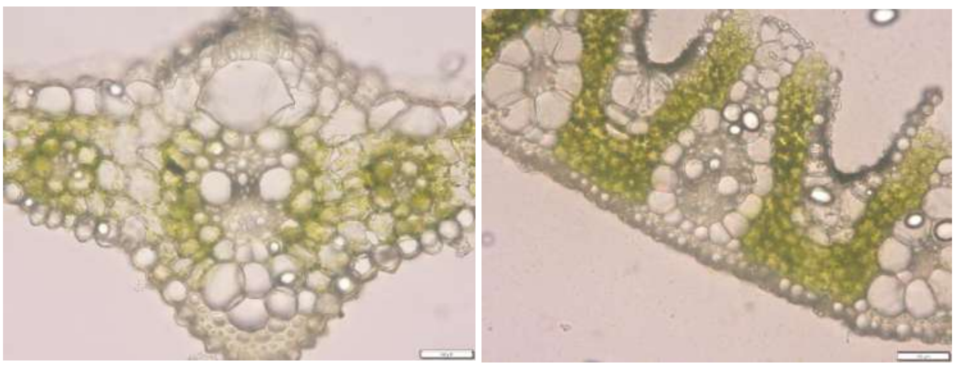


Fig. 13. Vascular bundles in the leaves of rice (left) and Uri dhan (right) (40×).

Optimizing chlorophyll fluorescence imaging system for photosynthetic efficiencies of rice in the salinity stress

Chlorophyll fluorescence is popular technique in plant physiology used for rapid non-invasive measurement of photosystem II activity. PSII activity is very sensitive to range of biotic and abiotic factors and therefore chlorophyll fluorescence technique is used as rapid indicator of photosynthetic performance of plants in different developmental stages and/or in response to changing environment. The advantage of chlorophyll fluorescence measurements over other methods for monitoring stresses is that changes in chlorophyll fluorescence kinetic parameters often occur before other effects of stress are apparent. Advances made in image-based phenotyping techniques provided an opportunity to use non-destructive imaging to screen for salinity tolerance traits in a wide range of germplasm in a reliable, quantitative and efficient way. However, the application of image-based phenotyping in the development of salt-tolerant rice remains limited. Therefore, the present investigation aimed to explore the use chlorophyll fluorescence-based imaging to characterize the salinity tolerance of rice at seedling stage. In the present study, IR58443 (standard tolerant check) and IRRI154 (standard sensitive check) were evaluated under soil-based salinity stress for 0, 6 and 12 dS/m stress. Chlorophyll fluorescence image was taken 24 (Day1), 48 (Day2) and 72 hrs (Day3) after stress application. Initial Fv/Fm values (Day1) were noticeably low, but they progressively increased and were kept very near to normal for the tolerant genotype (IR58443), whereas the pattern was exactly the opposite for the sensitive genotype (IRRI154) (**Fig. 14.**)

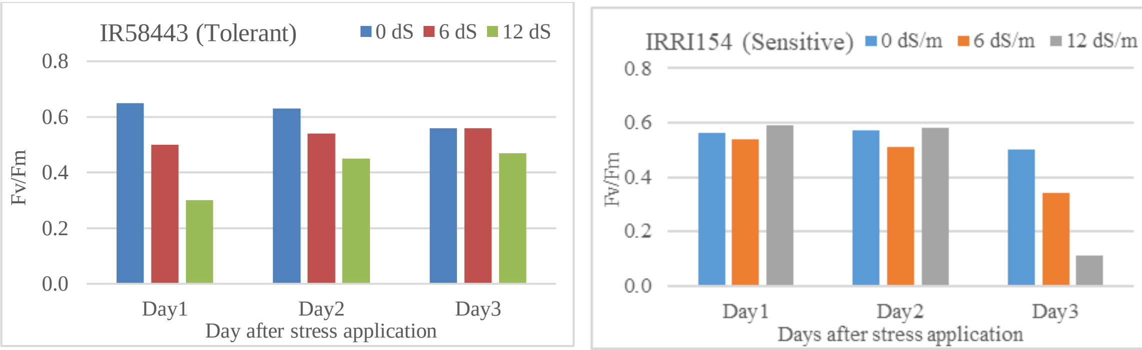


Fig. 14. Fv/Fm values at three distinct time periods at 0, 6, and 12 dS/m salinity str ess.

YIELD POTENTIAL

Generation of male sterile rice line for two-line hybrid system by editing TMS5 gene using CRISPR/Cas9 system

The two-line hybrid rice system is an important innovation for the better exploitation of hybrid vigoer (heterosis). Thermo-sensitive genic male sterile (TGMS) line has been shown to be an ideal replacement for cytoplasmic male sterility (CMS) and explored in two-line hybrid systems; particularly in rice. TGMS lines are sensitive to the temperature for the expression of male sterility or fertility. To design a CRISPR/Cas9 targeting the TMS5 gene in rice, a 19bp guide sequences (5′-ACCGTCGAGGGCTACCCCG-3′) was a protospacer adjacent motif lying within the TMS5 coding sequence (LOC_Os02g12290.1). The guide sequences were properly cloned into the binary vector pC1300-Cas9 (**Fig. 15**). The binary vector pC1300-Cas9 harboring Cas9/TMS5 sgRNA was mobilized into Agrobacterium tumefaciens LBA4404 by freeze-thaw method and confirmed through PCR-gel electrophoresis (**Fig. 16**). Plants were regenerated through Agrobacterium-mediated transformation. Genomic DNA was extracted from the leaves of transformed plants using the sodium dodecyl sulfate (SDS) method. Hygromycin phosphotransferase positive plants were identified using HPT primer pair designed from Hygromycin phosphotransferase resistant zone of the Cas9 vector (**Fig. 17**). PCRs amplifications are being performed using primer pairs which generated an amplicon harboring the target site, and the resulting amplicons are being sequenced using the Sanger method.

Fig. 15. Confirmation of vector constructs by alignment of sequence of recombinant pC1300-Cas9 harboring Cas9/*OsTMS5* sgRNA with guide sequence.

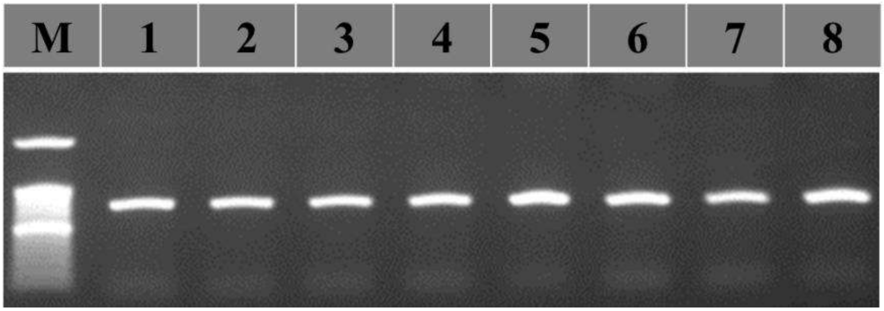


Fig. 16. Confirmation of *Agrobacterium* transformation through PCR-gel electrophoresis. *Agrobacterium tumefaciens* LBA4404 with recombinant pC1300-Cas9 harboring Cas9/*OsTMS5* sgRNA **(Lane 1-8)**. **M**: marker (50 bp DNA ladder).

Fig. 17. Hygromycin phosphotransferase positive plants for salinity tolerance.

Entomology Division

SUMMERY

The overall insect pest incidence was low in the reporting year. Among the five habitats i.e., seedbed, grass fallow, irrigated rice, rice bund and upland rice, the highest number of GH was found in transplanted rice (T. rice) followed by rice bund, grass fallow and seedbed at BRRI research farm, Gazipur at every week throughout the year. But higher numbers of natural enemies were found in the seedbed.

The highest peak of insect pests in light trap was found in November across the locations. The highest number of BPH was observed during the month of November at Gazipur. But YSB was observed highest at Barishal and Rajshahi in November and May respectively. In case of natural enemies, the highest catch of natural enemies in light trap was recorded at Habiganj followed by Barishal, Rajshahi, Gazipur, Rangpur, Sonagazi and Cumilla.

In T. Aman season, peak of BPH and WBPH was observed in October at the village of Fatepur, Pirganj, Rangpur. Among the natural enemies spider population was found highest in August to October. In Boro season, insect pest's incidence was very low. No yield loss occurred in researchers' practice field (T_1) where insect manage meat was done without insecticide in Boro season and one time application at T. Aman season. But farmers' practice field (T_2) insecticide was used 3 to 4 times.

FAW was monitored in eight weeks but no fresh window panes and infested plant was found during scouting. On average 0 to 0.31 moth/trap/day observed at BRRI farm, Gazipur. Irrespective of sex developmental period of *Cnaphalocrosis medinalis* from egg to adult was 28.88 days at 25°C and 26.04 days at 30°C.

Ecological engineering approaches reduced insecticide use and conserved natural enemies in rice ecosystem. The highest natural enemies, % egg parasitism of YSB and larval parasitism of rice leaffolder were observed in rice field with nectar-rich flowering plants on bunds (Eco-engineering). However, least natural enemies and parasitism were found in farmers' practice rice field where 3-4 times insecticides were applied. Moreover, there was no yield reduction observed in eco-engineering field compared to farmers practice field (insecticide application).

Pathogenicity of entomogenous fungi showed around 63% mortality of BPH after seven days of inoculation.

There was no significant difference was observed in tiller and panicle per hill in YSB infested hill and uninfested hill, Percent filled grain per panicle was found the highest (80.64%) in infested hills compared to un-infested hills (79.53%). This indicated that when YSB larvae damaged any tiller of a particular hill the plant supply more nutrient to other tiller of the same hill. As a result, more filled grain number was found in the panicle of infested hill which compensate the loss of damaged tiller. So, no yield loss was found by the damage of YSB at early crop stage when dead heart and white head remain below 3 and 1% respectively.

Rice leaffolder moth catches per pheromone trap per week increases from August to October. Highest number of leaffolder catches 5 moth/trap/day observed in October.

Among the six insecticides i.e., acetamiprid, spinosad, abamectin, chlorantraniliprole, fipronil and chlorpyrifos, abmectin was found relatively safer to natural enemies of rice insect pests.

A total of 104, 16 and 4 commercial formulations of insecticides were evaluated and 85, 14 and 4 insecticides were found effective respectively against BPH, YSB and rice weevil.

Tested nano-particles of Ag, Cu and ZnO showed less than 30% mortality of BPH nymph. More experiments with new nanoparticles are planned to be tested against more insect pests including BPH, leaffolder, rice hispa and stem borer.

In pesticide residue analysis, the concentrations of chlorantraniliprole, thiamethoxam and imidacloprid were 0.00012 to 0.00013, 0.0014 to 0.0073 and 0.0008 to 0.0013 mg/kg respectively in the polished rice grain of different treatments. In another analysis the concentrations of chlorantraniliprole was found 0.00058 to 0.0015 mg/kg. However, the detected amount of

chlorantraniliprole, thiamethoxam and imidacloprid in the samples were below the maximum residue limit (MRL).

A total of 350 F_3 lines from the population of BRRI dhan87 × IR101791-10-1-4-3-2-4 cross and 300 F_3 from the population of BRRI dhan89 × IR101791-10-1-4-3-2-4 cross lines were advanced to F_4 in Rapid Generation Advance (RGA) Nursery.

For BRRI dhan89, a total of 280 F_3 lines from the population of BRRI dhan89 X Acc489 cross were advanced to F_4 generation in Rapid Generation Advance nursery.

A total of 1335 advance breeding lines were screened to identify resistance sources against major insect pest BPH. Among them 78 line showed moderately susceptible reaction (SES score 5) against BPH.

We have employed CRISPR/Cas9 tool to create novel alleles of CYP71A1 leading to introduction of insect resistance into an elite rice variety BRRI dhan92. PCR analysis of putative transformants using primers targeting the flanking regions of sgRNA of CYP71A1 identified mutation in T0 generation. Sequence analysis of T0 lines identified mutations located within sgRNA region. This study has demonstrated the use of CRISPR/Cas9 in creating novel alleles of CYP71A1 to introduce insect resistance into any susceptible rice varieties.

To identify the resistance mechanism of BRRI dhan33 against gall midge we made a cross between BRRI dhan33 and BRRI dhan49. The true F_1 population was selected using RM5770 marker and was progressed to get F_2 population.

PI: Panna Ali, **CI:** Sadia Afrin

To develop improved BPH resistance three/two gene pyramiding lines using marker assisted breeding, we made a cross between IR 101791-10-1-4-3-2-4 which has two resistance genes (*Bph2* + *Bph32*) and BRRI dhan89 susceptible to BPH. The F_1 plants were confirmed using molecular marker. The selected F_1 plants were transplanted for crossing again with IR 101796-1-2-3-20 which carrying one BPH resistance gene (*Bph20*).

Among the four rodenticides Phostoxin was very effective followed by Rat killer, Lanirat and Zinc phosphide in the rice field.

SURVEY AND MONITORING OF RICE ARTHROPODS

Pest and natural enemy incidence at BRRI farm, Gazipur

Rice insect pests and natural enemies were monitored in five habitats (seedbed, grass fallow, irrigated rice, rice bund and upland rice) at BRRI research farm, Gazipur at every week throughout the year. Data were collected using 100 complete sweeps from each habitat. The overall insect pest incidence was low in the reporting year. Green leafhopper (GLH), white leafhopper (WLH) and grasshoppers (GH) were the most abundant pests and found in all habitats. The highest number of GH was found in transplanted rice (T. rice) followed by rice bund, grass fallow and seedbed (Fig. 1).

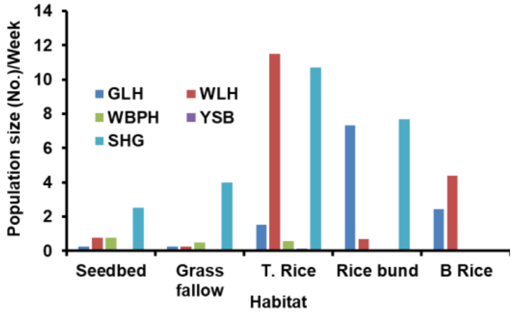


Fig. 1. Incidence of insect pest in different habitats at BRRI farm, Gazipur.

Higher numbers of natural enemies were found in the seedbed. Spider (SPD), damsel fly (DF), ladybird beetle (LBB) and carabid beetle (CDB) were the dominant predators in all the habitats of the reporting year (Fig. 2).

PI: Md Panna Ali, **CI:** Sadia Afrin, **PL:** Sheikh Shamiul Haque

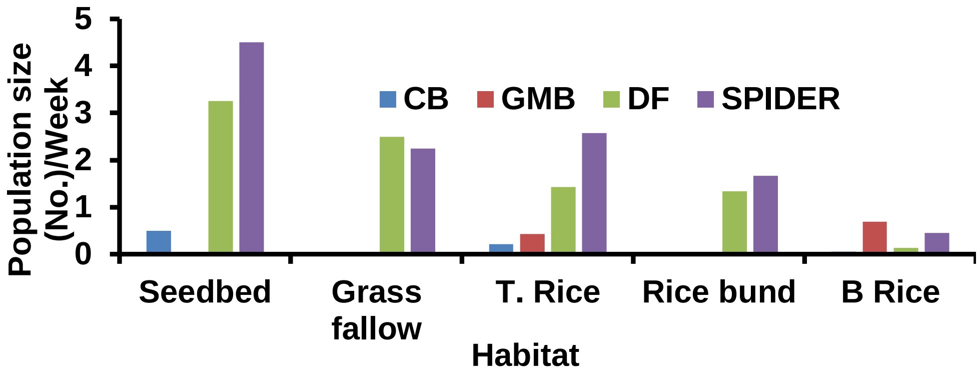


Fig. 2. Incidence of natural enemies in different habitats at BRRI farm, Gazipur

Incidence of insect pests and natural enemies in light trap

Rice insect pests and their natural enemies were monitored throughout the year by Pennsylvanian light trap from dusk to dawn BRRI HQ, Gazipur and six BRRI Regional stations. The abundance of BPH, WBPH, GLH and YSB was observed almost all the seven locations. Total number of insect pests was the highest at BRRI, Gazipur followed by Barishal, Rajshahi, Habiganj, Sonagazi, Rangpur and Cumilla (Fig.3).

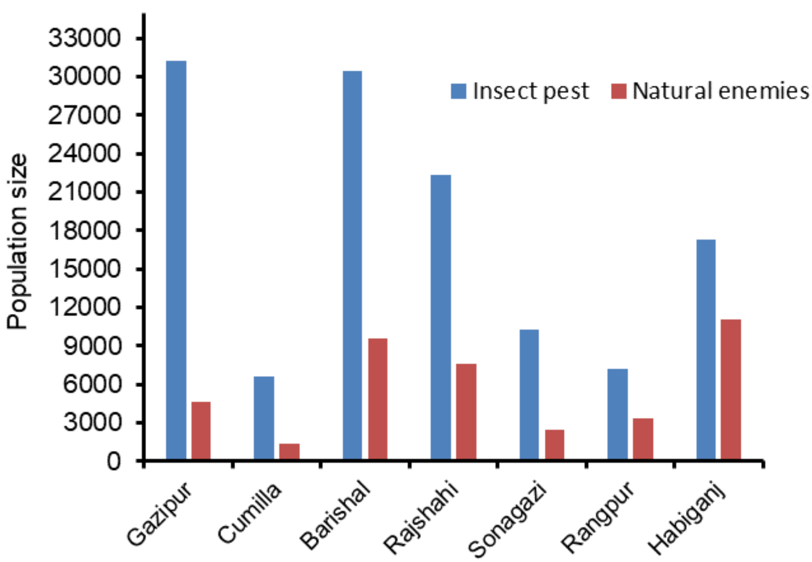


Fig. 3. Insect pests and natural enemies at BRRI HQ, Gazipur and six regional stations (RS).

Among the major insect pests, the highest number of BPH was observed in November and May at Gazipur. Three peak of WBPH was found in October, August and May at BRRI Gazipur and one peak in December observed at BRRI RS, Rajshahi. The highest peak of YSB was observed at BRRI RS Barishal in November and BRRI RS, Rajshahi in May. Usually stemborer shows two peaks in a year- one in April-May and the other in October-November (Fig 4). Higher populations of GLH was found in November at BRRI RS, Rajshahi and BRRI RS, Sonagazi. But GLH was found the highest in December at BRRI RS, Barishal (Fig. 4). In conclusion, the higher peak of insect pests was found in November-December and May to June across the locations.

PI: Sadia Afrin, **CI:** Sheikh Shamiul Haque

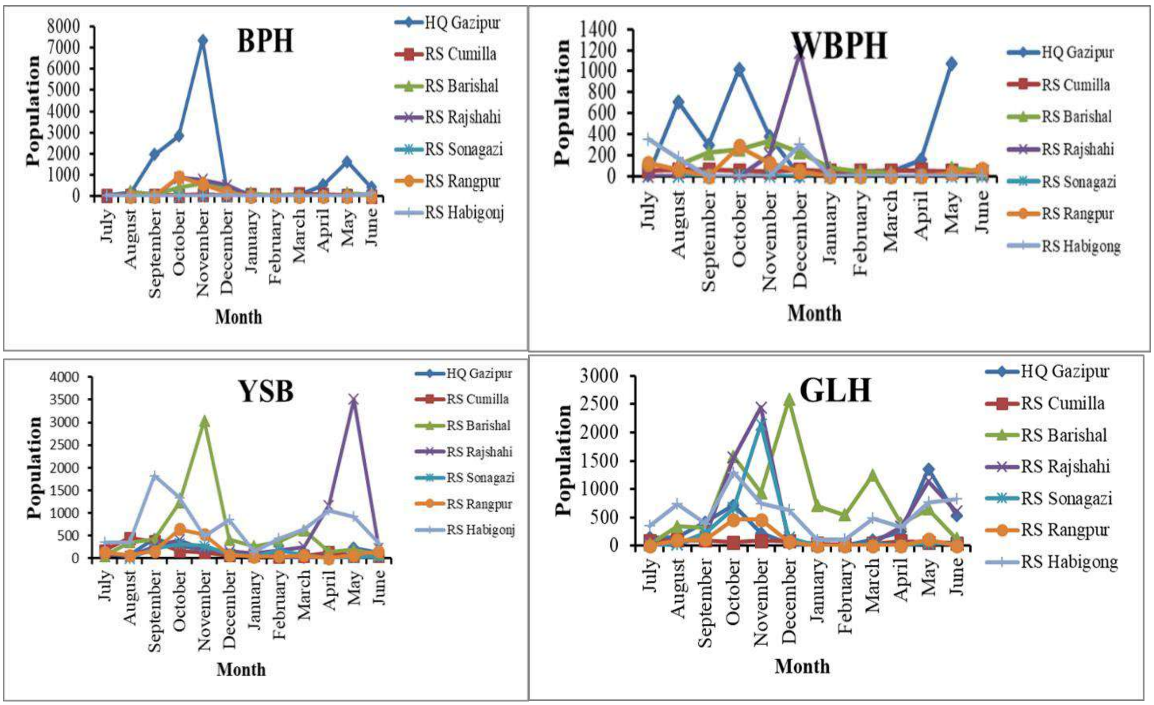


Fig. 4. Incidence pattern of major insect pests in light trap, BRRI HQ, Gazipur and regional stations during July 2021-June 2022.

On the other hand, among the natural enemies CDB showed the highest population at Habiganj in November and April (Fig. 5). GMB population of Rajshahi was higher than those of other stations. The highest peak was observed in June at Barishal. Similarly, in contrast, two peaks of STPD were observed at Barishal in March and October (Fig. 5). A small peak of STPD was observed in December at BRRI, Rajshahi. Among natural enemies, the highest peak was found in November and April for CDB, June for GMB, and March for STPD (Fig. 5).

PI: Sadia Afrin, **CI:** Md Panna Ali, **PL:** Sheikh Shamiul Haque

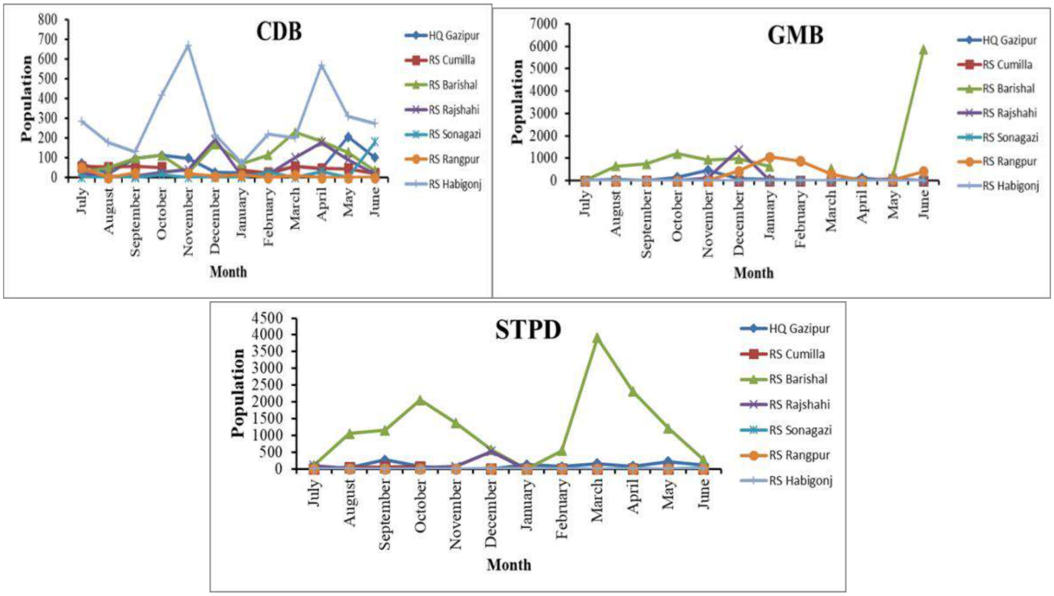


Fig. 5. Incidence pattern of natural enemies of rice insect pest in light trap, BRRI HQ and regional stations, July 2021-June 2022.

Survey and monitoring of rice arthropods and yield loss assessment in a selected village

The experiment was conducted in a block (7.92 acre) of 18 farmer's fields during T. Aman 2021 season at the selected village Fatepur, Pirganj, Rangpur. During Boro 2021-22 season, 12 experiments were conducted in 12 different farmers' field in Rangpur region. One portion of farmers' field was managed with BRRI recommended practices treated as T_1 (Researchers' practice). Another portion was remained under the respective farmers' supervision without any intervention treated as T_2 (Farmers practice). BRRI released high yielding variety BRRI dhan87 and BRRI dan89 were used in T. Aman and Boro season respectively both in T_1 and T_2 (Fig. 6). The highest brown planthopper (BPH) and white backed planthopper (WBPH) was observed in October and grasshopper (GH), in August to September (Fig. 7). Among the natural enemies Spider population found the highest during August- October (Fig. 7). Other natural enemies like damsel fly (Dam. Fly), dragons fly (Drag. Fly), LBB and green mirid bug (GMB) population reduced during October in comparison to Aug-September. That might be happened due to frequent insecticide application in neighbouring field (Fig. 7.). During Boro season, insect pest's incidence was very low. No yield loss occurred in researchers' practice field (T_1) where insect manage without insecticide in Boro season and one time insecticide application at ETL during T. Aman season. But farmers' practice (T_2) used insecticide 3 to 4 times. Similar grain yield was obtained both in research practiced field (T_1) and farmers practiced field (T_2) i.e., 5.36 and 5.13 t/ha respectively during T. Aman season and 7.81 and 7.75 t/ha in T_1 and T_2 respectively during Boro season (Fig 8). Two field days were conducted during two seasons. More than 100 neighbouring farmers were attended in each field day programme.

PI: Md Nazmul Bari, **CI:** All Entomologists

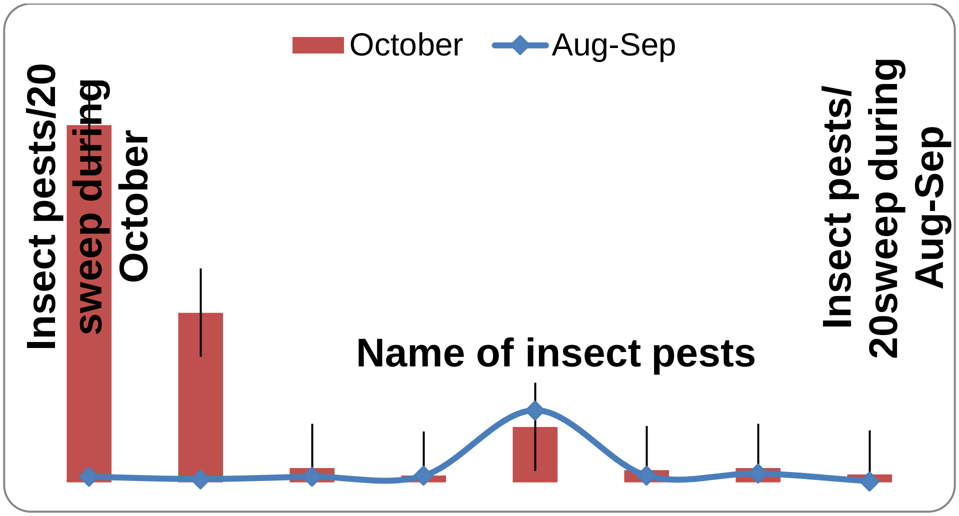


Fig. 6. Insect pests status during August-September in comparison with October at the village Fatepur, Pirganj, Rangpur during T. Aman 2021.

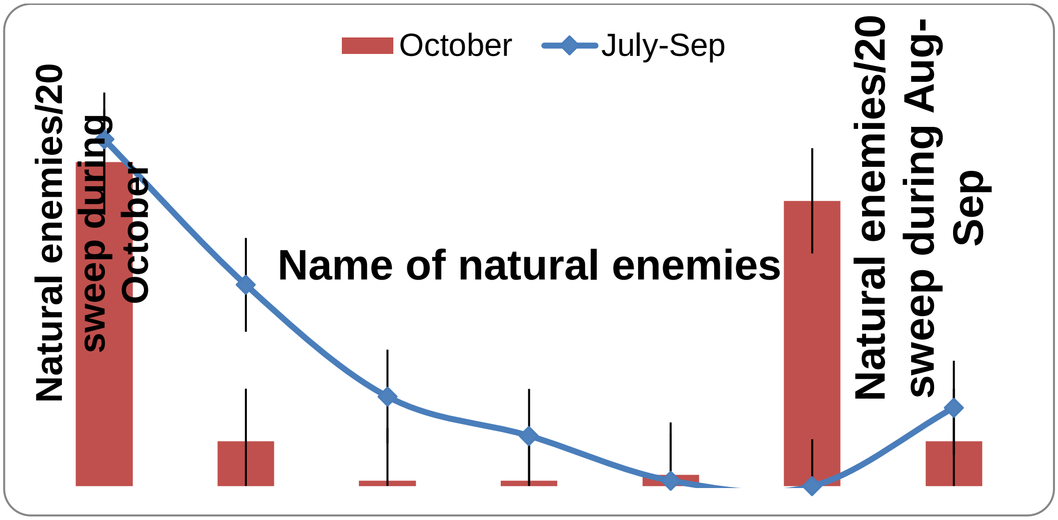


Fig. 7. Natural enemies status during August-September in comparison with October at the village Fatepur, Pirganj, Rangpur during T. Aman 2021.

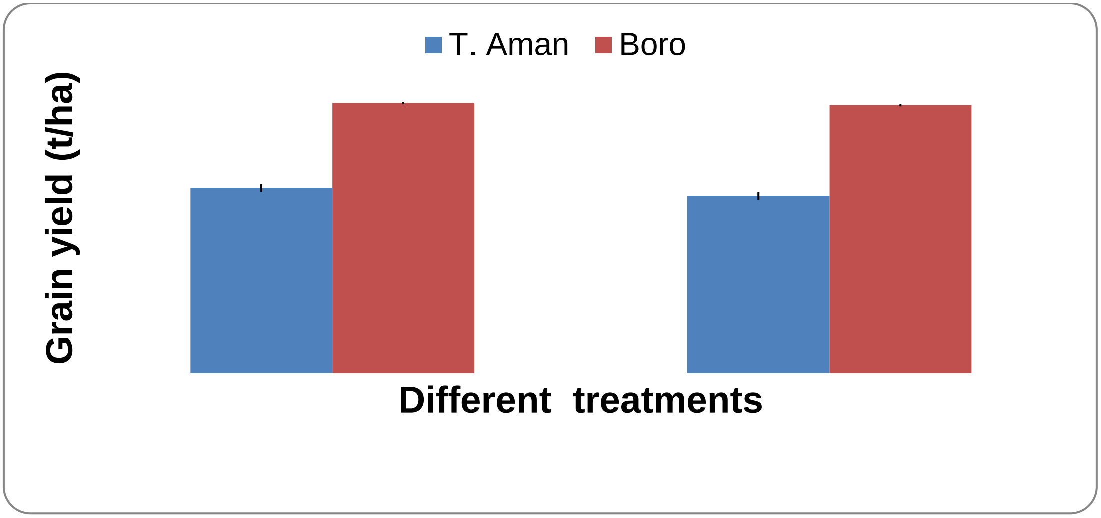


Fig. 8. Grain yield of BRRI dhan89 in researchers practice (RP) field and farmers practiced (FP) field at Rangpur during T. Aman 2021 and Boro 2021-22.

Fall Armyworm (FAW) monitoring through pheromone trap on rice crops

Five pheromone traps were set 100 m between traps (in separate fields) in rice from vegetative to ripening stage of rice crops (in separate fields) at BRRI HQ, Gazipur, during Boro 2021-22. There was no maize field at least 200 m apart. Every Monday the trap catch and field scouting data were collected and recorded. The highest population of FAW (7 moths/trap) was trapped in April 2022 at BRRI, Gazipur. FAW was monitored eight weeks but no fresh window panes and infested plant was found during scouting. On average 0 to 0.31 moth/trap/day observed at BRRI, Gazipur.

PI: Md Nazmul Bari, **PL**: Sheikh Shamiul Haque

BIO-ECOLOGY OF RICE INSECT PEST AND NATURAL ENEMY

Effect of temperature on the biology and lifecycle of rice leaffolder (*Cnaphalocrosis medinalis*)

Rice leaffolder (RLF) *Cnaphalocrocis medinalis* (Guenee) [Lepidoptera: Pyralidae] colony was maintained on BR3 plants under greenhouse conditions at BRRI, Gazipur to know the impact of elevated temperature on the development of RLF. Response to temperature will be assessed by exposing *C. medinalis* eggs to five constant temperatures (20, 25, 30, 35, and 40°C) in separate experiments in the growth chamber. Egg hatching period was almost similar in 25°C and 30°C temperature but at 20°C it was longer (Table 1).

Larval and pupal duration were higher in 20°C compared to 25°C and 30°C. Total duration of egg to adult was longer at 20°C. However in 30°C, adult longevity was higher. The growth duration of different stages was affected by temperature: the duration decreased as the temperature increased. The duration of the egg stage was similar in both the temperatures (25 and 30°C). At temperatures higher than 25°C, larval development took shorter period. At 25, and 30°C, pupal developmental duration was 7.98, and 5.9 d respectively (Table 1). At 25 and 30°C, egg - adult developmental duration was 28.88 and 26.02 d respectively (Table 1). Any deviation from the optimum temperature during their lifetime can cause changes in duration of life stages from larva to adult. More research of RLR in different temperatures is further needed to understand the mechanism of their behavioural adaptations.

PI: Farzana Nowrin, **CI:** Md Panna Ali

Table 1. Developmental duration from egg to adult (day) of leaffolder at different temperatures under 16L:8D photoperiod.

Temperature		Egg	Larva	Pupa	Egg to adult	Adult longevity
20°C	Number	36	26	24	24	20
	Mean	6	28	18	52	4.5
	Max.	7	30	19	56	6
	Min.	5	26	17	48	3
25°C	Number	66	66	62	65	35
	Mean	4.09	17.17	7.98	28.88	3.31
	Max.	5	20	13	34	7
	Min.	3	16	7	25	2
30°C	Number	29	22	21	21	14
	Mean	4.18	16.09	5.9	26.04	9.14
	Max.	6	20	8	31	13
	Min.	3	14	5	23	3
35°C	Number	50	Only 5% egg hatched (require more experiments)			
40°C	Number	50	Egg did not hatch (repeat the experiment)			

BIOLOGICAL CONTROL OF RICE INSECT PESTS

Leveraging diversity for ecologically based pest management

Two experiments were conducted with BRRI dhan87 and BRRI dhan88 at BRRI farm, Gazipur during T. Aman 2021 and Boro 2021-22 season respectively to conserve natural enemies through ecological engineering approaches and to reduce insecticide use in rice production. A large field (one acre) was divided into two blocks for two treatments. The treatments were T_1=Rice field with flowering plants (sesame and cosmos in T. Aman season Marigold and cosmos in Boro season) on bunds (to provide food and shelter for different parasitoids). T_2=Farmers practice i.e. prophylactic insecticide use. Insect pests status remained below the economic threshold level (ETL) in both the treatments and seasons. The highest numbers of natural enemies except Drag. fly were found in T_1 where insecticide was not used. Number of SPD, Dam. fly, LBB and CBB was found the highest 8.25, 8.0, 5.0 and 1.25 per 20 complete sweep respectively in $T_{1.}$ compared to T_2 (3.00, 1.25, 1.75 and 0.75 respectively) at BRRI farm, Gazipur (Fig. 9). YSB egg parasitisim and RLF larval parasitism observed the highest in T_1 (19.3 and 22.70 % respectively) compared to T_2 (0 and 2.25 % respectively) at BRRI, Gazipur (Fig. 10). Though grain yield was observed simillar both in T_1 and T_2 (5.81 and 5.85 t/ha respectively). But additional sesame produced in T_1 which increased the rice eqivalent yield (REY). As a result 4.25 % additional yield obtained in T_1 compared to T_2 (Fig. 10). During Boro season, the highest number of SPD, Dam. fly and LBB (3.83, 2.50 and 3.17 respectively per 20 complete sweep) were also found the highest in T_1 compared to T_2 (Fig. 11). But simillar yield (7.06 and 7.13 t/ha) was obtained in T_1 and T_2 respectively. The highest natural enemies, % egg parasitism of YSB and larval parasitism of rice leaffolder were observed in rice field with nectar-rich flowering plants on bunds (Eco-engineering). However, least natural enemies and parasitism were found in farmers' practice rice field where four times insecticides were applied. Moreover, there was no yield reduction observed in eco-engineering field compared to farmers' practice field (insecticide application). Not only that, extra profit was obtained from T_1 with no or less use of insecticide. So, farmers should avoid the toxic and hazardous insecticides to control the insect pests by growing nectar-rice flowering plants on the bunds of rice crop.

PI: Md Nazmul Bari, **PL:** Sheikh Shamiul Haque

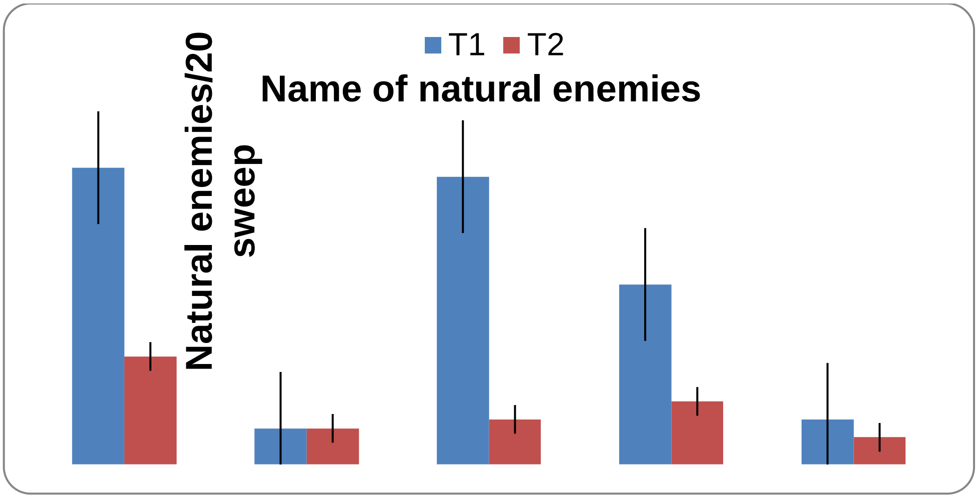


Fig. 9. Natural enemies' number per 20 complete sweeps in different treatments during T. Aman 2021, BRRI, Gazipur. (T_1=Rice field with flowering plant on bunds, T_2= Farmers Practice i.e., insecticide application).

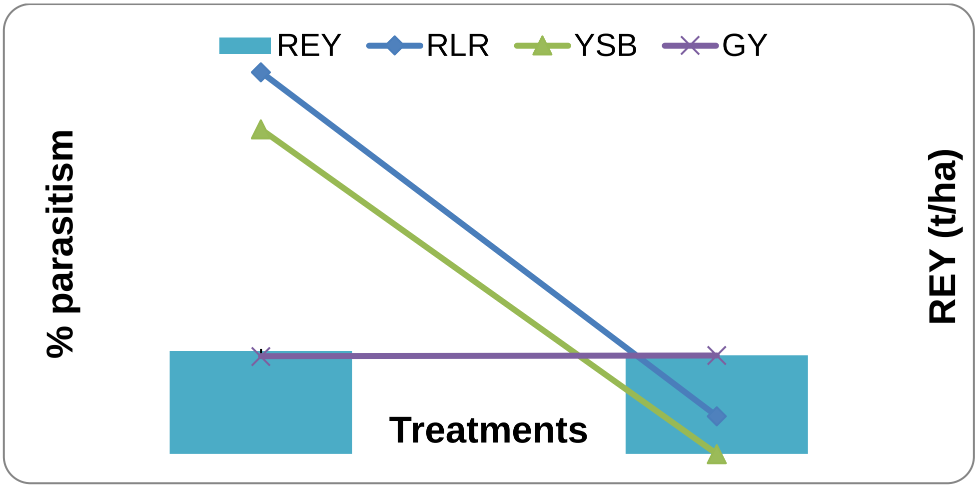


Fig.10. Rice equivalent yield (REY) and % parasitism of YSB and RLR larvae during T. Aman 2020, BRRI Gazipur. (T_1= T_1=Rice field with flowering plant on bunds, T_2= Farmers Practice i.e., insecticide application).

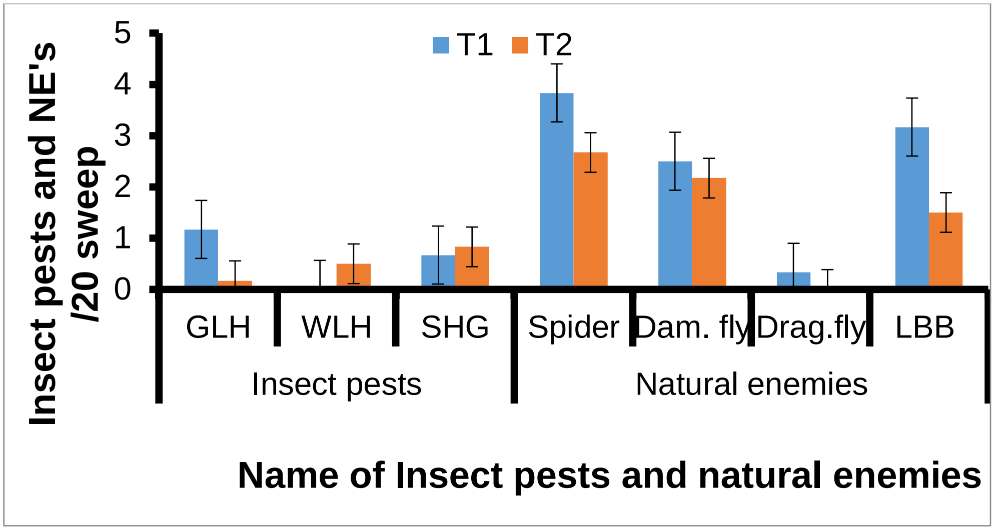
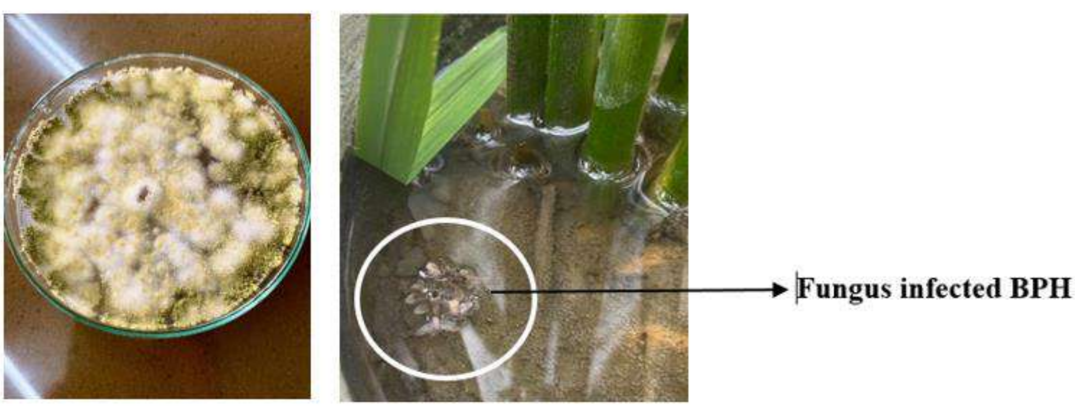


Fig. 11. Insect pests and natural enemies' number / 20 sweeps during Boro 2021-22
(T_1=Rice field with flowering plants on bunds, T_2= Farmers practice i.e., insecticide application).

Study on entomopathogenic fungi to control BPH

The study was conducted at Entomology greenhouse, BRRI to isolate the fungi from naturally infected BPH and to know the pathogenicity of entomogenous fungi against BPH. The infected BPH with chalky white mass of fungus either sticking to the leaf sheath or floating on standing water was collected in sterile glass tube for isolating the causal organism in the laboratory of Plant Pathology Division, BRRI. Then fungus culture was isolated and purified by standard protocol. Potted BR3 plants were infested by ten 3rd-4th instar BPH nymphs of greenhouse populations and confined by mylar film cages. Fungus was sprayed at the rate of 1 × 10^6 conidia/mL per plant. Two treatments including control were used in this study. The treatments were, T_1- Fungus spray before three days of insect infestation, T_2- Fungus spray after two days of insect infestation and T_3- Control. Each treatment had six replication with CRD in pots in the net house of Entomology Division.



Photograph. 4. Fungus isolation in the petri dish and infected dead BPH.
(White circle indicates the fungus infected BPH floating on water close to rice plants).

BPH mortality was observed 63% and 60% respectively in T_1 and T_2 whereas, control treatment showed 20% mortality. This result indicates that spraying of fungus before insect infestation is more effective than spraying after infestation which means fungus need time to grow on plants to show its pathogenicity.

PI: Farzana Nowrin, **CI**: Quazi Shireen Akhter Jahan **PL:** Sheikh Shamiul Haque

CROP LOSS ASSESSMENT

Effect of dead heart and white head on grain yield of BRRI dhan89

The experiment was conducted in a randomized complete block design (RCBD) with 16 replications in Boro season with BRRI dhan89 at BRRI research farm, Gazipur to determine the yield loss and recovery abilities of BRRI dhan89 against stem borer damage. Four hills were selected diagonally from each plot and infested with the 1st instar larvae of one egg mass after 35 days after transplanting (DAT). Another four hills from the same plots were also selected as control. On average 3.13 % dead heart and 0.77% white head was observed when rice plant infested at 35 DAT. There was no significant difference was found in tiller per hill between infested and un-infested hill when average 3.13% dead heart was found at 50 DAT in BRRI dhan89 (Table 2). At maturity stage, significant difference was also not found in panicle per hill, pant height and panicle length between infested and uninfested hill (Table 2). But significantly higher filled grain number (1705.73/hill) was found in infested hill compared to uninfested hill (1,634.57/hill). As a result significantly similar grain weight was found (80.64 g/hill) in infested hill and uninfested hill, 79.53 g/hill (Table 2). Again, unfilled grain number reduced significantly in infested hill (332.59/hill) compared to uninfested hill (410.33/hill). As a result, percent filled grain per panicle was found the highest (80.64%) in infested hills compared to uninfested hills (Table 1). This indicates that when YSB larvae damaged any tiller of a particular hill the plant supply more nutrient to other tiller of the same hill. As a result, more filled grain number was found in the panicle of infested hill which compensate the loss of damaged tiller. So, no yield loss was found by the damage of YSB at early crop stage when dead heart and white head remain below 3 and 1% respectively.

PI: Md Nazmul Bari **PL:** Sheikh Shamiul Haque

Table 12. Plant characteristics, yield component and yield of BRRI dhan89 in different treatments at BRRI, Gazipur, Boro 2021-22.

Treat	Tiller/ hill (Mean ±SE)	Pani/ hill (Mean ± SE)	Pl ht (cm)	Pani. length (cm)	FGN/hill (Mean ± SE)	UnFGN /hill	%FG/panicle (Mean ± SE)	Grain wt/hill (Mean ± SE)
T_1	14.08±0.35 n=60	13.53 ± 0.35 n=60	105.38 ± 1.62 n=60	21.83±0.18 n=60	1705.73 ± 3.78a n=60	332.58 ± 1.04 b n=60	80.64 ± 1.24 n=60	41.77 ± 0.83 n=60
T_2	13.83 ±0.36 n=60	13.52 ± 0.35 n=60	104.92 ± 0.55 n=60	21.78±0.14 n=60	1634.57 ± 3.25b n=60	410.33 ± 1.21 b n=60	79.53 ± 0.91 n=60	39.87 ± 0.86 n=60
Significance	*NS*	*NS*	*NS*	*NS*	*P<0.01*	*P<0.05*	*P<0.01*	*NS*

Data were analyzed using Statistix 10 program NS= Not significant T_1= Infested hill, T_2= Un-infested hill SE=Standard error

INTEGRATED PEST MANAGEMENT

Use of sex pheromone to control leaffolder, *Cnaphalocrosis medinalis*

Pheromone lures for rice leadfolder were collected from Ispahani Biotech (Ispahani Agro Limited) and used for these studies. The test was conducted in BRRI research field at Gazipur. The optimal blend of used pheromone for leaffolder was Z11-18: Ald, Z13-18: Ald, Z11-18: OH and Z13-18: OH at a ratio of 3: 25 : 3 : 3. For leaffolder, each trap contained one lure tube which was impregnated with a mixture of (Z)-11 hexadecenal + (Z)-9 hexadecenal in 3:1 ratio. Pheromone traps were placed at 30 cm above the crop canopy and maintained a distance 20 m from one trap to another one. Significant numbers of leaffolder were caught in each trap in Gazipur (Fig. 12). Number of moth catches varied to time. Figure 12 shows that catches per trap per week increases from August to October. However, the highest number of leaffolder catches was observed in 25 October. This result indicates that pheromone trap can be effective to monitor and control leaffolder in rice field.

PI: Md Panna Ali, **CI:** Farzana Nowrin, MM Moniruzzaman Kabir,

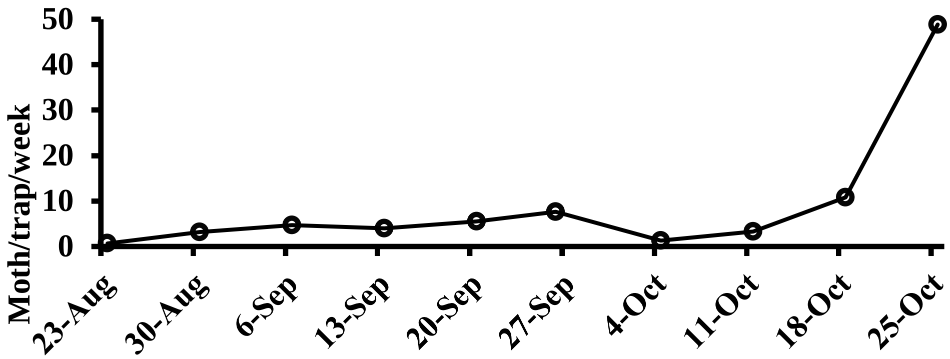


Fig. 12. Catches of leaffolder (LF) moths in sex pheromone trap in different dates of August to October. Dot represents the mean of 10 traps per week.

EVALUATION OF CHEMICALS AND BOTANICALS AGAINST RICE INSECT PESTS

Test of different insecticides against major insect pests

The effectiveness of commercial formulations of different insecticides against major insect pests of rice was evaluated in field and storage condition. A total of 104 commercial formulations of insecticides were evaluated against BPH. Among them 85 insecticides were found effective against BPH. For YSB, out of 16 commercial formulations, 14 found effective. Four insecticides were tested against RW and all were found effective. Among all the tested insecticides, one was biopesticide and it was found effective against BPH.

PI: Md Panna Ali, **CI:** Farzana Nowrin, PL: Sheikh Shamiul Haque

Use of nanoparticle to control rice insect pests

Three nanoparticles including Ag, Cu and ZnO were tested against brown planthopper (BPH). The efficacy of Ag, Cu and ZnO nanoparticles against BPH was tested at five different concentrations (4000, 2000, 1500, 1000, and 500 PPM), which were prepared by dilutions with distilled water. Distilled water was used as a negative control treatment. Ten-15-day-old rice seedlings were dipped into each nanoparticle solution at three concentrations. After one-minute seedlings were removed from the solution and allowed to air dry. The treated seedlings were then placed into a 25 ml test tube. Ten 3rd -4th instar nymphs of BPH were released into each test tube and kept them at 27 ± 1°C. In addition, nanoparticles were tested against BPH using seedling spray method. Mortality was recorded after 48 and 120 h. The nymphs were considered dead if they failed to move when gently prodded with a fine bristle. The size of Ag, Cu and ZnO nanoparticles is 20, 40 and 20-30 nm respectively. Tested nano-particles showed below 30% mortality of BPH nymph (Fig. 13). It indicates that tested nanoparticles were not effective against BPH. More experiments with new synthesis nanoparticles are planned to be tested again using more insect pests.

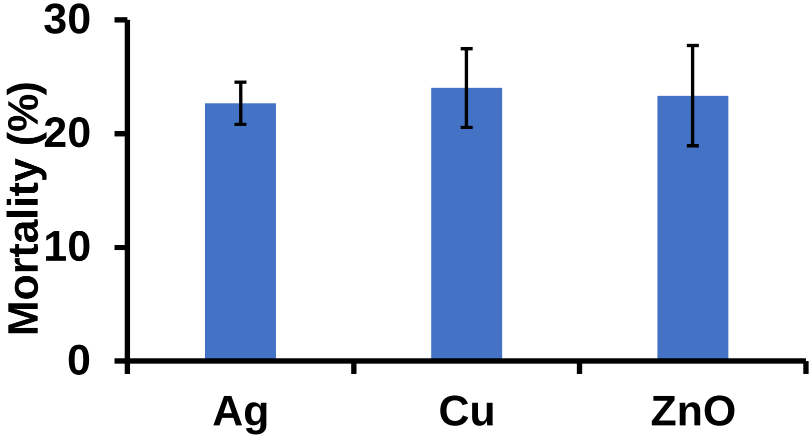


Fig. 13. Effect of nanoparticle on the mortality of brown planthopper (BPH). Error bar represents standard error.

Effect of insecticides on natural enemies of rice insect pests

Six **c**ommercially registered insecticides for rice of different chemical group were evaluated at BRRI, Gazipur to know the effect of insecticides on natural enemies of rice insect pests. The generic name of six insecticides are acetamiprid, spinosad, abamectin, chlorantraniliprole (virtako), fipronil and chlorpyrifos. Number of insect pests and non-pest insects (natural enemies and neutral insects) per 20 sweeps were counted after 48 hours of spraying. Total non-pest insects (466) were found the highest in control. But among the six insecticides, more non-pest insects were found in abamectin (311) which indicates that abamectin comparatively safe for natural enemies of rice pest.

PI: Md. Mosaddque Hossain, **PL:** Sheikh Shamiul Haque

INSECTICIDE TOXICOLOGY

Residues analysis of different insecticide in rice grain

Sample was collected from insecticide treated field and extraction was conducted using acetonitrile (ACN) following Association of Official Agricultural Chemists (AOAC) method of analysis with primary secondary amine (PSA). Pesticide residues were detected using a LC-MS2020 fitted with electrospray ionization (ESI) probe operated in the positive ion mode. The following parameters were optimized for chlorantraniliprole, thiamethoxam and imidacloprid: capillary voltage, 3500 V; ion source temperature, 150°C; desolvation gas temperature, 500°C; desolvation gas flow rate, 1000 L h-1 of nitrogen. Detection was carried out in multiple reactions monitoring (MRM) mode. The retention time of chlorantraniliprole was 2.3 minute, thiamethoxam 1.9 minute and imidacloprid 7.95 minute. The concentrations of chlorantraniliprole, thiamethoxam and imidacloprid in the tested samples were 0.00013 to 0.00012, 0.0073 to 0.0014 and 0.0008 to 0.0013 mg/kg in chlorantraniliprole, thiamethoxam and imidacloprid respectively in the polished rice grain of different treatments (Table 3). However, the detected amount of chlorantraniliprole, thiamethoxam and imidacloprid in the samples were below the Maximum Residue Limit (MRL: 0.4 mg kg-1 for chlorantraniliprole) and 0.6 mg kg-1 for thiamethoxam and imidacloprid, EU). Residue analysis of chlorantraniliprole in rice grain at different days after flowering (DAF) was also tested. The concentrations of chlorantraniliprole in tested samples were found 0.00058, 0.00060 and 0.0015mg/kg at 5, 10 and 15 DAF respectively which were also below MRL according to EU (Table 4).

PI: Md. Nazmul Bari **CI:** Md. Panna Ali, Farzana Nowrin and Sadia Afrin

Table 3. Residue analysis of chlorantraniliprole, thiamethoxam and imidacloprid in rice grain of different doses.

Treatment	Insecticide residue (PPM)			EU MRL*	EU MRL*
	chlorantraniliprole (CTP)	thiamethoxam (THM)	Imidacloprid (IMIDA)	CTP	THM and IMIDA
T_1=Prophylactic use (3times) @ std. dose	0.00013	0.0073	0.0008	0.4	0.6
T_2=Double of std.dose (one time)	0.00012	0.0014	0.0013		
T_3= Control	n.d.	n.d.*	n.d.*		

n.d.* = not detected, EU MRL*=European union Maximum residual limit

Table 4. Residue analysis of chlorantraniliprole in rice grain at different days after flowering (DAF).

Treatments	**Insecticide residue (PPM)**	**EU MRL***	
T_1= Insecticide application at 5 DAF	0.00058		
T_2= Insecticide application at 10 DAF	0.00060		R^2=0.9992597
T_3= Insecticide application at 15 DAF	0.0015	0.4	
T_3= Control	n.d.*		

n.d.* = not detected, EU MRL*=European union Maximum residual limit

Detection of chlorantraniliprole and thiamethoxam residue in different rice varieties

Different rice samples were collected from various sources including Indian and Thai rice varieties. Insecticide residues were detected using a LC-MS2020 fitted with electrospray ionization (ESI) probe operated in the positive ion mode. The retention time of chlorantraniliprole was 2.3 minute and thiamethoxam 1.9 minute. The concentrations of chlorantraniliprole and thiamethoxam in the tested samples were below the Maximum Residue Limit (MRL: 0.4 mg kg-1 for chlorantraniliprole) and 0.6 mg kg-1 for thiamethoxam, EU) (Table 5). In some samples i.e., Indian white rice, Thai home mali rice, Chinigura rice and Jasmine rice residues were not detected (Table 5).

PI: Md. Panna Ali, **CI.**: Dr. Md. Nazmul Bari

Table 5. Analysis of pesticide residues in rice grain of different varieties.

Rice variety	Insecticide residue (PPM)		EU MRL*	
	chlorantraniliprole (CTP)	thiamethoxam (THM)	CTP	THM
BRRI dhan49	0.004	0.034		
Indian white rice	n.d.	n.d.*		
Thai home mali rice	0.02	n.d.*		
Indian pusa white rice	0.05	0.39	0.4	0.6
Chinigura rice	0.03	n.d.*		
Jasmin rice	0.06	n.d.*		

n.d.* = not detected,

HOST PLANT RESISTANCE

Development of BPH resistance breeding lines through marker assisted selection

IR101791-10-1-4-3-2-4 is an indica introgression line with stable resistance to BPH, which was used for developing elite donor and introgress resistance gene into modern cultivar. BRRI dhan87 and BRRI dhan89, susceptible to BPH, was applied to develop mapping population by crossing with IR101791-10-1-4-3-2-4. For BRRI dhan87: A total of 350 F_3 lines were advanced from the population of BRRI dhan87 × IR101791-10-1-4-3-2-4 cross. For BRRI dhan89: A total of 300 F_4 lines were advanced from the population of BRRI dhan89 × IR101791-10-1-4-3-2-4 cross. F_4

generation was advanced in rapid generation advance (RGA) Nursery

PI: Sadia Afrin, **CI:** M P Ali and M R A Sarkar (PBD)

Identification of BPH resistance sources from local germplasm

Acc 489 (Digha-3) is an indica introgression line with stable resistance to BPH, which was used for developing elite donor and introgress resistance gene into modern cultivar. BRRI dhan89, susceptible to BPH, was applied to develop mapping population by crossing with Acc 489. For BRRI dhan89, a total of 280 F_3 lines were advanced from the population of BRRI dhan89 × Acc 489 cross nursery. F_4 generation was advanced in RGA Nursery.

PI: S Afrin **CI:** MRA Sarkar (PBD)

Evaluation of advanced breeding lines screening against Brown Planthopper (BPH)

A total of 1,335 advanced breeding lines were screened at green house of Entomology Division to identify resistance sources against major insect pest BPH. Among them 78 lines showed moderately susceptible reaction (SES score 5) against BPH.

PI: Sadia Afrin, **CI:** Sheikh Shamiul Haque

Screening of advanced breeding lines against major insect pests of rice

Among thirteen rainfed lowland rice (RLR), two lines BRH15-24-7-B and BRH14-9-13-16B were found moderately susceptible (score 5) against BPH. Among six drought tolerant Rice (DTR) lines, none was found resistant. Among four zinc enriched rice (ZER) two lines BR10005-25-8-4-7-20 and BR10022-2-8-9-5-22 were found moderately susceptible (score 5) against BPH. Among seven submergence tolerance rice (ALART) lines, one line IR16F1148 showed moderately susceptible reaction against GLH. Among five RYT-1 advanced breeding lines of deep water rice (DWR), one line BRH11-2-4-7B was found moderately susceptible to WBPH. Among seven RYT-2 and seven RYT-3 advanced breeding lines of deep water rice (DWR), no resistant entry was found. No entry showed any resistant reaction among ten Boro 2021-22 RYT insect resistance (IRR) lines, eight salinity tolerant rice (STR-RYT 1) lines, twelve salinity tolerant rice (STR-RYT 2) lines, three salinity tolerant rice (STR-ALART1) lines, six salinity tolerant rice (STR-ALART 2) lines, five premium quality (PQR) and five Boro 2021-22 zinc enriched rice (ZER) advanced breeding lines.

PI: Md Mosaddque Hossain, **PL:** Sheikh Shamiul Haque

Screening of INGER IRSBN lines against major insect pests of rice

A total of 21 INGER IRSBN (Set-17), T. Aman 2021 breeding lines including two local susceptible and resistant checks were evaluated against stem borer in field condition according to IRRI prescribed procedure. Infestation was not exceeded the ETL for stem borer. Among the entries dead heart ranged between 0 to 4.89% and white head ranged between 0.15% to 1.74%. Only five entries SV0245, SV1078, SV1093, SV2003 and SV2018 showed no dead heart.

PI: Md Mosaddque Hossain, **PL:** Sheikh Shamiul Haque

Suppression of serotonin synthesis in rice using CRISPR Cas9 for insect pest control

In the production of CYP71A1 knockout (CYP71A1-KO) rice plant, a 20 bp fragment (5'-TGGTCGCGTTGAGGAGGAGC -3') of CYP71A1 gene was successfully cloned into the transfer vector, Cas9/gRNA. Electrophoresis and sequencing results confirmed the generated recombinant Cas9/gRNA contained the target sequence of interest. Successful recombinant Cas9/gRNA-CYP71A1 vector was transformed into *Agrobacterium tumefaciens* LBA4404 competent cell. Electrophoresis confirmed the successful recombinant Agrobacterium with target gene of interest was confirmed by PCR and used for co-cultivation. Calli of BRRI dhan87, BRRI dhan89 and BRRI dhan92 were developed using tissue culture technique. Successful calli were co-cultivated with recombinant *Agrobacterium*. Calli were cultured with shoot and root inducing medium in MS media supplemented with different hormone and antibiotic. Shoot was developed from callus (Fig. 14) and healthy shoot was transferred to root inducing media in glass bottle (Fig. 14). After 20 days in rooting media, rooted plants were transplanted in plastic pot and kept in greenhouse for further growth (Fig. 14). Cas9 specific primers were used to confirm the genome edited plants. Electrophoresis results confirmed that five plants harbored Cas9/gRNA vector (Fig. 15). The plants confirmed with Cas9 were progressed to next stage and leaf of all growing plants were collected and stored for genomic analysis. Sequencing of genome edited plants shows mutation occurred in target part of CYP71A1 (Fig. 16). Clear mutation area was identified in CRISPR Cas9 edited plants (Fig. 16).

Fig. 14. Development of plants from callus. Shoot developed from callus in Petridis (Left side); Shoot was transferred in glass bottle for rooting (middle photo) and seedling transplanted in plastic pot (right side).

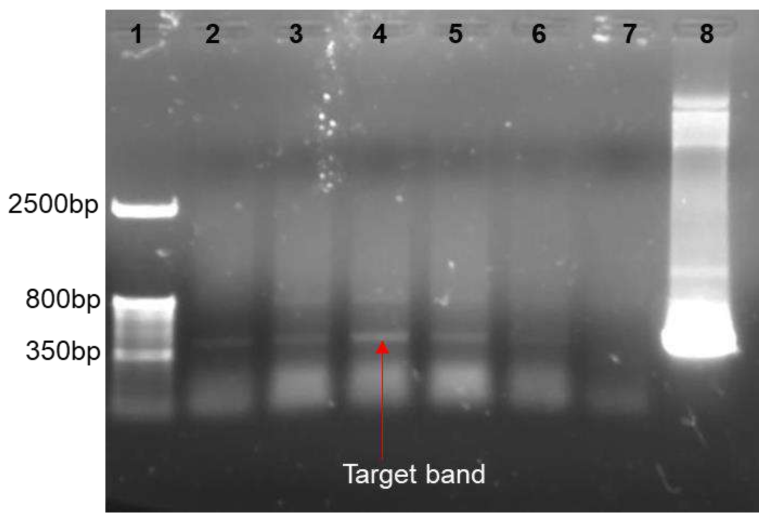


Fig. 15. Electrophoresis of PCR product amplified by SpCas9 primers. Lane 1: DNA ladder (50bp); lanes 2 - 6: CRISPR Cas9 edited plants (mutants); lane 7: BRRI dhan87 (control) and lane 8: Cas9/gRNA-CYP71A1 recombinant vector.

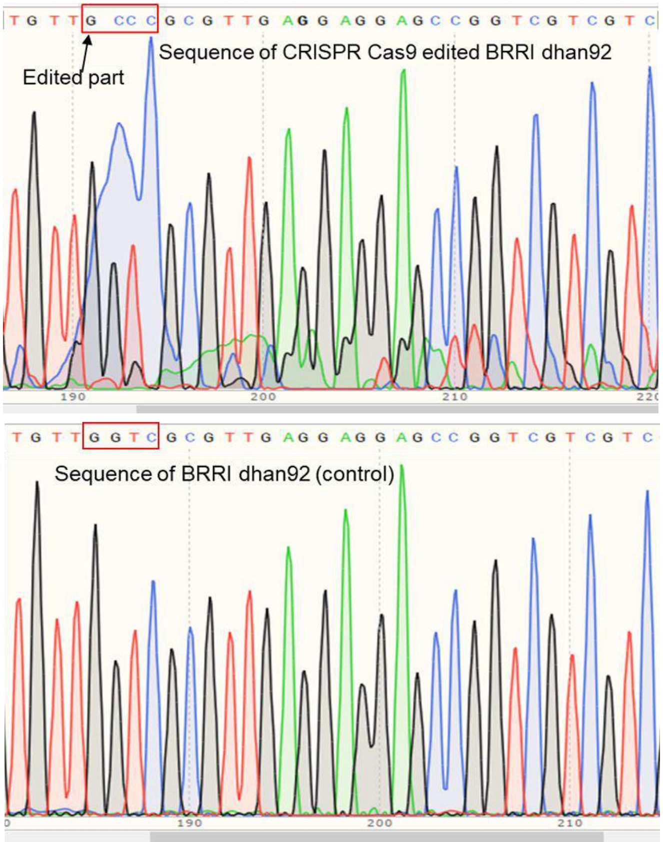


Fig. 16. Mutation area was identified in CRISPR Cas9 edited plants.

Resistance mechanism in BRRI dhan33 to rice gall midge

Previously we identified that BRRI dhan33 showed resistance to gall midge. However, mechanism of gall midge resistance is unknown. Therefore, this study was conducted to identify the gall midge resistance gene in BRRI dhan33. A gall midge resistant rice variety BRRI dhan33 was crossed with BRRI dhan49 which is highly susceptible to gall midge. The F_1 seeds were harvested and seeded to progress for next generation. We used RM5770 marker to identify the true F1 population. Selected F_1 plants were progressed to F_2 by selfing. Seeds from all F_2 plants were harvested and stored for phenotyping test against gall midge. In addition, we advanced some F_2 population and harvested seeds of F_3 population. BRRI dhan49, an elite mega cultivar for T. Aman rice, is famous for its good quality, high yield, and wide culturing in Bangladesh. Unfortunately, such elite paddy cultivar is highly susceptible to gall midge. BRRI dhan33 was crossed with BRRI dhan49 to improve gall midge resistance of BRRI dhan49 and identify the resistance mechanism of BRRI dhan33. The F_1 population was screened using molecular marker and identified five true F_1 population. Polyacrylamide gel electrophoresis picture shows the true F_1 population derived from their cross (Fig. 17). The seeds of true F_1 population were seeded to develop F_2 population and harvested F_2 seeds. The harvested F_2 population seeds were stored for phenotyping test against gall midge.

PI: Md Panna Ali, ; CI: Sadia Afrin

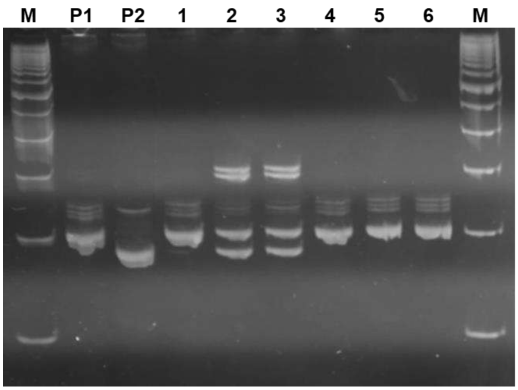


Fig. 17. Polyacrylamide gel electrophoresis patterns of SSR marker (RM5770). M = size marker; Lanes 1 - 6 = F1 population; P1 = BRRI dhan49; P2 = BRRI dhan33.

Pyramiding three BPH resistance genes (Bph2, Bph20, and Bph32) using marker-assisted selection in BRRI dhan89

We conducted this study in order to develop three/two gene pyramiding lines using marker assisted breeding. We made a cross between IR 101791-10-1-4-3-2-4 which has two resistance genes (*Bph2* + *Bph32*) and BRRI dhan89 susceptible to BPH. The F_1 plants were confirmed using molecular marker. The F_1 plant which showed two BPH resistance genes was selected and allowed to develop grains. At harvesting stage, seeds of selected plants were collected and seeded for crossing again with IR 101796-1-2-3-20 which carrying one BPH resistant gene (*Bph20*). We crossed IR 101791-10-1-4-3-2-4 and the elite indica variety BRRI dhan89 susceptible to BPH and got 5 F_1 plants. Gel electrophoresis picture shows the target gene in F1 population (Fig. 18). True F_1 plants were selected based on molecular marker and allowed to be progressed further development. Seeds from all true F_1 plants were harvested and stored for further studies. Some seeds of F_1 plants were seeded for further crossing with.

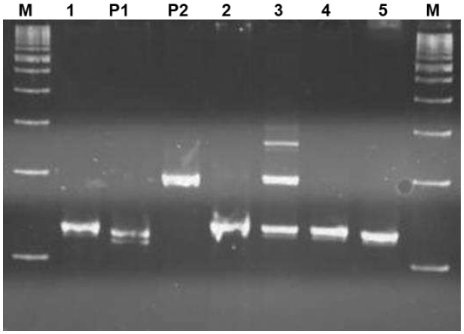


Fig. 18. Gel image (picture of the 1% agarose gel electrophoresis) showing target gene specific band after amplification. M = size marker; Lanes 1 - 5 = F1 population; P1 = BRRI dhan89; P2 = IR 101791-10-1-4-3-2-4.

PI: M P A **CI:** M R A

INSECT MOLECULAR BIOLOGY

Molecular characterization of *Nilaparvata lugens* population in Bangladesh based on COI analysis

Brown planthopper, *Nilaparvata lugens* (Stål) is an important pest in Bangladesh. The present study analyses the genetic diversity of *N. lugens* by employing a partial fragment of the mitochondrial gene encoding cytochrome oxidase I (COI) using samples from nine different localities of

Bangladesh. Nine full length COI gene sequences generated from this study with nine COI gene sequences retrieved from the Gene Bank were analyzed for genetic differentiation and haplotypes of *N. lugens* populations in order to determine the genetic structure. Based on the partial COI gene, high genetic homogeneity was detected in *N. lugens* populations of Bangladesh and they form a single genetic group. The Tajima's D test and Fu's F test also support our result, and indicate recent population expansion, while the phylogenetic tree suggests that geographically distinct populations of *N. lugens* do not exist in Bangladesh. However, our BPH population is distinctly different from Indian population (Fig. 1).

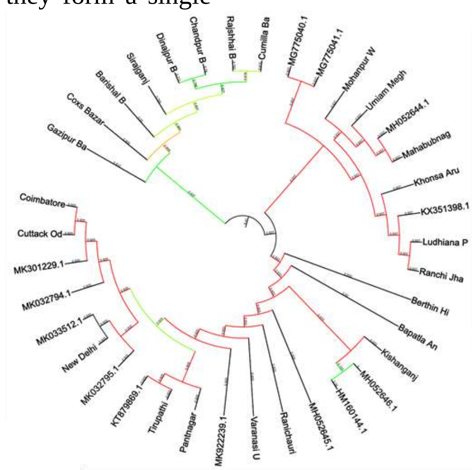


Fig.19. Phylogenetic tree of BPH population collected from nine locations of Bangladesh and compared to Indian population.

PI: Md Panna Ali, **CI:** Juel Datta

Genome sequencing of yellow stem borer (YSB)

Genome sequence information of economically important crop pests is important to provide genetic tools for designing next-generation pest-resistant rice. The development of such genomic data is crucial for understanding the epidemiological, evolutionary, and behavioural characteristics of crop pests. The importance of genomic information is evident with the increasing number of insect genomes being reported. However, genomic resources are sparsely available for YSB. With this background, genome information of YSB can provide insights into the structure, function, biology, molecular mechanisms, monophagy, and gene regulation. We reared YSB in greenhouse and collected sufficient number of adults, and females were selected based on the morphological features and were subject to whole-genome sequencing. For whole genome sequencing we sent collected samples to USDA/ARS, USA international partner. They are processing for further analysis. The DNA was isolated from the female adult YSB using a standard CTAB method and checked for quality and quantity on 0.8% agarose gel and Nanodrop, respectively.

VERTEBRATE PEST MANAGEMENT

Study on the efficacy of different commercial rodenticides against rice field rats

Efficacy of four different rodenticides available in market namely Lanirat, Zinc phosphide, Rat killer and Phostoxin were evaluated to control rat in rice field of BRRI, Gazipur in T. Aman 2021 and Boro 2021-22. Phostoxin was very effective followed by Rat killer, Lanirat and Zinc phosphide.

PI: Md Mosaddque Hossain, Md Mofazzel Hossain, **PL:** Sheikh Shamiul Haque

Plant Pathology Division

SUMMARY

Disease survey was conducted in different rice ecosystems (covering nine districts) during T. Aman 2021 and Boro 2021-22. Incidence pattern and severity of rice diseases over the locations and varieties were assessed. Bacterial blight (BB), sheath blight (ShB) and brown spot were observed predominant irrespective of season.

Distinct variations among wheat blast and rice blast, and leaf and neck blast were generated during gel electrophoresis. All of these DNA samples were sent to Malaysia for sequencing. Based on the pathogenicity and molecular analyses, new differential isolates will be selected. Distinct variations among BPB, BLS and BLB were generated during gel electrophoresis. Based on the pathogenicity and sequence data, BPB strain(s) will be confirmed.

The indication was there that the diseased seeds could be a source of natural infection in both blast and false smut diseases. However, further research is needed to arrive into a solid conclusion. The aggregated patterns of localized source of infection and the percentage of diseased hills reduction by 7% for each 10 cm distance towards the higher elevation are the indications of soilborne nature of false smut rice disease.

Seed associated fungi especially *Aspergillus flavus* (*A. flavus*) were recorded during storage period. In general, the incidence of *Aspergillus flavus* associated with rice increased in course of time irrespective of rice sample and storage condition.

Host range of the blast pathogen was evaluated. Three grass weed blast isolates did not show any symptom on leaves of rice, foxtail millet and wheat. But rice blast isolate developed symptoms of blast disease on leaves of BRRI dhan28 excluding foxtail millet and wheat leaves.

Among the BB and blast resistant advanced lines genotype BR (Path) 13800-BC3-134-252 (7.80 t/ha, 155 days), genotypes (long duration) BR (Path)13800-BC$_3$-224-5 (10.27 t/ha) and genotype (medium duration) BR (Path)13800- BC$_3$-8-8 (9.93 t/ha) performed better compared to the check varieties. All the advanced lines showed resistance to highly resistant disease reaction for blast and bacterial blight inoculation. Heterozygosity of the populations was confirmed through respective molecular marker for the improvement of high yielding varieties.

For bacteria blight resistance, genotype (Long duration) BR (Path)13800-BC$_3$-134-7 and BR (Path)13800-BC$_3$-224-9 produced the highest yield (10.6 t/ha) while the lowest (5.71 t/ha) was recorded for BRRI dhan58 (check). Growth duration ranged from 147 days to 160 days. For medium duration, highest yield hector^{-1} (10.1 ton) was recorded from the genotype BR(Path)13800-BC$_3$-134-4 with 147 to 156 days growth duration.

Among the tested genotypes, in the background of BRRI dhan63, BR (Path)13811-BC$_3$-8 produced the highest average yield (7.2 t/ha) while in the background of BRRI dhan81, BR (Path)13811-BC$_3$-12 and BR (Path)13811-BC$_3$-60 produced the highest average yield (6.9 t/ha). All the advanced lines showed highly resistant disease reaction for blast and bacterial blight inoculation.

Among the tested genotypes for BB and false smut resistance BR (Path)13804-BC$_3$-44-3 and BR (Path)13804- BC$_3$-55-7 produced the highest average yield (6.9 t/ha). All the advanced lines showed highly resistant disease reaction for blast and bacterial blight inoculation.

All the seven advanced lines (introgressed with *Pi9* gene) showed resistance to rice blast disease during Boro season. Similar results were also observed in the seedbed evaluation. Considering no blast infection, similar growth duration to check and higher yield advantages five blast resistance advanced lines viz BR12454- BC2-56-81-27-3-30, BR12454- BC2-69-97-39-5-44, BR12454- BC2-71-91-6-23-26, BR12454- BC2-75-32-31-39-7, BR12454- BC2-48-10-88-81-32 could be suggested for ALART in the next year.

Three lines harboring *Pi9* in the genetic background of BRRI dhan63 were found resistant against both leaf and neck blast diseases. In addition, 3700 LST lines were developed again and now cultivating in BRRI farm for evaluating its agronomic potentiality and disease resistance.

To identify the novel loci underlying rice blast and BB resistance, 128 Bangladeshi germplasm

were selected from 3024 of 3K genome project, IRRI. The whole genome sequences file contains data of 3,024 genotypes and 404388 SNP marker. The final genotype file contains 128 Bangladeshi germplasm and 808776 SNP data point covering whole genome. Three distinct clusters were identified containing 8, 1 and 119 genotypes.

Out of 9,956 and 1,577 advanced breeding lines (TRB project) including OYT, AYT and RYT, 2,436 were found resistant against BB and 776 were resistant against blast, respectively.

One hundred germplasms were screened out and five (Acc.127, Acc.1934 (HR), Acc.1931, Acc.1933, Acc.1998) were found resistant against bakanae disease of rice.

Among the tested 19 INGER materials, eight entries showed moderate resistant reaction against leaf blast disease. These entries will be tested again in the next year to confirm the resistance.

Advanced breeding lines (140) was screened against sheath rice blight disease. All the rice genotypes were susceptible to highly susceptible to sheath blight disease.

A total 24 Aus germplasms from India, Philippines, Thailand, Ivory Coast, Malaysia and Bangladesh were tested against rice blast disease. Among them 19 entries were found resistance, three moderately resistance and two susceptible.

Under the experiment of crop loss assessment neck blast disease was found major in studied areas where farmers mostly cultivated BRRI dhan28. The yield reduction was significantly correlated with disease incidence as well as severity. As maximum as 65% of yield reduction was recorded in highly infested plot compared to diseased plot.

A model of early warning system of rice blast has been developed based on wheat blast model in collaboration CIMMYT. Data were also generated in last Boro season to validate the model.

The results under the in vitro evaluation of six different nanoparticles against blast, sheath blight and bacterial blight pathogen revealed that AgNPs had the potentiality of mycelial growth inhibition of *Magnaporthe oryzae* and *Rhizoctonia solani* over control. After five days of incubation, K and CuO NPs created inhibitory zone on bacterial growth.

Antagonistic bacteria effective against sheath blight pathogen was evaluated for Phosphate solubilizing capacity, catalase activities and hydrogen cyanide (HCN) production abilities. Among the six antagonistic bacteria all the isolates were positive to hydrogen cyanide production and two were positive to phosphate solubilization and catalase activities.

In net house trial the highest increased plant height was recorded in diseased control (8.2%) followed by AgNo3 (1mM) (5.2%) treated seeds. Root length was somewhat increased (6.4%) in silver nano (neem leaf) treated plants compared with healthy control plants.

Bacterial biopesticide in formulation-1 could survive up to 12 months or more whereas, in formulation-2 could survive up to six months or more in liqiid form.

Yield was increased in T. Aus in different treatments with biocontrol agents compared to control in both Habiganj and in Cumilla. More yield increase was observed at Habiganj (1.1-1.4t/ha) where bakanae infection was observed. In T. Aman 2022 it was observed that more yield increased in BRRI dhan32 compared to BR22 where higher disease incidence was observed in BRRI dhan32. In Habiganj, Tricho-compost (1.5 t/ha) resulted higher yield followed by Tricho-compost (1.5 t/ha)+Bacteria (spray) and the lowest yield was observed in control in BRRI dhan49.

Total 20 new chemicals were evaluated against sheath blight disease. Also, another 20 new chemicals were evaluated against blast. Among them nine and seven chemicals were found effective against sheath blight and blast, respectively.

Application of Amister Top (Azoxystrobin + Difenoconazole) reduced soil bacterial population. The toxic effects of the fungicides were more pronounced immediately after the application of fungicides. On the other hand, with an increasing incubation period, the bacterial population tended to increase.

The particle size of the prepared nano particles (AgNP, ZnONP and CuONP) was measured using scanning electron microscope (SEM) in Plant Pathology Division, BRRI.

Unfortunately, size of the particles was greater than 100 nm. The ratio of precursor and glucose need to be changed for reducing more of the target particle.

An artificial environment was created using polyethylene houses at the Blast Nursary, BRRI. Hourly temperature (ºC) and relative humidity (%) pattern were higher in modified environmental conditions than natural conditions. In modified environmental conditions, both leaf and neck blast disease incidence were significantly higher than the natural conditions. Distinct varietal differentiations to blast disease incidence were also found.

Seven batches of a 'day-long' training programme on integrated rice disease management were conducted at Gazipur, Sirajganj, Cumilla and Habiganj districts of Bangladesh. Each training programme consisted of 30 farmers having both male and female participants.

TRANSFERABLE TECHNOLOGY USEFUL SCIENTIFIC INFORMATION EPIDEMIOLOGY OF RICE DISEASE

Survey and monitoring of rice diseases

Disease survey was conducted in different rice ecosystems (covering nine districts) during T. Aman 2021 and Boro 2021-22. Bacterial blight (BB), sheath blight (ShB) and brown spot were observed predominant irrespective of season. False smut incidence was less in Habiganj and Rangpur districts in T. Aman season and to some extent more in Shirajganj district (Char land ecosystem). Neck blast was prevalent in BRRI dhan28 and BRRI dhan81 at all the locations during Boro season in Shirajganj district. Average bacterial leaf blight incidence was predominant during T. Aman whereas severity of narrow brown spot was high during Boro season in Barishal. Higher narrow brown spot was also recorded in Gazipur during Boro season. Bacterial leaf streak was observed in Rajshahi but neck blast was not recorded during Boro season. Neck blast disease was found predominant in Cumilla and Khagrachari (Hilly areas) during Boro season. Neck blast disease was also found predominant in the aromatic rice varieties, BRRI dhan34 (27% DI, DS 9) and Kalijira (1% DI, DS 7) during T. Aman in Cumilla. Severe tungro incidence was found in high disease prone region, Cumilla only during T. Aman. A considerable percentage of sheath blight incidence was recorded in Boro season which indicates the threat for rice production in this season.

■ T H Ansari, Q S A Jahan, M Hossain, S Mia, M A I Khan, S Akter, M M Rashid, A Ara, M Ahmed, S A I Nihad, R Akter, H A Dilzahan, H R Hira and M A Latif

PATHOGEN POPULATION STRUCTURE AND BIOLOGY OF MAJOR PATHOGEN

Improvement of differential system for rice blast disease in Bangladesh

To improve the existing differential system for rice blast disease resistance, 45 blast infected samples including rice blast, wheat blast and grass blast, and also leaf and neck blast samples were used during Boro season 2021-22. Among them 14 isolates were purified as single spore isolation those used for molecular analysis. DNA extractions of nine isolates were done following standard protocol for sequencing (ITS region) and 1 kb DNA ladder was used in this experiment. ITS profile of ITS1 and ITS4 primer was generated from nine blast fungal isolates (Fig. 1). Distinct variations among wheat blast and rice blast, and leaf and neck blast were generated during gel electrophoresis. All of these DNA samples were sent to Malaysia for sequencing through Invent Bangladesh Ltd. Based on the pathogenicity and molecular analyses, new differential isolates would be selected.

■ M A I Khan, PhD student, M R Bhuiyan, S A I Nihad, H R Hera, M M Rashid, M A Latif and Y. Fukuta

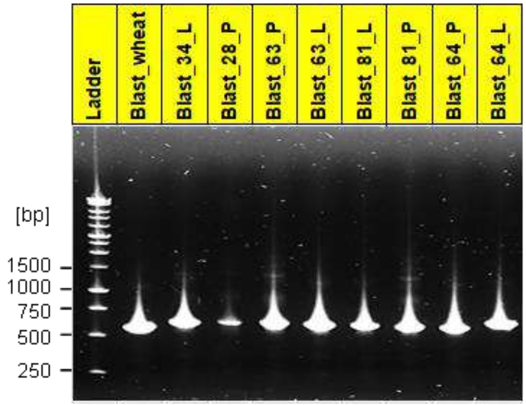


Fig. 1. ITS profile of ITS1 and ITS4 prim er generated from nine blast fungal isolates denoted by Blast_wheat= wheat blast; Blast_34_L=rice blast from BRRI dhan34 leaf (Aman); Blast_28_P=rice blast from BRRI dhan28 panicle (Boro); Blast_63_P=rice blast from BRRI dhan63 panicle (Boro); Blast_63_L=rice blast from BRRI dhan63 leaf (Boro); Blast_81_L=rice blast from BRRI dhan81 leaf (Boro); Blast_81_P=rice blast from BRRI dhan81 panicle (Boro); Blast_64_P=rice blast from BRRI dhan64 panicle (Boro); Blast_64_L=rice blast from BRRI dhan64 leaf (Boro); Ladder= 1 kb DNA ladder.

Etiology, epidemiology and management of bacterial panicle blight (BPB): An emerging and climate sensitive rice disease in Bangladesh

Molecular studies of bacterial panicle blight (BPB) was investigated at Plant Pathology Division, BRRI. A total of 25 infected panicles were collected and 14 isolates were purified as single colony culture. These isolates were characterized using selective media of King's B and CCNT and found only three as *Burkholderia glumae*, causal organism of BPB. DNA extractions of four bacterial strains including 2 BPB, 1 bacterial leaf streak (BLS) and 1 bacterial leaf blight (BLB) were done following standard protocol for short sequencing. Distinct variations among BPB, BLS and BLB were generated during gel electrophoresis. All DNA samples were sent to Malaysia for sequencing through Invent Bangladesh Ltd. Pathogenicity tests of all the isolates will also be done using apparently resistant and susceptible rice varieties. Based on the pathogenicity and sequence data, BPB strain(s) will be confirmed.

■ M A I Khan, M S Student, R Akhter, M M Rashid, M R Bhuiyan, H R Hera, S Das and M A Latif

Identification of the source of infection of major rice diseases

Experiments were conducted to find out the source of infection of major rice diseases. Four varieties (BR11, BRRI dhan34, BRRI dhan49 and BRRI dhan51) were transplanted in three times (25 July, 09 August and 24 August) in 2020 and (15 July, 31 July and 12 August) in 2021 using two seed sources - healthy and diseased. The incidence of both blast and false smut disease tended to be lower on plants generated from healthy seeds compared to diseased seeds; the pattern of disease development was similar in 2020 and 2021. The incidence of both the diseases was higher in 2021 compared to 2020. This was particularly evident in false smut disease in 2020: 1.82±0.50 in diseased seeds and 0.03±0.07 in healthy seeds ($P<0.05$). On the other hand, blast disease was significantly higher in 2021: 24.66±1.33 in diseased seeds compared to healthy seeds 21.87±1.32, ($P<0.05$). The differences in the incidence of false smut disease in 2021 and blast disease in 2020 on healthy and diseased seeds were not statistically significant.

■ B Nessa, M A I Khan and M A Latif

Spatial pattern of natural spread of rice false smut (Ustilaginoidea virens) disease in fields

The spatial pattern of rice false smut disease revealed mostly aggregated patterns of spread in the ecosystem. The aggregated patterns are indication of localized source of infection, which suggest the disease is that soilborne. This study further showed rice hills located towards the proximity of lower land elevation infected with more disease than those towards higher land elevation. A regression of percentage of diseased hills against the proximity of the location of the hills from lower land elevation in a field explained 93% variability. This analysis shows that for each 10 cm distance away from lower elevation (between 50 and 150 cm distance range), the percentage of diseased hills reduced by 7%. The aggregated patterns of localized source of infection and the percentage of diseased hills reduction by 7% for each 10 cm distance towards the higher elevation are the indications of soilborne disease of rice false smut.

■ B Nessa, M A I Khan and M A Latif

Determination of population of different storage fungi and aflatoxins by Aspergillus spp. at different moisture levels in storage condition

To determine the population of different storage fungi and aflatoxin at different moisture levels three rice samples viz Basmati, Chinigura and local fine rice were kept in four types of storage like refrigerator (S1), plastic jar (S2), tin (S3) and brown pack (S4) in room temperature up to 10 months. Moisture content and associated fungi especially *Aspergillus flavus* were recorded every two months of intervals. Percentage of grain moisture content (MC%) of all the sample didn't vary significantly in course of time interval irrespective of rice type and storage condition. Initial MC% of the rice sample was 10.8, 8.0 and 8.4 for Basmati, Chinigura and Local fine rice, respectively and after 10 months of storage the MC% level reached almost 10 for all the sample. Intial inicidence of *A flavus* was 0-1% but inciednce increased gradually and was recorded 85% in Basmati rice irrespective of storage condition after 10 months of storage and 90% in refrrigerated condition irrespective of variety (Fig. 2).

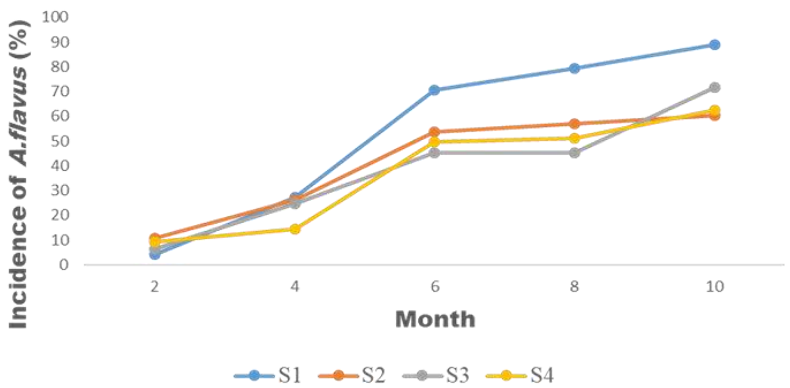


Fig. 2. Effect of storage duration on *A. flavus* (%) associated with seed irrespective of variety (S1= Refrigerator, S2= Plastic jar, S3=Tin and S4= Brown pack in normal condition).

■ S Akter and MA Latif

PATHOGEN POPULATION STRUCTURES AND BIOLOGY DISEASE RESISTANCE AND MOLECULAR STUDIES

Evaluation of BB and blast resistant advanced lines in multilocation trial.

To develop BB and blast resistance varieties multilocation trials of eight advanced lines having BB (Xa21) and blast (*Pi9*, *Pb1*) genes were evaluated in six different locations during Boro 2021-22 season. Field reaction of all the materials against blast diseases were recorded (Table 1). Average yield of the genotypes were ranged from 4.30 to 9.20 t/ha, while growth duration ranged from 141 to 166 days. The yields were comparable to the susceptible check variety BRRI dhan29 (7.42

t/ha, 156d), BRRI dhan58 (6.58 t/ha, 151 d). Among the tested genotypes BR (Path) 13800-BC3-134-252 produced the highest average yield (7.80 t/ha) with yield range 5.39-8.82 t/ha and average growth duration was 155 over the locations. All the lines showed resistant over the locations. No or very low blast incidence was recorded.

■ M A Latif, M H R Hera, S A I Nihad, M R Bhuiya and M A I Khan

Table 1. Yield of BLB resistant advanced lines at different locations in Boro 2021-22.

Genotype	Yield (t/ha)						BB and Neck/panicle blast infection (%)					
	Rangpur	Sonagazi	Cumilla	Habiganj	Sirajganj	Gazipur	Rangpur	Sonagazi	Cumilla	Habiganj	Sirajganj	Gazipur
BR (Path) 13800-BC3-109-181	6.22	7.29	5.79	5.13	5.56	7.56	1	0	0.34	0	4	0
BR (Path) 13800-BC3-118-37	7.39	7.66	8.93	4.30	7.19	7.30	1	0	0	0	4	0
BR (Path) 13800-BC3-124-133	7.85	7.26	8.53	4.47	8.13	8.26	1	0	0	0	2	0
BR (Path) 13800-BC3-126-166	7.89	7.16	8.35	5.02	8.66	8.55	1	0	0.17	0	1	0
BR (Path) 13800-BC3-134-96	8.28	8.43	7.67	4.46	8.06	8.78	1	0	3.33	0	1.5	0
BR (Path) 13800-BC3-134-252	8.06	7.69	8.12	5.39	8.71	8.82	1	0	0	0	2	0
BR (Path) 13800-BC3-125-143	7.71	8.00	7.95	4.75	8.40	8.31	1	0	0	0	3	0
BR (Path) 13800-BC3-224-12	7.86	8.57	7.64	4.56	9.20	8.64	1	0	0	0	1.5	0
BRRI dhan29 (ck)	7.49	7.73	8.14	4.71	8.55	7.89	3	0	0	0	3	0
BRRI dhan58 (ck)	5.99	7.24	7.94	4.03	7.05	7.25	3	0	0	0	5	0
BRRI dhan88	-	7.36	-	4.45	-	-	-	0	-	0	-	-
BRRI dhan81	-	-	6.83	-	-	-	-	-	0	-	-	-
Bangabandhu dhan100 (ck)	-	-	7.65	-	-	-	-	-	3.33	-	-	-

[a]Percent panicle infection based on SES, IRRI 2013 as resistant ≤10% neck/panicle infection.

*Data not available

Development of multiple disease resistant (blast and bacterial blight) pre-breeding materials using gene pyramiding approach (Long duration).

Ten advanced lines having blast (*Pi9* and *Pb1*) and BB (*Xa21*) resistant fixed lines along with two checks (BRRI dhan29 and BRRI dhan58) were evaluated during the Boro 2021-22 season to develop multiple disease resistant (blast and bacteria blight) pre-breeding materials. Average yield of the genotypes were ranged from 7.01 to 10.27 t/ha. The yields were compared to the susceptible check varieties BRRI dhan29 (7.23 t/ha, 160 d) and BRRI dhan58 (5.71 t/ha, 152). Among the tested genotypes BR(Path)13800-BC$_3$-224-5 produced the highest average yield (10.27 t/ha). All the advanced lines showed highly resistant disease reaction for blast and bacterial blight inoculation. Homozygosity of the populations was confirmed through respective molecular marker (Fig. 3-5).

■ M A Latif, M H R Hera, S A I Nihad, M R Bhuiya and M A I Khan

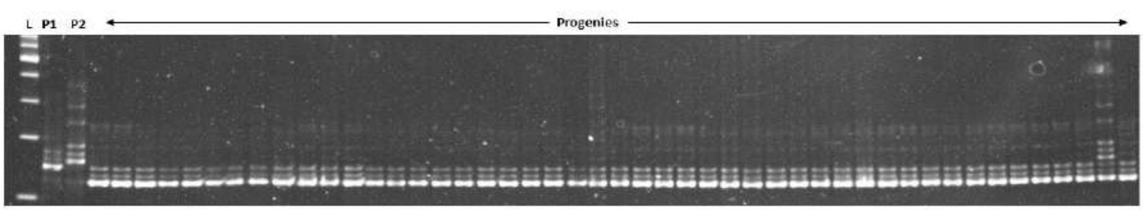


Fig. 3. Partial gel picture of RM206 primer (*Pb1* gene linked). Here, P1- resistant check, P2- susceptible check, L- 100 bp ladder, G1 to G22 represents advanced resistant materials.

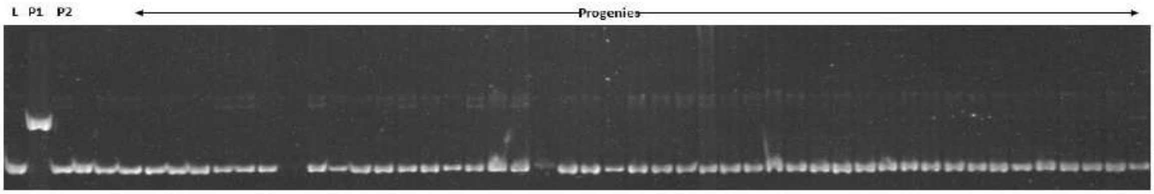


Fig. 4. Partial gel picture of gene-based primer 195R (*Pi9* gene linked). Here, P1- resistant check, P2- susceptible check, L- 1000 bp ladder, G1 to G30 represents advanced resistant materials.

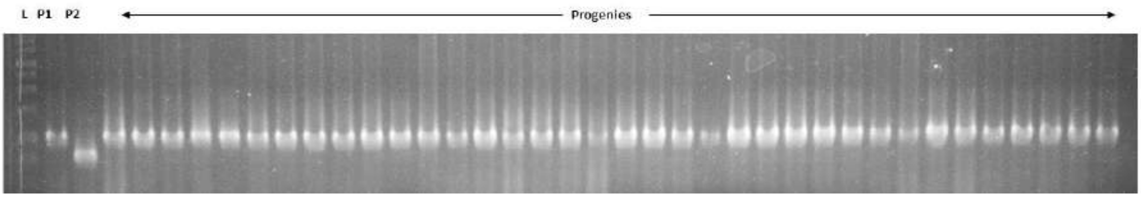


Fig. 5. Partial gel picture of Pta-248 primer (*Xa21* gene linked). Here, P1- resistant check, P2- susceptible check, L- 1000 bp ladder, G1 to G30 represents advanced resistant materials.

Development of multiple disease resistant (blast and bacterial blight) medium growth duration pre-breeding materials for Boro 2021-22

Ten BB and blast resistant fixed lines along with a check BRRI dhan29 and BRRI dhan58 were evaluated during the Boro 2021-22 season. BRRI dhan58 (check) had the lowest plant height (119 cm) while advanced lines BR (Path) 13800- BC_3-8-5 and BR (Path)13800- BC_3-8-9 had highest plant height (129 cm). Number of tiller hill^{-1} ranged from 15 to 19 while number of panicle hill^{-1} ranged from 14 to 19. Panicle length ranged from 24 cm to 26 cm. The highest yield hectare^{-1} (9.93 ton) was recorded from the genotype BR (Path)13800- BC_3-8-8 while lowest (5.71 ton) was recorded for BRRI dhan58 (check). On the other hand, growth duration ranged from 147 days to 160 days.

■ M A Latif, M H R Hera, S A I Nihad, M R Bhuiya and M A I Khan

Development of bacteria blight resistant pre-breeding materials using gene pyramiding approach (Long duration).

Twelve advanced lines having BB (*xa13&Xa21*) resistant fixed lines along with two checks (BRRI dhan29 and BRRI dhan58) were evaluated during the Boro 2021-22 season to develop bacteria blight resistant pre-breeding materials using gene pyramiding approach (Long duration). BRRI dhan58 (check) had the lowest plant height (119 cm) while advance lines BR(Path)13800-BC_3-8-1 had the highest plant height (129 cm). Number of tiller hill^{-1} ranged from 15 to 19 while number of panicle hill^{-1} ranged from 14 to 20. Panicle length ranged from 24 cm to 26 cm. The highest yield hectare^{-1} (10.6 ton) was recorded from the genotype BR(Path)13800-BC_3-134-7 and BR(Path)13800-BC_3-224-9 while lowest (5.71 ton) was recorded for BRRI dhan58 (check). On the other hand, growth duration ranged from 147 days to 160 days (Table 2).

■ M A Latif, M H R Hera, S A I Nihad, M R Bhuiya and M A I Khan

Table 2. Yield and yield attributing characters of BB resistant advanced lines.

Line	PtH (cm)	NTH	NPH	PL (cm)	YH (ton)	GD (days)	Disease score	
							Blast	BB
BR(Path)13800-BC_3-8-1	129	18	17	26.33	9.61	148	1	1
BR(Path)13800-BC_3-8-2	127	18	16	25.67	9.18	157	0	0
BR(Path)13800-BC_3-8-3	126	15	14	25.33	9.97	150	1	1

BR(Path)13800-BC$_3$-109-4	127	18	16	25.33	8.64	155	1	0
BR(Path)13800-BC$_3$-8-5	125	20	18	25.67	7	150	0	1
BR(Path)13800-BC$_3$-134-6	122	18	17	23.67	8.6	149	1	1
BR(Path)13800-BC$_3$-134-7	125	18	17	24.67	10.6	152	0	0
BR(Path)13800-BC$_3$-116-8	126	16	15	25.67	9.63	147	1	1
BR(Path)13800-BC$_3$-224-9	125	16	15	24.67	10.6	156	0	0
BR(Path)13800-BC$_3$-12-10	124	17	15	25.00	7.32	153	1	1
BR(Path)13800-BC$_3$-134-11	122	18	17	25.67	8.93	157	1	0
BR(Path)13800-BC$_3$-224-12	124	18	16	25.33	8.28	151	0	1
BRRI dhan29 (check)	122	15	13	25.00	7.23	160	1	1
BRRI dhan58 (check)	119	14	12	23.67	5.71	152	0	0

PtH- plant height; NTH- number of tiller hill^{-1}; NPH^{-1}- number of panicle hill^{-1}; PL- panicle length; YH-yield hactor^{-1}; GD- growth duration

Development of bacterial blight resistant medium duration pre-breeding materials for Boro 2021-22

To develop bacterial blight resistant medium duration pre-breeding materials 12 BB resistant (xa13 and xa21) fixed lines along with a check BRRI dhan29 and BRRI dhan58 were evaluated during the Boro 2021-22 season. In case of bacterial blight resistant advanced lines BRRI dhan58 (check) had the lowest plant height (119 cm) while BR (Path)13800- BC$_3$-110-1, BR (Path)13800- BC$_3$-8-2 and BR(Path)13800- BC$_3$-8-8 had the highest plant height (127 cm). Number of tiller hill^{-1} ranged from 16 to 20 while number of panicle hill^{-1} ranged from 14 to 19. Panicle length ranged from 24 cm to 26 cm. The highest yield hector^{-1} (10.1 ton) was recorded from the genotype BR (Path)13800- BC$_3$-134-4 while the lowest (5.71 ton) was recorded for BRRI dhan58 (check). On the other hand, growth duration ranged from 147 days to 156 days.

■ M A Latif, M H R Hera, S A I Nihad, M R Bhuiya and M A I Khan

Pyramiding of blast and bacterial blight resistant genes into the genetic background of BRRI dhan63 and BRRI dhan81

Twenty advanced lines having blast (*Pi9* and *Pb1*) and BB (*Xa21*) resistant fixed lines along with the checks (BRRI dhan63 and BRRI dhan81) were evaluated during Boro 2021-22. Average yield of the genotypes ranged from 6.3 to 7.2 t/ha (BRRI dhan63 background) and 6.3 -6.9 t/ha (BRRI dhan81 background). The yields were compared to the susceptible check variety BRRI dhan63 (6 t/ha, 145 d) and BRRI dhan81 (5.9 t/ha, 147 d). Among the tested genotypes (BRRI dhan63 background) BR (Path)13811-BC$_3$-8 produced the highest average yield (7.2 t/ha) whereas genotypes (BRRI dhan81 background) BR(Path)13811-BC$_3$-12 and BR (Path)13811-BC$_3$-60 produced the highest average yield (6.9 t/ha). All the advance lines showed highly resistant disease reaction for blast and bacterial blight inoculation.

■ M A Latif, M H R Hera, S A I Nihad, M R Bhuiya and M A I Khan

Development of pre-breeding materials of BB and false smut resistance in the background of BRRI dhan49

Fourteen advanced lines of BB and false smut resistant fixed lines along with a check (BRRI dhan49) were evaluated during the Boro 2021-22 season. Average yield of the genotypes ranged from 5.5 -6.9 t/ha. The yields were compared to the susceptible check variety BRRI dhan49 (5.2 t/ha, 136 d). Among the tested genotypes BR (Path)13804- BC$_3$-44-3 and BR(Path)13804- BC$_3$-55-7 produced the highest average yield (6.9 t/ha). All the advanced lines showed highly resistant disease reaction for blast and bacterial blight inoculation.

■ M A Latif, M H R Hera, S A I Nihad, M R Bhuiya and M A I Khan

Improvement of high yielding varieties for resistance to blast and bacterial blight diseases using marker assisted backcross breeding

To introgress bacterial blight (BB) and blast resistant genes in high yielding variety, parent materials were grown during T. Aman 2021 and Boro 2021-22. Four sets of parents were grown with seven days interval for the synchronization of flowering among the parents. Seeding was started from 17 July 2021 in Aman season and for Boro season it was started from 17 December 2021. In Aman 2021 and Boro 2021-22, selfing was done to obtain seeds from advanced generation of BB and blast resistant advanced lines. Heterozygosity of the populations was confirmed through respective molecular marker.

■ M A Latif, M H R Hera, S A I Nihad, M R Bhuiya and M A I Khan

Evaluation of blast resistance advanced lines

The developed blast resistant advanced lines were screened against rice blast disease to observe the resistance level in different conditions. Seven blast resistant advanced lines introgressed with *Pi9* gene was screened along with blast susceptible four popular Boro varieties viz BRRI dhan28, BRRI dhan29, BRRI dhan89 and BRRI dhan92, including US2 in the blast nursery. All of them showed susceptible severity scores. However, all the advanced lines showed resistance to rice blast disease (Table 3). Similar results were also observed in the seedbed evaluation. Further evaluation in the crop field showed high node blast incidence (18.3%) and 4.2% neck blast incidence in BRRI dhan89. These results indicated that all the tested advanced lines showed resistance to rice blast disease.

Table 3. Rice blast severity score in the blast nursery at Gazipur, 2022.

	Blast nursery			
Line/Check variety	Obs-1	Obs-2	Obs-3	Obs-4
BR(Path)12454-BC2-87-24-32-1-29	0	0	0	0
BR(Path)12454-BC2-56-81-27-3-30	0	0	0	0
BR(Path)12454-BC2-69-97-39-5-44	0	0	0	0
BR(Path)12454-BC2-71-91-6-23-26	0	0	0	0
BR(Path)12454-BC2-75-32-31-39-7	0	0	0	0
BR(Path)12454-BC2-48-10-88-81-32	0	0	0	0
BR(Path)12454-BC2-13-81-88-87-HR	0	0	0	0
BRRI Dhan28	5	3	4	5
BRRI Dhan29	4	5	3	5
BRRI Dhan89	5	5	5	5
BRRI Dhan92	3	5	4	5
US2 (S ck)	5	5	5	5

■ T H Ansari, M Ahmed and M S Mian

Regional yield trial (RYT) and multi-location trials (MLT) of blast resistance advanced lines with *Pi9* gene

Experiments were conducted to evaluate specific and general adaptability of the advanced blast resistance breeding lines as compared with standard cheeks in on-station and on-farm conditions. RYTs were conducted at BRRI stations while MLTs was conducted in the farmers' field. Leaf blast infection was observed in BRRI dhan89 (node 18.3% and neck 4.2%) at Gazipur and BRRI dhan29 at Sonagazi (huge leaf blast) fields only. While the resistant lines had no blast infection. The growth duration of the lines was similar compared to the check varieties irrespective of RYTs and MLTs. On station (RYT) experiments showed no significant difference in rice yield which ranged from 6.86-7.2 t/ha. On the other hand, on-farm results (MLTs) indicated that BR12454- BC2-56-81-27-3 to 30, BR12454- BC2-69-97-39-5-44, BR12454- BC2-71-91-6-23-26, BR12454- BC2-75-32-31-39-7, BR12454- BC2-48-10-88-81-32 produced higher yield similar to the checks (6.91-7.51 t/ha). Further yield average of all 13 locations (RYT and MLT) showed that the above-mentioned blast resistance lines could be suggested for ALART in the next year (Table 4).

Table 4. Average plant height, growth duration and yield of blast resistant lines from different RYT and MLT experiments (13 locations), Boro 2021-22.

Genotype	Plant height (cm)	Growth duration (d)	Yield (t/ha)	
			BLUE	BLUP
BR12454-BC2-87-24-32-1-29	116	157	6.54	6.69
BR12454- BC2-56-81-27-3-30	117	158	6.97	6.98
BR12454- BC2-69-97-39-5-44	108	158	7.25	7.17
BR12454- BC2-71-91-6-23-26	114	158	6.98	6.99
BR12454- BC2-75-32-31-39-7	115	157	6.93	6.95
BR12454- BC2-48-10-88-81-32	108	159	6.97	6.98
BR12454-BC2-13-81-88-87-HR	117	159	6.90	6.93
BRRI dhan29 (S. ck)	105	159	7.18	7.12
BRRI dhan89 (S. ck)	110	157	7.31	7.21
LSD	2.88	1.42	0.36	0.3
H2	94	58	67	

■ T H Ansari, M Ahmed and M S Mian

Development of pre-breeding materials of tungro resistance

To introgress tungro resistant gene in high yielding variety, parent materials were grown during Aman 2021 and Boro season of 2021-22. Five sets of parents with seven days interval were grown for the synchronization of flowering among the parents. Seeding was started from 14 July 2021 in Aman season and for Boro season it was started from 6 December, 2021-22. In Aman 2021 four crosses and in Boro 2021-22 season four crosses were made among the parents. Heterozygosity of the population was confirmed by using the respective marker. After confirmation crossing was done to make the next generation.

■ S A I Nihad, M M Rashid, M S Mian, M A Latif

Introgression of blast resistance gene(s) into BRRI dhan58 using marker assisted backcross breeding

To introgress blast resistance gene (s), *Pi9* and *Pb1*, in high yielding BRRI dhan58 parent materials were grown during Aman 2021 and Boro 2021-22. Seeding was started from 16 July 2021 in Aman season and 1 December 2021 in Boro Season. Primer/marker NMSM-Pi9 was used to detect *Pi9*, while RM206 was used for *Pb1* confirmation. During Aman 2021, a total of 29 progenies were selected out of 39 at BC3F4 stage; while 23 progenies were selected out of 29 grown in Boro 2021-22. Here, primer (NMSM-Pi9-1) was used for *Pi9* detection which amplified susceptible homozygous allele of 250bp in BRRI dhan58 (and resistant homozygous allele of 168bp in IRBL9-W (Fig. 6).

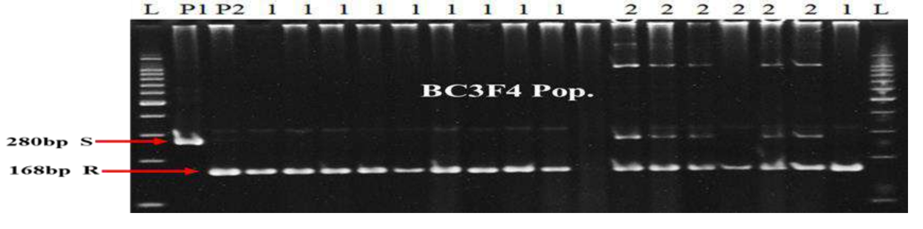


Fig. 6. PCR analysis of the parental lines and BC3F4 plants against blast resistance gene *Pi9*. P1- BRRI dhan58; P2- IRBL9-W. 1-Homogenous resistant plant; 2-Heterogenous resistant plant.

■ M R Bhuiyan, M A I Khan, M Khatun & M A Latif

Multilocation trial of tungro resistance advanced lines in tungro hot-spot areas

A total of 150 tungro resistance advanced lines derived from the crosses of TW-16, Matatga-1, IR69705-1-1-1-3-2 and BRRI dhan48, BRRI dhan71 were evaluated in tungro hotspot area during Aman 2021. Among them, fifty lines which showed good phenotypic performance were selected for seed multiplication. Table 5 presents the selected lines and their cross combination. Seeding was started from 14 July 2021 in Aman season and for Boro 2021-22 season it was started from 6 December 2021-22.

Table 5. List of crosses and the number of plants selected for the respective cross.

Cross combination	Aman 2021		Boro 2021-22	
	Generation	# Plants selected	Generation	# Plants selected
BRRI dhan71*TW-16	BC_3F_5	85	BC_3F_6	25
BRRI dhan48*IR69705-1-1-1-4-2	BC_3F_5	35	BC_3F_6	15
BRRI dhan48*Matatag-1	BC_3F_5	30	BC_3F_6	10

■ S A I Nihad, M M Rashid, M S Mian, M A Latif

Development of blast resistance rice by CRISPR/Cas9-Targeted mutagenesis of the *OsERF922* gene

To develop blast resistant variety by targeted mutagenesis of *OsERF922* gene by CRISPR/Cas9 method, targeted site of *OsERF922* gene was ligated with SK-gRNA vector**.** Ligated site with target sequence was cut by restriction enzyme KpnI and BgII and ligated into final vector pc1300-Cas9. This final vector was transformed into Agrobacterium for the transformation into rice variety BRRI dhan81. Mutated plants were generated and confirmed through DNA sequencing. Mutated lines will be screened against blast pathogen to see the response of the mutated lines.

■ S A I Nihad, M A I Khan, H N Barman, R Bhuiyan and M A Latif

Transcriptome analysis for the detection of novel sheath blight resistant gene (s) in Orgoja, landrace

To identify novel resistant gene of sheath blight disease four sets of Orgoja and BR11 were planted in the pot with four replications during Aman 2021. Leaf samples were collected at 0 hr, three days, five days and seven days after inoculation and preserved in -80℃ for further analysis. Both of Orgoja and BR11 inoculated with virulent sheath blight isolate. We need to confirm disease resistant potentiality of Orgoja first then transcriptomic analysis. This is an on going experiment.

■ S A I Nihad, S Akter and M A Latif

Development of blast resistant varieties using differential system and molecular Markers (JIRCAS)

To improve the genetic background of popular rice variety BRRI dhan28, BRRI dhan29, BRRI dhan63 and BRRI dhan64 against blast disease, a maker assisted backcross breeding followed by pathogenicity tests were started in collaboration with JIRCAS, Japan in 2014. Different sources of *Pi9*, *Piz-t*, *Pish*, *pi21* and *Pb1* were used as donor. The recombinant lines were screened both in artificial conditions and also natural conditions in blast hot spots. A total of 61 lines were selected as blast resistance with different agronomic characteristics in Boro 2020-21. Those lines were again tested in Boro 2021-22 for the confirmation of blast resistance. Among them three lines harboring *Pi9* in the genetic background of BRRI dhan63 were found resistant against both leaf and neck blast disease. Twenty-fine lines those mostly harbored *pi21* genes showed resistance against leaf blast but susceptible to neck blast. All of the check varieties showed susceptible reactions against both leaf and neck blast disease. In addition, 3,700 LST lines were developed again and now cultivating in BRRI farm for evaluating its agronomic potentiality and disease resistance.

■ M A I Khan, M R Bhuiwan, M M Rashid, Emam Hossain, Mahmuda Khatun, Y Fukuta and M A Latif

Detection of novel loci underlying rice blast and BB resistance by integrating a genome-wide association study and evaluation of resistant genes in the background of 186 local germplasm

To identify the novel loci underlying rice blast and BB resistance, 128 Bangladeshi germplasm were selected from 3,024 of 3K genome project, IRRI. The whole genome sequences data of these germplasm are now available in website. The genotype data was in separated files when downloaded from the data repository of 3K Rice Genome Project. Twelve genotype file was merged in order to obtain one single genotype file covering whole genome and named it as 3k-core-v7-chr1 to 12.hmp. This file contains data of 3,024 genotype and 4,04,388 SNP marker. We have sorted out the genotype data for the 128 Bangladeshi germplasm. The final genotype file contains 128 Bangladeshi germplasm and 8,08,776 SNP data point covering whole genome.

An UPGMA dendogram have been constructed (Fig. 7) and calculated the genetic distance using TASSEL 5. 2.43 software. Three distinct clusters were identified containing 8, 1 and 119 genotypes. KOIYA DIGHA (IRIS_313-9445) comprised alone in a single cluster. In this season, artificial inoculation data will be available and we will identify new genomic positions responsible for Blast and BLB resistance.

■ M A I Khan, Md Ruhul Quddus, Md Rejwan Bhuiwan, M Rafiqul Islam, M Sazzadur Rahman, Anjuman Ara, S A I Nihad, Montasir Ahemd, M M Rashid and M A Latif

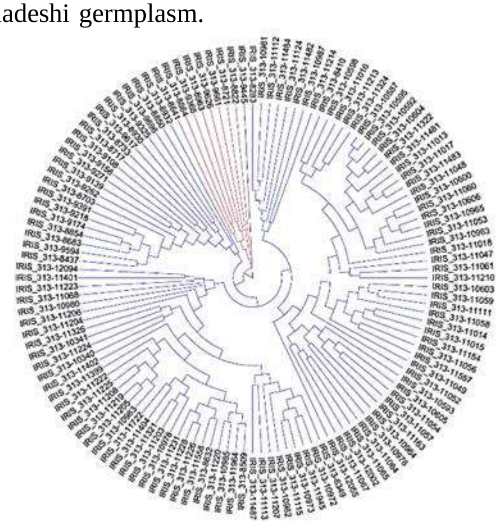


Fig. 7. UPGMA dendogram showing relatedness of 128 Bangladeshi germplasm based on the data repository of 3K Rice Genome Project.

Screening of advanced breeding lines against bacterial blight and blast (TRB)

A total of 9,956 and 1,577 advanced breeding lines including OYT, AYT and RYT were screened against BB and blast, respectively. The most virulent BB and blast isolates were used for artificial inoculation during the last T. Aus 2021, T. Aman 2021 and Boro 2021-22 season. The plants were inoculated by leaf clipping method at maximum tillering stage for BB screening and 18-21-day-old seedlings were used for leaf blast inoculation by spraying spore suspension. Data of leaf damage area (%) were collected 21 days after inoculation for BB and eight days after inoculation for blast. The collected data were then converted to disease severity scale (0 to 9) following SES 2013, IRRI Philippines.

Out of them, 2,436 were found resistant against BB and 776 were resistant against blast. The results were sent to Plant Breeding Division and the resistant materials are now evaluating again for confirmation.

■ M A I Khan, S Das, Md. Rejwan Bhuiwan, A Ara, M Khatun, P S Biswas and M A Latif

Screening of rice germplasms against Bakanae disease

To find out new source of resistance against bakanae disease of rice 100 rice germplasms were collected from GRS division. The seeds were surface sterilized with 70% ethanol, washed with sterilized distilled water and then soaked overnight in sterilized distilled water. The water drained out and seeds were further soaked in spore suspension (10^6 conidia/mL) of the virulent isolate for 48 h. The seeds were then planted in sterilized soil in trays (2 kg soil/tray) and were arranged in a completely randomized design with three replications (15 seeds/replication). Pre-soaked seeds for the control treatment (susceptible variety BR1 and resistant check variety BR3) were soaked further in sterile distilled water for 48 h before sowing. Out of 100 germplasms five (Acc.127, Acc.1934 (HR), Acc.1931, Acc.1933, Acc.1998) were found resistant to bakanae disease of rice.

■ Q S A Jahan, S. Akter, T. Khatun, B. Nessa and M Khalequzzaman

Formulation of nano particles and in vitro test of nano particles derived from plant products for controlling bakanae disease

Experiments were conducted in net house of BRRI HQ, Gazipur to formulate nano particles from organic sources for controlling bakanae disease and to use nano particles from organic sources for safe environment. Nano particles synthesized from neem leaf @ 12 mg/L controlled bakanae disease infection in root deep method. In net house trial it was observed that the highest plant height was increased in diseased control (8.2%) followed by AgNo3 (1mM) (5.2%) treated seeds. Plant height was somewhat shorter (-2.4%) in silver nano (neem leaf) treated plants compared with healthy control plants. This plant height shortness was found in the trays also.

In case of root length, it was observed that root length was somewhat increase (6.4%) in silver nano (neem leaf) treated plants compared with healthy control plants. The lowest root length was observed in diseased control plants (44% decreased) followed by AgNo3 (16% decreased) treated seeds.

■ Q S A Jahan and A. khaton

Multiplication and formulation of bacterial bioagents and shelf life study

Experiment was conducted to formulate nano particles from organic sources for controlling bakanae disease. The identified potential biocontrol agent (*Serratia* sp.) was formulated in liquid medium and in water. Two types of formulations were prepared. Formulation-1 was formulated with and without glycerol in combination with starch in nutrient broth (100%) in conical flask and stored in room temparature. Formulation-2 was formulated with and without glycerol in combination with starch in water and in combination with nutrient broth. It was observed that *bacterial biopesticide* in formulation-1 can survive up to 12 months or more whereas, in formulation-2 can survive up to six months or more in liqiid form. Formulation-2 may active more and is in progress.

■ Q S A Jahan and A. khaton

Efficacy of biocontrol agents to manage bakanae disease in field condition

Three and two trials were conducted during T. Aus 2021 and T. Aman 2021, respectively in Cumilla and Habiganj. Four treatments were applied including control. In T. Aus, it was observed that yield increased in different treatments compared to control in both Habiganj and in Cumilla. More yield increase was observed at Habiganj (1.1- 1.4t/ha) where bakanae infection was observed. During T. Aman 2021, in BRRI dhan32 at Cumilla, bakanae disease incidence was higher (25-30%) compared to BR 22 (15-20%). In Habigonj disease incidence was 10-14% in BRRI dhan49. More yield increase was observed in BRRI dhan32 compared to BR 22 (Fig. 8). In Habiganj higher yield was also recorded in all treatments compared to control in BRRI dhan49. Among the treatments trialed T1: Tricho-compost (1.5 t/ha) resulted higher yield followed by T3: Tricho-compost (1.5 t/ha)+Bacteria (spray) and lowest yield was observed in T4: Control. This higher yield increase was due to increase of flag leaf length and 1000 grain weight in T1 and in T3 compared to T4.

■ Q S A Jahan, M Hossain, M M Rashid and M A Latif

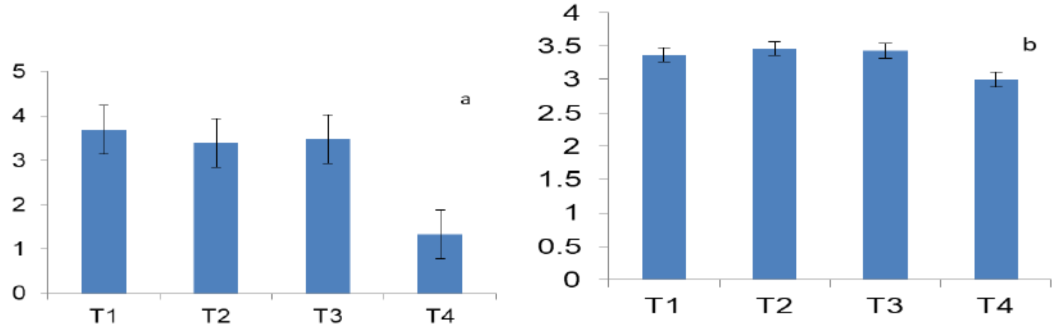


Fig. 8. Comparison of yield in different treatments at Cumilla in T. Aman 2021 (a= BRRI dhan32, b= BR22). T1: Tricho-compost (1.5 t/ha), T2: Bacteria, T3: Tricho-compost (1.5 t/ha)+Bacteria (spray), T4: Control

Screening of INGER materials against leaf blast disease of rice

A total of 96 INGER materials were tested against leaf blast disease in the blast nursery in 2020-21 to evaluate the resistance against blast disease. Among them, 19 materials showed moderate resistant to moderate susceptible. Seedlings of these 19 materials were grown in the blast nursery. Ripen panicles of each line were harvested. After drying the panicles, seeds were kept in store room for next year use. These 19 materials were tested again in the blast nursery with BRRI dhan28 and BRRI dhan33 as local susceptible and resistant check. Recommended fertilizer doses were maintained in the test nursery. Rice blast nursery protocol was followed for screening. Among the tested 19 materials, eight entries showed moderate resistant reaction against leaf blast disease. These entries will be tested again in the next year to confirm the resistance.

■ M S Mian, T H Ansary, M Hossain and M A Latif

Studies on host range of the blast pathogen.

An experiment was conducted to investigate the host specificity among the rice, foxtail millet (*Setaria italic*) and wheat under control condition following RCB design. Three samples of torpedo grass weed (*Panicum repens*) infected with blast fungi were collected from Wheat Research Centre, Dinajpur and infected rice plants were also collected from BRRI HQ farm, Gazipur. Three grass weed blast isolates and one rice blast isolate (single conidia) were isolated from grass weeds and rice plant respectively. Rice (BRRI dhan28), foxtail millet (Local variety) and wheat (Pradip) were used in this study. The conidial suspension was adjusted to a concentration of 1×10^5 spores per ml and each isolate was sprayed on 20-day-old seedling in a plastic tray. Plants were examined for symptoms at seven days after inoculation. Three grass weed blast isolates inoculated in three trays did not show any symptom on leaves of rice, foxtail millet and wheat. But rice blast isolate developed symptoms of blast disease on leaves of BRRI dhan28 excluding foxtail millet and wheat leaves (Table 6). More isolates from torpedo grass and foxtail millet need to test further for confirmation.

Table 6. Host specificity of blast isolates.

Blast isolate	Disease reaction		
	Rice	Wheat	Foxtail millet
IsolateP8 (from torpedo grass)	-	-	-
IsolateP9 (from torpedo grass)	-	-	-
Isolate10 (from torpedo grass)	-	-	-
IsolateR6 (from rice)	+	_	_

■ M S Mian, T H Ansari, M Hossain and M A Latif

Screening of advanced breeding lines against bacterial blight and sheath blight diseases

To identify new resistant source(s) against BB, 178 and 19 materials including resistant, susceptible and standard checks were screened against bacterial blight (Xanthomonas oryzae pv. oryzae) pathogen in Aman 2021 and Boro 2021-22, respectively. The experiment was conducted under field conditions using artificial inoculation at BRRI HQ, Gazipur. The RCB design was followed with three replications. Plants were inoculated with a virulent isolate of the major race at maximum tillering stage following leaf clipping method (Kauffman *et al*. 1973). The disease severity data were recorded at 14 days after inoculation from 10 leaves in each entry. In Aman 2021, among 178 breeding lines, 11 advanced breeding lines are found as moderately resistant and five as moderately susceptible against bacterial blight disease. Other genotypes were found as susceptible to highly susceptible to bacterial blight disease. In Boro 2021-22, among 19 breeding lines, all the lines were found as highly susceptible to bacterial blight disease. In case of sheath blight, during T. Aman 2021-22, plants were inoculated with pathogen at maximum tillering to booting stage using mycelial plug placement in the center of hill. A total of 140 lines including 10 checks were tested and all the materials showed susceptible to highly susceptible reaction against the pathogen.

■ S Akter, R Akter, M A I Khan and MvA Latif

Response of upland Aus rice germplasm to blast disease

A total of 24 Aus germplasms were collected from India, Philippines, Thailand, Ivory Coast, Malaysia and Bangladesh to find out blast resistance Aus germplasm. These germplasms were tested against leaf blast disease in blast nursery of BRRI HQ, Gazipur. BRRI dhan33 and US2 were used as local resistant and susceptible check in the test nursery. Five-week-old plants were inoculated artificially. Data of leaf blast infection were collected 14 days after inoculation. Among the tested materials, 19 entries showed resistance. But these materials need further test to confirm the resistance.

■ Dilzahan, M Hossain, M R Bhuiwan, M A I Khan and M A Latif

C. EPIDEMIOLOGY, YIELD LOSS AND GRAIN QUALITY STUDIES

Development of early warning system of rice blast disease

To develop an early warning system (EWS), BRRI Plant Pathology Division, together with scientists from Agricultural Statistics, Entomology and Irrigation and Water Management Divisions, are collaborating with CIMMYT-Bangladesh and Embrapa-Brazil. Ice blast disease data have been provided to CIMMYT-Bangladesh. A model of EWS of rice blast has been developed based on wheat blast model with the collaboration of CIMMYT. Data were also generated in last Boro season to validate the model.

■ M A I Khan, M S student, B Nessa, M R Bhuiwan, M M Rashid, S A I Nihad, Bellal Hossain, Moin-US-Salam and MA Latif

Crop Loss Assessment of rice due to major diseases

To determine the actual crop loss due to diseases, a study was undertaken during Boro 2021-22 with the help of BRRI RSs (Rangpur, Sherajganj and Shonagazi). Three villages named Changmari, Dobila and West Chagolnaya, respectively were selected as study areas. Fifty plots were selected randomly across the village and two crop-cut from each plot done during data collection. Details cultivation information and disease data were collected. In addition, yield and yield contributing characters were also collected from the plot. Data were collected digitally using Open Data Kit (ODK). Neck blast disease was found major in studied areas where farmers mostly cultivated BRRI dhan28. The yield reduction was significantly correlated with disease incidence as well as severity. As maximum as 65% of yield reduction was recorded in highly infested plot compared to the healthy plot.

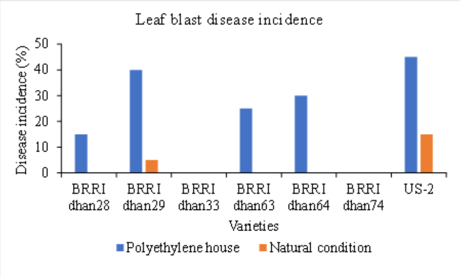
■ M A I Khan, M Hossain, S Akter, R Akhter, Al Imran Hasan, M S Miah, B Nessa, M H R Hera, H

A Dilzahan, T K Ray, S M M S Tonmoy, A Qayum, M A Rouf Sarker, M R Bhuiwan, M R Hasan, M S Rahman, B Karmokar, and M A Latif

Environmental variation affects rice blast outbreak in Bangladesh

To determine the effect of temperature and relative humidity on the occurrence of rice blast disease caused by *Pyricularia oryzae*, seven rice varieties were used for experimentation. Two environmental conditions such as natural condition and modified environmental conditions were adopted at the Blast Nursery of Plant Pathology Division, BRRI where blast inoculum potentials were well distributed. The modified environmental conditions were created by establishing polyethylene house in the Blast Nursery with automated mist system. Yield and yield contributing characters were also collected during the harvest. Leaf and neck blast disease incidence and severity data, plant height and normalized differences vegetation index (NDVI) were collected at seven days interval. Hourly temperature (ºC) and RH (%), light intensity (Lux), Co_2 concentration (ppm), total volatile organic compound TVOC (mg/m^3), Formaldehyde *HCHO* (mg/m^3) were recorded in both modified conditions. Hourly temperature (ºC) and RH (%) pattern were higher in modified environmental conditions than natural conditions. In modified environmental conditions, both leaf and neck blast disease incidences were significantly higher than natural conditions. Distinct varietal differentiations to blast disease incidence were also found (Fig. 9).

■ M A I Khan, N Ausraf, MHR Hera, M M Rashid, M R Bhuiyan, M A Latif, M Maniruzzaman and J C Biswas



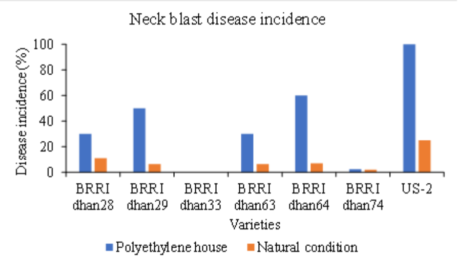


Fig. 9. Leaf blast (A) and neck blast (B) disease incidence under modified environmental conditions (polyethylene house) and natural conditions (open place)

DISEASE MANAGEMENT

Sustainable management of blast, sheath blight and bacterial blight diseases of rice through nano-particles (NPs) (KGF Project)

To control the major rice diseases nano-particles, Ag, CuO, ZnO, SiO_2, MgO and K, were green synthesized from different leaf extract. Six different nano particles (Ag, CuO, ZnO, SiO_2, MgO and K) were characterized with X-ray diffraction (Smart Lab, Rigaku, Japan) and Fourier transform infrared spectroscopy (Perkin Elmer, Spectrum II). The XRD pattern showed strong diffraction peaks at certain degrees of 2θ which confirmed that AgNPs, CuONPs, ZnONPs, SiO_2, MgONPs and KNPs were crystallined in nature and the crystalline size were ~45 nm, ~64 nm, ~37 nm, ~0.931 nm, ~17 nm and ~95 nm, respectively (Figs. 10-15).

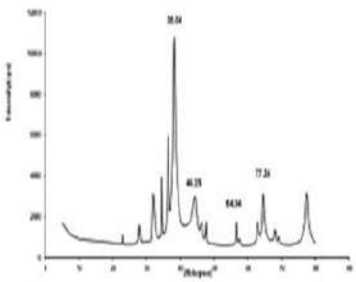


Fig. 10. X Ray diffraction pattern of powder sample of AgNPs.

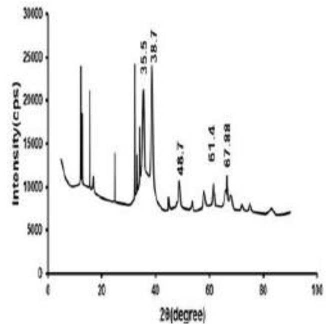


Fig. 11. X Ray Diffraction pattern of powder sample of CuONPs.

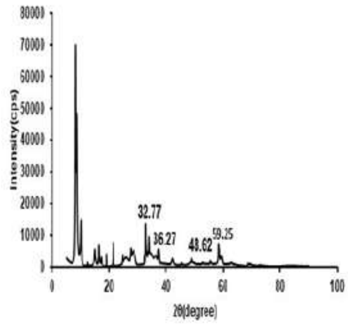


Fig. 12. X Ray Diffraction pattern of powder sample of ZnONPs

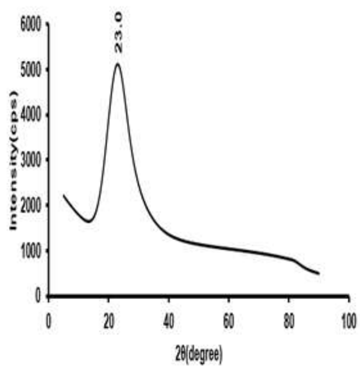


Fig.13. X Ray diffraction pattern of powder sample of SiO2NPs.

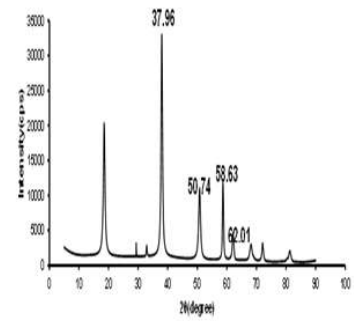


Fig. 14. X Ray diffraction pattern of powder sample of MgONPs.

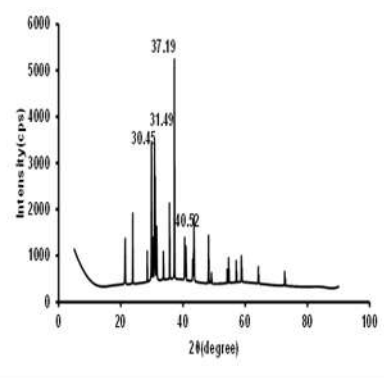


Fig.15. X Ray diffraction pattern of powder sample of KNPs.

In vitro evaluation of different nano-particles against blast, sheath blight and bacterial blight pathogen:otic sexy

In vitro assay was carried out on PDA treated with 800 ppm of AgNPs, ZnONPs and CuONPs. The results revealed that Ag-Nano has the potentiality of mycelial growth inhibition of *Magnaporthe oryzae*. In the other experiment, 1 ml of six (Ag, CuO, ZnO, SiO_2, MgO and K) different nano-particles with various concentration were added to 15 ml PDA medium and AgNPs showed the highest significant mycelium growth reduction over control at ~20 ppm concentration. In another test, four concentrations (0.25M, 0.125M, 0.06M and 0.03M) of potassium (K) and copper oxide (CuO) nano-particles (NPs) along with a control (DH_2O) were evaluated using paper disc method in PSA media. After five days of incubation, K and CuONPs created 1.7±0.023cm and 2.0±0.033 cm inhibitory zone respectively on bacterial growth of *X. oryzae* pv. *oryzae* at the concentration of 0.25M.

M A Latif, S Akter, M A I Khan, M H R Hera, A K M S Islam and R Akter

Development of nano particle mediated fungicide for rice blast disease management

To prepare silver (Ag), zinc oxide (ZnO) and copper oxide (CuO) nano-particles (NPs), silver nitrate (AgNO3), zinc sulphate (ZnSO4.7H2O) and copper sulphate (CuSO4.5H2O) were used respectively as the precursor of respective nano-particles. Microwave assisted starch stabilization technique was used for NPs syntheses where D-glucose was used as reducing agent and boric acid for creating congenial environment.

The particle size of the prepared nano particles was measured using Scanning Electron Microscope (SEM) in Plant Pathology Division, BRRI. Unfortunately, size of the particles was greater than 100 nm. The ratio of precursor and glucose need to be changed for reducing more of the target particle. The experiment is going on.

■ M A I Khan, PhD student, R. Akhter, S. Akter, M R Bhuiwan, M M Rashid and M A Latif

Evaluation of new chemicals against blast and sheath blight diseases of rice

An experiment was conducted at the Blast Nursery of Plant Pathology Division, BRRI, Gazipur during Boro season 2021-22 for the evaluation of new chemicals against leaf blast disease of rice. Blast pathogen was sprayed on BRRI dhan81 for artificial inoculation. A total of 20 test chemicals and a standard check, Nativo 75WG were sprayed three days after inoculation and data on leaf blast infection were collected 14 days after inoculation. Among them, only seven fungicides controlled more than 80% blast disease. These chemicals are suggested to evaluate further before recommending. In sheath blight experiment, BR11 was planted with 20 × 20 cm spacing. The RCBD design was followed with three replications for both the experiments. Chemical was sprayed in PI stage. A total of 21 chemicals including Amister top (ck) were evaluated during T. aman season 2021. Among them, only nine fungicides were controlled more than 80% sheath blight disease. These chemicals were recommended to Plant Protection Wing, DAE for registration already.

M Hossain, H A Dilzahan, M S Mia, M M Rashid, M A I Khan, A Ara and M A Latif

Characterization of antagonistic bacteria effective against sheath blight pathogen

A total of 124 isolates were isolated from 17 samples following dilution technique previously. Among them six were found to inhibit the growth of *R. solani* (*in-vitro*) initially and selected for further studies. Those isolates were tested against major rice pathogens (other than *Rhizoctonia solani*) namely *Pricularia oryzae (Po)*, *Fusarium oryzae (Fm)*, *Bipolaris oryzae (Bo)*, *Microdhochium oryzae (Mo)*. Phosphate solubilizing capacity, catalase activities, hydrogen cyanide (HCN) production abilities were determined. Among the selected six isolates four showed inhibition capacity against the pathogens. And they inhibited the mycelial growth of blast pathogen Po strongly by almost 80%. All the isolates were able to produce HCN and showed positive reaction to catalase test. Two isolates were able to solubilize tricalcium phosphate.

S AKTER AND M A LATIF

Determination of residual effect of tricyclazole group fungicide in rice using LCMS

Method validation was done to determine tricyclazole group of fungicidal residues in rice grain using liquid chromatography tandem mass spectrometry (LC-MS). QuEChERS method and its modification described by Anastassiades *et al.* (2003) and Lehotay *et al.* (2005) were adopted for extraction and clean-up of tricyclazole from a rice grains. Separation of the analyte was achieved on a C18 column (150 x 2 mm i.d.) with a column oven temperature of 40oC. The mobile phase A consisted of 0.0314g ammonium formate (5mM) + 2mL MeOH + 10µL formic acid (0.01%) and the volume made up with HPLC water to 100 mL, and the mobile phase B. contained 0.0314g ammonium formate (5mM) + 10µL formic acid (0.01%) and volume made-up with 100 percent MeOH to 100mL, and delivered at a flow rate of 0.4mL min–1. The residual concentration of tricyclazole was below the standard concentration (European union) which indicated that residual concentration was non-toxic (Table 7).

R Akter, M A I Khan, H B Shozib, N Bari and M A Latif

Table 7. Residual effect of tricyclazole group fungicide in rice using LCMS.

Sample	Ret. time	Area	Height	Concentration
Farmers field (Trooper sprayed BRRI dhan 34)	4.505	224908	16756	0.010 ppm
BRRI field (Trooper sprayed BRRI dhan34)	4.506	158218	14305	0.007 ppm
Control (BRRI dhan 34)	4.507	45039	4238	0.003 ppm

Residual effect of fungicide on microbial community in phylloplane and phyllosphere

To investigate the changes occur in soil microbial communities following use of Amister Top (Azoxystrobin + Difenoconazole) rice variety BR11 were grown during Aman 2021. Four treatments viz Amister top (Azoxystrobin + Difenoconazole), sheath blight, Amister top + sheath blight and healthy control were used. The Amister top (500 ml/ha) was sprayed three days after sheath blight in the plants. Rhizospheric soil samples were collected at booting stage when soil microbial activity was maximum. Soil sample were collected (from 15 cm depth) at three days before, three, seven and 14 days after spray of Amister top. Maximum number of colonies was found at three days before fungicide spray in all treatments. Number of colonies was significantly reduced after spraying of Amister top. The toxic effects of the fungicides were more pronounced immediately after the application of fungicides. On the other hand, with an increasing incubation period, the bacterial population tended to increase (Table 8).

H A Dilzahan, H B Shozib, M R Bhuiwan, S Akter, M A I Khan and M A Latif

Table 8. bacterial colony found in PDA medium from sampled soil.

Treatment	bacterial colony (CFU)×10^{-6}			
	3 days before spray	3 days after spray	7 days after spray	14 days after spray
Amister top	246 ± 10.7 a	51 ± 1.53 c	116 ± 10.15 c	189 ± 5.57 b
Sheath blight	241.33 ± 6.01 a	263.67 ± 4.18 a	242 ± 10.21 a	233 ± 15.28 a
Amister top + Sheath blight	261.33 ± 3.84 a	56.67 ± 3.48 c	182.67 ± 20.92 b	190 ± 14.01 b
Healthy control	235 ± 9.24 a	214.67 ± 31.83 b	231.33 ± 9.53 a	248 ± 13.32 a
CV=10.88				
LSD=36.3151				

Efficacy of commercial and bio-synthesized nanoparticles against bacterial blight disease

Experiment was carried out to find out the effective nano-particles in BB management. Screening of Mg (marigold), K (marigold), ZnO (neem) and CuO (dhol kolmi) was done against *Xanthomomas oryzae.* Among them ZnO and CuO showed clear inhibition zone after five days and onward. Commercial ZnO NP showed better control than biosynthesized nanoparticle from neem but both commercial and biosynthesized CuO NP showed almost similar inhibition against BB.

R Akter, M A I Khan, S Akter and M A Latif

Farmers training on integrated rice disease management

Seven batches of a ‘day-long’ training programme on integrated rice disease management were conducted at Gazipur, Sirajganj, Cumilla and Habiganj districts of Bangladesh. Each training programme consisted of 30 farmers having both male and female participants. Therefore, altogether 210 farmers were trained on different rice diseases and its management technique under changing climatic condition of Bangladesh.

T H Ansary, Q S A Jahan, M Hossain, M S Mian, M A I Khan, S Akter, B Nesa, S A I Nihad, M H R Hera, R Akter, H A Dilzahan and M A Latif

Rice Farming Systems Division

SUMMARY

A field survey on tobacco cultivation was conducted in 2021 in eight upazilas throughout the country where tobacco was a prominent crop. The objective of the survey was to identify the drivers that motivate farmers to adopt tobacco cultivation. Semi-structured questionnaire was used for the survey and it was followed by a focus group discussion consisting randomly selected fifty tobacco grower farmers in each upazila. Data were collected on different issues of tobacco farmers, tobacco cultivation procedures and it’s processing as well as marketing. The results indicate that tobacco cultivation is more profitability than the other crops, assurance of selling tobacco at pre-declared fixed price, opportunity of family labour employment, various incentives from tobacco companies especially tobacco cultivation cost and on the contrary unpredictable market price of winter vegetables also push the farmers for the business. Most of the farmers believe the hazardous issues of tobacco at an insignificant level.

The study was conducted in farmers’ fields at Rangpur Sadar, Rangpur during 2021-22 to find out the suitability of newly released BRRI rice varieties under Potato-Boro-T. Aman cropping pattern and to maximize the production as well as framers’ income. Significantly the highest REY (27.73 t/ha) was observed in BRRI dhan95-Potato-BRR dhan98 followed by BRRI dhan95-Potato-BRRI hybrid dhan5 (26.15 t ha), BRRI dhan75-Potato-Bangabandhu dhan100 (25.5 t ha) and BRRI dhan95-Potato-BRRI dhan88 (25.23 t ha) where the lowest REY (22.03 t/ha) was found in Swarna-Potato- BRRI dhan28. The similar trend was found in gross margin ranged from 2,43,640 to 1,88,640 Tk/ha.

An experiment was carried out during 2021-22 at BRRI HQ research farm, Gazipur to determine the profitable cropping patterns on system productivity consisted of eight cropping pattern combinations.Among the tested cropping pattern, the highest rice equivalent yield (38.80 t ha^{-1}) was observed in Bush bean-Onion-Amaranth-T. Aus-T. Aman whereas the highest gross margin (431860 Tk ha^{-1}) was found in Onion-Jute-T. Aman cropping pattern.

A study was conducted on inclusion of T. Aus in Fallow-Fallow-T. Aman cropping pattern in farmers' fields of Rangamati and Khagrachari districts during Aus and Aman 2021. In T. Aus season, BRRI dhan48 produced grain yield ranging from 4.65 to 4.88 t ha and total rice yield varied from 9.27 to 10.81 t/ha among the tested patterns in different locations.

A total of 30 trials in the Jhum cultivation system were conducted in seven upzilas of Bandarban, Rangamati, and Khagrachhari districts. BRRI dhan83 produced a higher grain yield (3.75 t/ha) followed by BRRI dhan48, BRRI dhan82, BRRI dhan85, BR26 in the Jhum system. Among the local varieties, the higher grain yield was observed from Mongthongno (3.32 t/ha) followed by Kokro (3.17 t/ha) and Ranqui (3.19 t/ha).

Four nitrogen fertilizer treatments viz, T1=Farmer's practice (neither manure nor fertilizer; control), T2=Localized placement (Ring placement around dibbing hole), T3=Row placement in between dibbling lines, T4= ½ Basal + ¼ at tiller initiation and ¼ at maximum tillering stages were conducted to identify the best fertilizer management practices in jhum system at three upazila of Chattogram hill tract. Ring placement around dibbing hole (treatment T2) performed better (3.42 t/ha) among the treatments. Ring placement may be a viable option for efficient fertilizer management in the Jhum system.

A large scale multi-location trial of improved cropping pattern of Mustard - Boro -T. Aman was conducted in six different locations, viz, three districts of Chattogram Hill Tracts, Dhanbari in Tangail, Trishal in Mymensingh and Kaligang in Gazipur districts during 2021-22 with a view to improve the farmers existing cropping pattern of Boro-Fallow-T. Aman by inclusion of mustard. Medium short duration T. Aman rice varieties were used and transplanting time was optimized to widen the gap between T. Aman and Boro to accommodate mustard. Short duration HYV mustard variety BARI Sarisha-14 was used. Use of newly released appropriate rice varieties and inclusion of mustard increased about 25% to 55%

of rice equivalent yield (15.40 to 21.60 t ha^{-1}) and gross margin (100900 to 2,58,800 Tk ha^{-1}) considerably.

A study was conducted at Katiadi and Pakundia upazila in Kishoreganj district during 2021-22 to scale up the improved cropping pattern to increase the total productivity. Among the tested three cropping patterns, Potato-Jute-T. Aman produced the highest REY (25.84 t/ha) followed by Mustard-Maize-T. Aman (17.52 t/ha) against the existing cropping pattern Boro-Fallow-T. Aman (10.06 t/ha). The similar trend was also observed in gross margin where it was 358% and 146% higher in the improved patterns compared to the existing one.

An experiment was conducted in the Aman 2021 and Boro 2021-22 season at Gazipur, Jhenaidah and Dinajpur district to determine the optimum transplanting window, sowing time and seedling age were simulated using the ORYZA v3 simulation model. For short duration varieties in T. Aman, 20-30 days older seedling with seed sowing between 20 June to 5 July yielded higher while 35-45 days older seedlings with sowing dates in between November 16 and December 1 produced statistically higher grain yield.

SURVEY

Survey on Tobacco Based Cropping System

A field survey on tobacco cultivation was conducted in 2021 in eight upazilas throughout the country where tobacco was prominent crop. The objective of the survey was to identify the drivers that motivate farmers to adopt tobacco cultivation. Semi-structured questionnaire was used for the survey and survey was followed by a focus group discussion consisting randomly selected fifty tobacco grower farmers in each upazila. Data were collected on different issues of tobacco farmers, tobacco cultivation procedures and its processing as well as marketing. Tobacco is distributed in 14 cropping patterns concentrated in 45 upazilas of 15 districts. Total tobacco area was recorded as 49 thousand hectares which is equivalent to 0.57% of net cropped area in Bangladesh. Farmers consider tobacco farming as a business and as a guaranteed cash crop at a pre-declared price rate. Poor farmers explore the opportunity of family labour employment in tobacco production and processing. Various incentives from tobacco companies especially funding of cultivation cost in advance and on the contrary unpredictable market price of winter vegetables also push the farmers for the business.

The major findings of the survey indicate that tobacco cultivation is interlinked with many social, economic and individual factors. The most dominant cause of tobacco farming is its more profitability than the other crops. The other factors are mainly having much money at a time, opportunity of family labour employment, assurance of selling tobacco at pre-declared fixed price and so on (Figure 1). In the poor family, it is a business which is mainly based on family labors. Women and school going children are engaged in tobacco field operation, harvesting, curing and all other activities. More family labor support leads a farmer to cultivate more tobacco.

The factors shown in the figure 1 are the determinants for the preference of tobacco cultivation. Among these factors most of them are linked with socio-economic consideration of the farmers. Here one factor is a very strong decider that is the short life cycle of the plant. In addition, in Bangladesh cropping systems are extremely dominated by rice. In kharif-II season (wet season) Aman rice is the only option. Tobacco passes its seedling stage up to 50 days in the seedbed. As a result, its duration in the main field is again shorter than its total life span. Tobacco can easily be transplanted after harvest of Aman rice. If the Aman harvest is late, tobacco can also be transplanted in rice field as standing crop in a relay cropping system. These are the diversified ways through which tobacco is pushing itself in cropping system without disturbing the preceding crop.

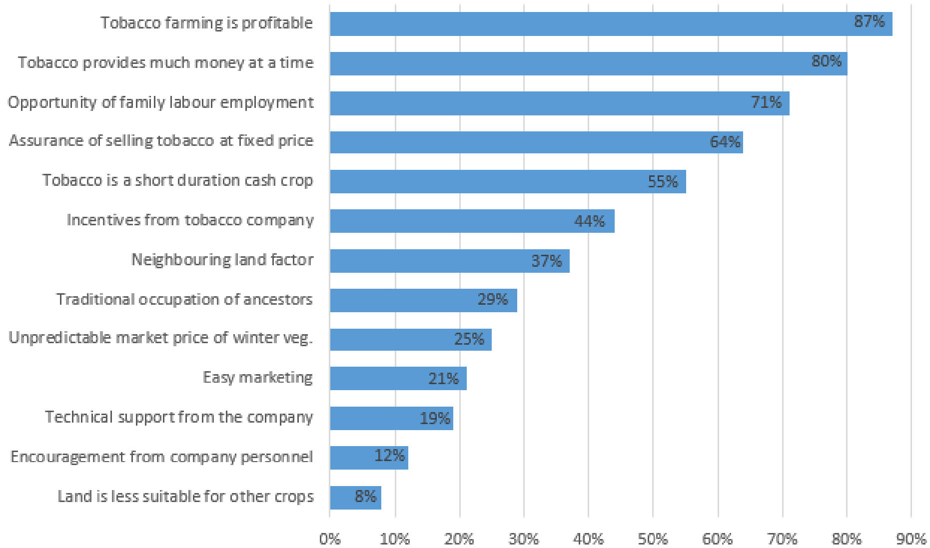


Fig. 1. Determinants for the preference of tobacco cultivation

DEVELOPMENT OF CROPPING SYSTEM AND COMPONENT TECHNOLOGY FOR FAVORABLE ENVIRONMENT

Evaluation of newly released BRRI rice varieties under Potato-Boro-T. Aman cropping pattern

The study was conducted in farmers' fields in Rangpur Sadar, Rangpur during 2021-22 to find out the suitability of newly released BRRI rice varieties under Potato-Boro-T. Aman cropping pattern and to maximize the productivity as well as framers' income. Six improved cropping pattern combinations were tested in RCB design and each farmer was considered as one replication. Recommended fertilizer dose and management practices for rice and non-rice crops were followed.

In T. Aman season, BRRI dhan95 performed better (4.82-4.99 t/ha) where BRRI dhan98 yielded higher (6.18 t/ha) in Boro season. The yield of potato ranged from 26.72 to 36.6 t/ha in different farmers' field. Significantly the highest REY (27.73 t/ha) was observed in BRRI dhan95-Potato-BRRI dhan98) which is similar with CP_6 (26.15 t/ha), CP_3 (25.5 t/ha) and CP_4 (25.23 t/ha). The lowest REY (22.03 t/ha) was found in the existing cropping pattern (Table 1).

Table 1. Yield and cost-return analysis of different cropping combinations under Potato-Boro-T. Aman cropping pattern, Rangpur, 2021-22.

Cropping pattern	Potato (t/ha)	Boro (t/ha)	T. Aman (t/ha)	REY (t/ha)	TVC ('000 Tk/ha)	GM ('000 Tk/ha)
CP_1: BRRI dhan75-Potato- BRRI dhan88	26.72^{b}	6.02^{a}	4.80	22.95^{bcd}	366.41	138.48
CP_2: BRRI dhan75-Potato-BRRI dhan96	27.12^{b}	5.45^{bc}	4.65	22.43^{cd}	366.41	127.04
CP_3: BRRI dhan75-Potato-BRRI dhan100	32.37^{ab}	5.98^{a}	4.81	25.5^{abc}	366.41	194.58
CP_4: BRRI dhan95-Potato-BRRI dhan88	31.7^{ab}	5.91^{a}	4.82	25.23^{abcd}	366.41	188.64
CP_5: BRRI dhan95-Potato-BRRI dhan98	36.6^{a}	6.18^{a}	4.96	27.73^{a}	366.41	243.64
CP_6: BRRI dhan95-Potato-BRRI hybriddhan5	33.61^{ab}	5.85^{ab}	4.99	26.15^{ab}	366.41	208.88
CP_7: Swarna-Potato- BRRI dhan28 (Control)	27.02^{b}	5.30^{c}	4.45	22.03^{d}	366.41	118.24
CV (%)	8.11	9.91	7.82	8.59	-	-

Means with the same letter are not significantly different

Market price (Tk/Kg): Rice = 22, Potato = 10; Potato variety: BARI alu-13, BARI Alu-25 and Elga-7

The highest gross margin (GM) was obtained from CP_5 (2,43,640 Tk/ha) followed by CP_6 (2,08,880 Tk/ha) and CP_3 (1,94,580 Tk/ha) (Table **1**). These three patterns produced 64.56%, 106.05% and 76.65% higher GM compared to the existing pattern (CP_7). BRRI dhan95 in T. Aman season, BRRI dhan98 and BRRI dhan88 in Boro season were quite high yielders and cropping pattern with these varieties produced the higher economic return.

Evaluation of profitable rice based cropping pattern

The experiment was carried out from during 2021-22 at BRRI HQ research farm, Gazipur to determine the profitable cropping patterns on system productivity. The treatments consisted of eight cropping pattern combinations of Boro, T. Aus, T. Aman, onion, jute, field pea, mungbean, potato, pumpkin, mustard, bush bean and stem amaranth.

Among the tested cropping patterns, the highest rice equivalent yield (38.80 t ha^{-1}) was observed in Bush bean - Onion-Amaranth-T. Aus-T. Aman followed by Potato/Pumpkin (Relay)-T. Aus-T. Aman (36.21 t ha^{-1}). Between the three cropped cropping patterns, the REY (35.30 t ha^{-1}) of rice-non rice cropping pattern of Onion-Jute-T. Aman was higher than rice-rice cropping pattern of Boro-T. Aus-T. Aman. The highest gross margin (4,31,860 Tk ha^{-1}) was found in Onion-Jute-T. Aman followed by CP_6 (334790 Tk ha^{-1}) and CP_8 (326230 Tk ha^{-1}) cropping patterns. The lowest gross margin (75150 Tk ha^{-1}) was recorded in CP_1 followed by CP_7 (90330 Tk ha^{-1}) cropping pattern.

DEVELOPMENT OF CROPPING SYSTEM TECHNOLOGIES FOR HILL ECOSYSTEM

Intensification of Fallow-Fallow- T. Aman area through the inclusion of modern Aus rice in plain land in hilly areas

To increase the system productivity of single T. Aman area a total of 21 trials were conducted in farmers' fields with the collaboration of Department of Agricultural Extension of four upazilas of Rangamati and Khagrachhari districts during Aus and Aman 2021. BRRI dhan48, BRRI dhan55 and BRRI dhan82 were evaluated in Aus and BRRI dhan75, BRRI dhan87 in Aman season.

The higher total rice yield (10.59 t/ha) was observed with the combination of BRRI dhan48 and BRRI dhan87 at Sadar, Khagrachhari followed by the combination of BRRI dhan82 and BRRI dhan87 (10.45 t/ha). Inclusion of T. Aus in the existing cropping pattern, increased the total rice production (Table 3).

Table 2. Yield (t ha^{-1}) and cost return of tested cropping patterns, 2021-22.

Pattern	Onion/Field pea/Mustard/Potato/Bushbean	Boro	Amaranth/ Mungbean/S.gourd	T.Aus/ Jute	T. Aman	REY	TVC ('000 Tk/ha)	GM ('000 Tk/ha)
CP_1	-	7.01				7.69	90.53	75.15
CP_2	-	6.92			6.10	15.34	179.43	128.19
CP_3		5.63		5.34	5.07	18.62	228.02	182.35
CP_4	11.20			3.21	5.27	35.30	274.22	431.86
CP_5	5.22		1.24	5.55	5.14	29.69	266.40	262.61
CP_6	15.89		13.06	5.27	5.40	36.21	389.43	334.79
CP_7	1.22		1.10	4.59	5.04	15.94	228.49	90.33
CP_8	9.03		14.90	5.31	5.19	38.80	449.67	326.23
CV (%)						5.70	90.53	75.15
LSD						2.50	179.43	128.19

REY= Rice equivalent yield, TVC = Total variable cost and GM= Gross margin

Price (Tk/kg): Mustard = 50, Field pea = 30, Potato = 12, Bushbean = 30, Rice = 20, Straw = 2, Mungbean = 65, Sweet gourd = 20, Jute = 60, Onion = 30, Stem Amaranth = 20

CP_1: Boro (BRRI dhan92)-Fallow-Fallow	CP_5: Fieldpea-Mungbean-T. Aus (BRRI dhan82)-T. Aman (BRRI dhan75)
CP_2: Boro (BRRI dhan92)-Fallow-T. Aman (BRRI dhan87)	CP_6: Potato/Pumpkin (Relay) or Mungbean-T. Aus (BRRI dhan82)- T. Aman (BRRI dhan75
CP_3: Boro (BRRI dhan88)-T. Aus (BRRI dhan82)-T. Aman (BRRI dhan75)	CP_7: Mustard-Mungbean-T. Aus (BRRI dhan82)-T. Aman (BRRI dhan75);
CP_4: Onion-Jute-T. Aman (BRRI dhan71)	CP_8: Bush bean (BARI jharshim-1)-Onion-Amaranth (BARI sabuj data-1)-T. Aus (BRRI dhan82)-T. Aman (BRRI dhan71)

Table 3. Yield of T. Aus and T. Aman rice in piedmont plain land, Chittagong Hill Tract, 2021.

Cropping pattern	T. Aus	Yield (t/ha)	T. Aman	Yield (t/ha)	Total yield (t/ha)
Fallow -T. Aus-T. Aman	BRRI dhan48	4.735	BRRI dhan75	5.04	9.77
		4.82	BRRI dhan87	5.77	10.59
	BRRI dhan55	4.49	BRRI dhan87	5.72	10.21
		4.4	BRRI dhan75	4.78	9.175
	BRRI dhan82	4.695	BRRI dhan87	5.75	10.45
		4.71	BRRI dhan75	4.66	9.37
Fallow –Fallow -T. Aman (check)	-	-	BR11	4.21	4.21
			BRRI dhan49	4.53	4.53
			Babilon	4.78	4.78

Improvement of Jhum cultivation through the replacement of local rice with the modern Aus rice in hilly areas

To increase system productivity by adopting HYV Aus varieties and comparing them to local varieties in jhum culture, 30 trials in the Jhum cultivation system were conducted in seven upzilas of Bandarban, Rangamati, and Khagrachhari districts. The low-yielding local rice varieties of Khamarang, Khalabadia, Badui, Pidi, Mongthongno, Khoborok, Kokro, Churoi, Kanbui, Gallon, Compani, Amedhan, Gunda, Binni,. Rangapati, Surjomani were cultivated in the jhum system.

Average grain yields of BRRI dhan83 was 3.53 t/ha under in different locations (Table 4). Among the local varieties, average higher grain yield of 2.63 t/ha was found in the tested sites. Farmers in ethnic minority societies expressed interest in sticky rice types with slight aroma. Drought resistant, profuse tillering capacity, and high yielding varieties are also required for the Jhum system.

Fertilizer management in HYV Aus rice in Jhum cultivation

To develop a fertilizer application method for HYV Aus in jhum cultivation an experiment was conducted in jhum system at Matiranga upazila of Khagrachhari district, Rajasthali upazila of Rangamati district, Thanchi upazila of Bandarban district in Aus 2021. Four nitrogen (N) fertilizer treatments were used: T_1=Farmer's practice i.e. neither manure nor fertilizer (control), T_2=Localized placement (Ring placement around dibbling hole), T_3=Row placement in between dibbling lines, T_4= ½ Basal + ¼ at tiller initiation and ¼ at maximum tillering stages (broadcasted).

Promising modern Aus rice varieties BRRI dhan48, BRRI dhan82, BRRI dhan83 and BRRI dhan85 were used in the trials. Urea, TSP and MoP were applied at the rate of 60-10-40 kg/ha according to the treatments. Management practices were followed as per recommendations. The seeds of rice were sown by dibbling method with the help of *tagol* (one kind of knife) May 2021. The rice crops were harvested at maturity in September 2021.

Table 4. Yield of Aus rice under Jhum cultivation, Chittagong Hill Tract, Aus 2021.

Aus rice variety	Grain yield (t/ha)	Variety	Grain yield (t/ha)
BRRI dhan48	3.46	Local	2.16
BRRI dhan82	3.41	Local	2.34
BRRI dhan83	3.53	Local	2.45
BRRI dhan85	3.33	Local	2.42
BRRI dhan26	3.24	Local	2.63

Table 5. Yield of Aus rice under different fertilizer application methods in jhum cultivation system, Chittagong Hill Tract, Aus 2021.

Treatment	Grain yield (t/ha)			
	Matiranga	Rajosthali	Thanchi	Mean
		BRRI dhan48		
T_1	2.27	2.45	2.25	2.32
T_2	3.63	3.66	3.52	3.60
T_3	3.33	3.49	3.48	3.43
T_4	3.47	3.44	3.55	3.49
		BRRI dhan82		
T_1	2.49	2.20	2.44	2.38
T_2	2.86	3.34	3.36	3.19
T_3	3.23	3.01	3.28	3.17
T_4	3.14	2.94	3.21	3.10
		BRRI dhan83		
T_1	2.25	2.27	2.35	2.29
T_2	3.70	3.54	3.58	3.61
T_3	3.57	3.52	3.38	3.49
T_4	3.52	3.44	3.61	3.52
		BRRI dhan85		
T_1	2.16	2.01	2.34	2.17
T_2	3.25	3.28	3.32	3.28
T_3	3.14	3.03	3.31	3.16
T_4	2.94	3.21	3.23	3.13
$LSD_{0.01}$ for treatment (T)	0.52			
$LSD_{0.01}$ for variety (V)	0.53			
$LSD_{0.01}$ for location (L)	0.46			
$LSD_{0.01}$ for T×V	0.11			
$LSD_{0.01}$ for L×V	0.91			
$LSD_{0.01}$ for T×L×V	0.18			
CV (%)	3.7			

Irrespective of location and variety, the treatment T2 performed better (3.42 t/ha) among the treatments. Ring placement may be a viable option for efficient fertilizer management in the Jhum system. BRRI dhan83 (3.23 t/ha) and BRRI dhan48 (3.21 t/ha) performed better than the of hers in all locations and treatments (Table 5).

Inclusion of mustard in Boro – Fallow –T. Aman cropping pattern in piedmont plain land

To strengthen Boro-Fallow-T. Aman system productivity by adding mustard an experiment was conducted in 30 farmers' fields of different upazilas of Bandarban, Rangamati and Khagrachhari districts during 2021-22. Six improved cropping pattern combinations with two existing cropping patterns were tested in this study (Table 6). BARI Sarisha-14 (Mustard) was the transition period crop. Management practices were followed as per recommendations.

VALIDATION AND DELIVERY OF CROPPING SYSTEM TECHNOLOGY

Intensification of Boro – Fallow – T. Aman cropping pattern through the inclusion of mustard in irrigated ecosystem of Madhupur Tract

Farmers' participation production programme was conducted to maximize the productivity and to scale up the Mustard-Boro-T. Aman cropping pattern at Dhanbari upazila of Tangail district. Table 7 shows six improved cropping pattern combination with the checks those were tested. Cropping pattern based recommended fertilizer dose and other recommended management practices were followed.

Table 6. Yield of component crops of Mustard – Boro – T. Aman cropping pattern in piedmont plain land, 2021-22.

Cropping pattern	Yield (t/ha)			REY (t/ha)
	T. Aman	Mustard	Boro	
CP1=BRRI dhan71- BARI Sarisha-14 - BRRI dhan89	4.64	1.23	7.16	15.74
CP2=BRRI dhan71- BARI Sarisha-14 -BRRI dhan92	4.95	1.45	7.52	17.11
CP3=BRRI dhan75- BARI Sarisha-14 -BRRI dhan89	4.73	1.27	7.33	16.12
CP4=BRRI dhan75- BARI Sarisha-14 -BRRI dhan92	4.90	1.31	7.68	16.77
CP5=BRRI dhan87- BARI Sarisha-14 -BRRI dhan89	5.64	1.48	7.45	17.83
CP6=BRRI dhan87- BARI Sarisha-14 -BRRI dhan92	5.41	1.36	7.47	17.23
CP7=BRRI dhan49- Fallow- BRRI dhan28 (ck 1)	4.11	-	5.21	9.32
CP8=BRRI dhan49-Fallow-Jonokraj (ck 2)	4.28	-	6.82	11.10
CV (%)				9.3
LSD				0.61

Price: Mustard = 80 Tk/kg, Rice = 25 Tk/kg, Mustard variety: BARI Sarisha-14

Table 7. Yield and economic performance of T. Aman, mustard, and Boro under Madhupur Tract soil, Dhanbari, Tangail, 2021-22.

Cropping pattern	Yield (t/ha)			REY (t/ha)	TVC ('000 Tk/ha)	GM ('000 Tk/ha)
	T. Aman	Mustard	Boro			
CP1: BRRI dhan71-Mustard-BRRI dhan89	5.55	1.68	8.87	19.80	258.7	236.3
CP2: BRRI dhan71-Mustard-BRRI dhan92	5.67	1.71	9.45	20.59	258.7	255.9
CP3: BRRI dhan75-Mustard-BRRI dhan89	5.63	1.64	8.76	19.64	258.7	232.4
CP4: BRRI dhan75-Mustard-BRRI dhan92	5.69	1.67	9.49	20.52	258.7	254.3
CP5: BRRI dhan87-Mustard-BRRI dhan89	6.81	1.64	8.64	20.70	258.7	258.8
CP6: BRRI dhan87-Mustard-BRRI dhan92	6.74	1.73	9.32	21.60	258.7	281.3
CP7: BRRI dhan49-Fallow-BRRI dhan28 (ck)	5.43	-	6.31	11.74	157.3	136.2
CV (%)				5.7		
LSD				0.53		

Price (Tk/kg): Mustard = 80, Rice = 25; Mustard variety: BARI Sarisha-14

Table 7 also presents the individual crop yield and REY of respective cropping patterns. The highest REY (21.60 t/ha) was observed in BRRI dhan87- BARI Sarisha-14 -BRRI dhan92 (CP6) followed by BRRI dhan87- BARI sarisha-14 -BRRI dhan89 (CP5) (20.70 t/ha) and BRRI dhan71-BARI Sarisha-14-BRRI dhan92 (CP2) (20.59 t/ha) and the lowest was observed in existing cropping pattern CP7 (11.74 t/ha). The similar trend was found in gross margin (GM) ranged from 2,54,300 Tk/ha to 2,81,310 Tk/ha. The pattern CP5 and CP6 produced 90% and 107% higher GM compared to the existing pattern CP7 (Table 7) followed by CP1, CP2, CP3 and CP4. Intervention of suitable varieties in Boro (BRRI dhan89, BRRI dhan92) and T. Aman (BRRI dhan87) along with BARI Sarisha-14 the total productivity was increased considerably.

BRRI dhan87 (5.53 t/ha) in T. Aman and BRRI dhan92 (7.56 t/ha) in Boro season showed better performance among the tested varieties in the trials where BARI Sarisha-14 yielded 1.23 to 1.48 t/ha (Table 6). The higher REY (17.83 t/ha) was found in BRRI dhan87-Mustard-BRRI dhan89 followed by the pattern BRRI dhan87-Mustard-BRRI dhan92 (17.23 t/ha). Incorporating mustard in between T. Aman and Boro rice, the productivity of the present pattern might be enhanced, ensuring crop diversification and food security as well.

Increasing productivity of Boro-Fallow-T. Aman cropping pattern in Mymensingh region

The experiment was conducted at Balipara union under Trishal upazila of Mymensingh district during 2021-22 to improve the productivity of existing Boro-Fallow-T. Aman cropping pattern with inclusion of mustard as a transition crop. Mustard (BARI Sarisha-14)-Boro (BRRI dhan88)-T. Aman (BRRI dhan87) were used in improved cropping pattern, while BRRI dhan28/29 for Boro rice and BRRI dhan49 for T. Aman rice were used in the existing cropping pattern. Findings reveal that rice equivalent yield of improved cropping pattern was 16.20 t ha^{-1} which was 53% higher than that of existing pattern (10.57 t ha^{-1}) (Table 8). Land use efficiency (76.65%) and labour employment (373.5 man days ha^{-1} year^{-1}) of improved cropping pattern were 34% and 25% higher than the existing cropping pattern. Whereas production efficiency (44.82 t ha^{-1} year^{-1}) was lower than the existing cropping pattern (45.95 t ha^{-1}) due to lower yield of mustard than rice (Table 9). The mean gross margin (Tk 100,950 ha^{-1}) of improved cropping pattern was 73% higher than the existing cropping pattern (gross margin Tk 58,500 ha^{-1}) due to inclusion of high price and yield of mustard (Table 8). Therefore, farmers in Mymensingh region could follow improved cropping pattern for higher crop productivity and profitability in their high and medium high land where lands remain fallow after harvesting of T. Aman rice.

Integration of mustard in the Boro-Fallow-T. Aman cropping pattern in irrigated ecosystem

This trial was conducted in farmers' fields at Kaliganj, Gazipur during 2021-22 to intensify Boro-Fallow-T. Aman cropping pattern through inclusion of mustard as well as to evaluate the performance with economic productivity of newly released BRRI rice varieties under Mustard-Boro-T. Aman cropping pattern. BRRI dhan81, BRRI dhan88, BRRI dhan96, BRRI dha 98 in Boro season and BRRI dhan71, BRRI dhan75, BRRI dhan87 in T. Aman season were used with BARI Sarisha-14 as transition period crop. Twenty dispersed farmer's fields were selected for this trial and each farmer's field represents one replication. Recommended fertilizer and other management practices were followed. Table 10 shown the treatment combination and result.

BRRI dhan98 turned out with about 17% and 24% of higher grain yield than BRRI dhan29 and BRRI dhan28, respectively. In the T. Aman season, BRRI dhan87 produced the highest grain yield which was about 68% and 42% higher than the yield of Ranjit and BRRI dhan49, respectively. The Rice equivalent yield (REY) of different cropping pattern combinations were also varied significantly and BARI Sarisha-14-BRRI dhan98-BRRI dhan87 turned out with the highest REY (1,37,300 Tk/ha) among the tested combinations. BARI sarisha-14-BRRI dhan98-BRRI dhan75, BARI sarisha-14-BRRI dhan98-BRRI dhan87 and BARI sarisha-14-BRRI dhan98-BRRI dhan71 were found most profitable with higher gross margin among the tested cropping pattern combinations.

Table 8. Yield and cost-return of improved pattern (Mustard-Boro-T. Aman) against existing pattern (Boro-Fallow-T. Aman), Trishal, 2021-22.

Treatment	Yield (t ha^{-1})			REY (t ha^{-1})	GR ('000 Tk ha^{-1})	TVC ('000 Tk ha^{-1})	GM ('000 Tk ha^{-1})
	Mustard	Boro	T. Aman				
Mustard-Boro-T. Aman	1.25	6.25	5.45	16.20	235.5	134.5	100.9
Boro-Fallow-T. Aman	-	5.92	4.65	10.57	180.7	122.2	58.5

Price (Tk/kg): Rice = 25, Mustard = 90

Table 9. Land use efficiency, production efficiency and labour employment of improved pattern (Mustard-Boro-T. Aman) against existing pattern (Boro-Fallow-T. Aman), Trishal, 2021-22.

Cropping pattern	Land use efficiency (%)	Production efficiency (tha^{-1} year^{-1})	Labour employment (man days ha^{-1} year^{-1})
Mustard-Boro-T. Aman	76.65	44.82	373.5
Boro-Fallow-T. Aman	57.23	45.95	298.8

Table 10. Grain yield of component crops, REY and economic performance of different cropping pattern combinations, Kaliganj, Gazipur, 2021-22.

Cropping pattern	Mustard (t/ha)	Boro (t/ha)	T. Aman (t/ha)	REY (t/ha)	TVC ('000 Tk/ha)	GM ('000 Tk/ha)
BARI sarisha-14-BRRI dhan88-BRRI dhan75	0.99 a	4.41 b	4.05 b	13.76 a	227.03 d	94.95 cd
BARI sarisha-14-BRRI dhan88-BRRI dhan87	1.06 a	4.36 b	5.31 a	14.20 a	231.69 bcd	101.48 c
BARI sarisha-14-BRRI dhan88-BRRI dhan71	1.07 a	4.33 b	5.01 a	14.25 a	228.67 cd	105.48 c
BARI sarisha-14-BRRI dhan96-BRRI dhan75	0.97 a	4.50 b	4.09 b	13.84 a	221.52 d	102.40 c
BARI sarisha-14-BRRI dhan96-BRRI dhan87	1.22 a	4.21 b	4.85 a	14.25 a	224.70 d	109.69 c
BARI sarisha-14-BRRI dhan96-BRRI dhan71	1.18 a	4.01 b	5.11 a	13.95 a	221.11 d	106.09 c
BARI sarisha-14-BRRI dhan98-BRRI dhan75	1.22 a	5.23 a	4.48 b	14.99 a	220.69 d	130.02 b
BARI sarisha-14-BRRI dhan98-BRRI dhan87	0.96 a	5.34 a	5.17 a	15.40 a	223.87 cd	137.30 a
BARI sarisha-14-BRRI dhan98-BRRI dhan71	1.02 a	4.97 a	4.82 a	15.10 a	220.28 bcd	133.71 ab
BARI sarisha-14-BRRI dhan81-BRRI dhan75	1.02 a	4.16 b	4.25 b	13.91 a	237.01 bc	88.07 de
BARI sarisha-14-BRRI dhan81-BRRI dhan87	1.20 a	4.01 b	5.31 a	14.31 a	241.81 ab	93.76 d
BARI sarisha-14-BRRI dhan81-BRRI dhan71	1.09 a	4.08 b	4.98 a	14.21 a	237.18 bcd	95.61 cd
BRRI dhan28-Ranjit	-	4.07 b	3.11 c	8.91 b	159.95 e	53.89 e
BRRI dhan28-BRRI dhan49	-	4.29 b	3.74 c	9.61 b	158.05 e	72.59 e
BRRI dhan29-Ranjit	-	4.38 ab	3.05 c	9.25 b	172.12 e	49.88 e
BRRI dhan29-BRRI dhan49	-	4.46 ab	3.53 c	9.65 b	172.82 e	58.78 e
CV (%)	14.53	9.60	7.85	10.89	13.28	12.72

Within a column, data sharing the different lower-case letters are significantly different at $P < 0.05$.

REY calculation Price: Rice: 22.50 Tk/Kg, Mustard: 80 Tk/Kg

Improvement of Boro-Fallow-T. Aman cropping pattern in Kishoreganj district

The trial was conducted in farmers' fields at Katiadi and Pakundia upazila in Kishoreganj district during 2021-22 to intensify Boro-Fallow-T. Aman cropping pattern through inclusion of mustard as well as to evaluate the performance with economic productivity of newly released BRRI rice varieties. Twenty-four dispersed farmer's fields were selected for this trial and each farmer's field represents one replication. Recommended fertilizer and other management practices were followed. Table 11 shown the treatment combination and result.

Table 11. Grain yield of component crops, REY and economic performance of different cropping pattern combinations, Katiadi and Pakundia, Kishoreganj, 2021-22.

Cropping pattern	Mustard (t/ha)	Boro (t/ha)	T. Aman (t/ha)	REY (t/ha)	TVC ('000 Tk/ha)	GM ('000 Tk/ha)
BARI sarisha-14-BRRI dhan88-BRRI dhan75	1.00	5.87 b	3.95 b	13.01 b	222.07	103.18
BARI sarisha-14-BRRI dhan96-BRRI dhan75	1.05	6.25 b	4.02 b	13.61 b	222.07	118.28
BARI Mustard-14-BRRI hybrid dhan5-BRRI dhan87	1.12	7.03 a	4.56 a	15.18 a	222.07	157.31
BRRI dhan28-Fallow-BRRI dhan49	-	6.15 b	4.38 a	10.53 c	170.67	92.53
LSD	-	0.67	0.34	0.79	-	-
CV (%)	-	6.36	4.82	3.61	-	-

Means with the same letter are not significantly different.
Price of different crops, mustard-80 Tk/kg, Boro-25 Tk/kg, T. Aman-25 Tk/ha.

Table 11 shows the individual crop yield. The highest REY (15.18 t/ha) obtained from BARI Sarisha-14-BRRI hybrid dhan5-BRRI dhan87 followed by BARI sarisha-14-BRRI dhan96-BRRI dhan75 (13.61 t/ha) and BARI sarisha-14-BRRI dhan88-BRRI dhan75 (13.01 t/ha). The existing pattern BRRI dhan28-Fallow-BRRI dhan49 produced the lowest REY (10.53 t/ha). The highest gross margin obtained from BARI sarisha-14-BRRI hybrid dhan5-BRRI dhan87 (1,57,310 Tk/ha) followed by BARI Sarisha-14-BRRI dhan96-BRRI dhan75 (1,18,280 Tk/ha) which was 70% and 28% higher than the existing BRRI dhan28-Fallow-BRRI dhan49 (92,530 Tk/ha) cropping pattern.

Piloting of profitable cropping patterns to increase the system productivity

The activity was conducted during 2021-22 at Katiadi and Pakundia upazila, Kishoreganj to scale up of improved cropping patterns to expedite the total productivity. Two improved cropping patterns viz., Mustard-Maize-T. Aman and Potato-Jute-T. Aman were designed against Boro-Fallow-T. Aman cropping pattern in RCB design where each farmer was considered as one replication. During Rabi season, BARI sarisha-14, BARI Hybrid Bhutta-16 and BARI Alu-32 were used, BJRI Tushapat-8 was cultivated in Kharif season. BRRI dhan87 and BRRI dhan90 were used in T. Aman season where farmers usually cultivated BRRI dhan49 in their existing cropping pattern. Recommended fertilizer doses and management practices were followed. To compare the system productivity non-rice crops yield was converted to rice equivalent yield.

Among the tested three cropping patterns, Potato-Jute-T. Aman produced the highest REY (25.84 t/ha) followed by Mustard-Maize-T. Aman (17.52 t/ha) cropping pattern and existing pattern Boro-Fallow-T. Aman produced the lowest (10.06 t/ha). The highest gross margin was found in Potaoto-Jute-T. Aman (3,73,710 Tk/ha) followed by Mustard-Maize-T. Aman (2,00,710 Tk/ha) cropping pattern. The gross margin was 358% and 146% higher in the improved cropping patterns compared to the existing cropping pattern.

Determination of the effects of rice seedbed sowing date, seedling age, and rice growth duration on yield of popular premium quality rice varieties for T. Aman

This experiment was conducted in the T. Aman 2021 season in Dinajpur, Gazipur and Jhenaidah to generate rice crop data for simulation modeling by using the ORYZA v3 simulation model to determine optimum transplanting window, sowing time, seedling age, target yield, associated management recommendations for increased rice yields of popular premium quality rice varieties. In each location, the experiment was established in a split-split plot design with three replications. The main plot factor was three PQR varieties: BRRI dhan75, BRRI dhan87 and BRRI dhan34. The sub-plot factor was five seed bed-sowing dates (20 June, 5 July, 20 July, 4 August, and 19 August), and the sub-sub plot factor was seedlings of three ages: 20-day old, 30-day old, and 40-day old.

The interaction effect of seedling age and date of seed sowing on rice grain yields across varieties and sites was significant (Table 13). For generally long duration variety, seedlings of 20 days older produced higher yield between 20 June to 20 July. Similar findings were observed for variety with a medium duration. For relatively short duration variety, 20-day-old seedlings and 5 July seeding are optimum.

Table 12. Yield and cost-return analysis of different cropping patterns, Katiadi and Pakundia, Kishoreganj, 2021-22.

Cropping pattern	Mustard (t/ha)	Potato/Maize (t/ha)	Boro (t/ha)	Jute (t/ha)	T. Aman (t/ha)	REY (t/ha)	TVC (‘000 Tk/ha)	GM (‘000 Tk/ha)
Mustard-Maize-T. Aman	1.16	8.32	-	-	3.20	17.52 b	237.34	200.71
Potato-Jute-T.Aman	-	34.25	-	3.00	4.80	25.84 a	272.23	373.71
Boro-Fallow-T. Aman	-	-	5.89	-	4.17	10.06 c	169.8	81.58
LSD at 0.05%	-	-	-	-	-	0.87	-	-
CV	-	-	-	-	-	3.08	-	-

Means with the same letter are not significantly different.
Price of different crops, mustard-80 Tk/kg, Maize-30 Tk/kg, Boro-25 Tk/kg, T. Aman-25, T. Aman (BRRI dhan90)-30, Jute-50 Tk/kg, Jute stick-5 Tk/kg and Potato-10 Tk/kg, BCR-Benefit-cost ratio

Table 13. Effect of different seedbed sowing dates and seedling ages on grain yield of different premium quality rice (PQR) varieties in Aman 2021 in Jhenaidah, Dinajpur, and Gazipur locations.

Variety	Seed bed sowing date	Seedling age (day)			Mean
		20	30	40	
	20 Jun	3.12 ab	3.30 ab	2.90 b	3.11 b
	5 Jul	3.38 a	3.93 a	3.27 a	3.36 a
BRRI dhan34	20 Jul	3.25 ab	3.09 ab	2.96 b	3.10 b
	4 Aug	2.95 b	3.00 b	2.75 b	2.90 c
	19 Aug	2.15 c	2.06 c	1.74 c	1.98 d
Mean		2.97 A	2.98 A	2.73 B	
	20 Jun	4.99 b	4.69 a	4.23 ab	4.61 a
	5 July	5.36 a	5.10 a	4.77 a	5.08 a
BRRI dhan75	20 Jul	5.37 a	5.02 a	4.87 a	4.91 a
	4 Aug	4.78 b	4.19 ab	3.33 bc	4.10 bc
	19 Aug	4.30 c	3.40 b	2.69 c	3.99 c
Mean		4.96 A	4.47 B	3.88 C	
	20 Jun	6.40 a	6.21 a	5.68 a	6.07 a
	5 Jul	6.22 a	6.06 a	5.65 a	5.98 a
BRRI dhan87	20 Jul	6.49 a	6.12 a	5.54 a	6.05 a
	4 Aug	5.54 b	5.14 b	3.96 b	4.88 b
	19 Aug	4.20 c	3.83 c	2.56 c	3.53 c
Mean		5.77 A	5.45 B	4.68 C	

Agricultural Economics Division

SUMMARY

This study examined how profitable aromatic rice cultivars are, how inputs were used, and the factors that influence the adoption of aromatic rice cultivars. The profitability analysis showed that the average output of aromatic rice is 3,239 kg per hectare. The farmers in Naogaon had greater gross returns than the farmers in the Jashore. The empirical marginal effects results showed that education, ln farm size, price difference, market demand, eating quality, extension service, and credit are all positive and significant means increasing uses of these factors would boost the adoption of more aromatic cultivars in the research region.

Rice cultivation in the wetlands of the northeastern part of Bangladesh, known as *haor* areas, have accounted for one-fifth of the total rice production in the country. However, *haor* areas have been bearing the brunt of climate change for many decades. About 91% and 96% farmers of haor areas from Netrakona and Sunamganj district, respectively, believe that they have perception about climate change in their areas. A notable percentage of respondent farmers of both the areas mentioned that events like temperature, intensity of day time heat, unpredicted rainfall, changes of monsoon season, occurrences of drought, long summer season etc. has been increased in their respective areas over the last 20 years. Typically, long duration rice varieties in those areas face the loss from flash flood but this year, almost all of the cultivated variety got affected by the early flash flood as it occurred in the late March when the crop was in booting to ripening stage. Shifting of harvesting maturity, early transplanting, taking loan, migration etc. were identified as major adaptation strategies for last few years whereas lack of money, land and information were being reported as main constraints in those studied *haor* areas. Fewer number of marketing intermediaries were observed in those areas which makes the marketing channel relatively shorter than the other areas of the country.

Rice is the staple food of the 165 million of Bangladesh where rice security often is often considered as the food security. Good quality seed alone can increase the yield by 15-20%. The study was conducted in Jashore district taking 60 seed growers evenly from the contract and non-contract growers of both Aman and Boro seasons. In Boro season, CGs used 27 kg seed per hectare while non-CGs used 28 kg per hectare on average. Both type of growers used more fertilizer than the recommended dose in two seasons. Total cost of contract growers and non-contract growers was Tk 198,726 and Tk 212,214 respectively in Boro season while in Aman season it was Tk 1,94,965 and Tk 1,80,018 respectively. In Boro season, per kg cost of rice seed production was Tk 29.36 for CGs and Tk 30.68 for non-CGs while it was Tk 34.54 for CGs and Tk 32.27 for non-CGs in Aman season.

Rice price always remains at the center of controversy in Bangladesh. Major 12 spatially separated wholesale rice markets are found as co-integrated during 2012 to 2020. Mainly bidirectional causality directions have been observed among those markets but in few cases unidirectional causal relationships have been evident which are not in line with the surplus, deficit and/or central characteristics of those studied markets. Moreover, poor price transmission, high and persistent volatilities have been identified among 12 major wholesale rice markets in the country. All these findings highlight the inevitability of public interventions in the rice market of Bangladesh.

The aim of this study is to figure out the market share and concentration of existing popular rice brands in Bangladesh. In the upazila level markets, BR28 is the most popular rice brand contributing about 40% of the available rice, followed by Minikit (17.7%), Swarna (14.5%), and BR29 (12.1%). Whereas, in the city markets the contribution of Minikit is the highest (33.5%), followed by BR28 (19.4%), Zira (19.2%), and Nazir (8.5%). The traders are highly concentrated to produce the top four rice brands without exercising any competition in the market.

For the import and export substitution of aromatic rice with export potential, such as BRRI dhan50, Bangladesh enjoys a comparative

advantage. High pricing for aromatic rice on the global market, increased yields per unit, and a somewhat narrow price differential between wholesale and retail levels are all possible explanations for these outcomes.

DRIVERS INFLUENCING ADOPTION DECISION OF AROMATIC RICE IN SOME SELECTED AREAS OF BANGLADESH: AN ECONOMETRIC APPROACH

In T. Aman season, the aromatic rice cultivars are widely adopted in Jashore and Naogaon districts. Therefore, the current research was intended to get a more profound knowledge of the economic insights and drivers of the fragrant rice variety, with the following particular objectives to:

- To assess the profitability of aromatic rice cultivars; and
- To identify the factors influencing the adoption decision of aromatic rice varieties.

The study included both primary and secondary sources of data. For this study, Jashore and Naogaon districts were chosen purposively. One upazila from each district was purposefully chosen. The survey was conducted in sadar upazila Jashore and Mohadebpur in Naogaon district. A pre-tested structured questionnaire was used to conduct in-person interviews with 100 randomly chosen agricultural families, 50 of which came from each upazila.

Analytical technique. Profitability was calculated in terms of gross return, gross margin, net return, and the benefit-cost ratio (BCR).

The econometric model. The purpose of this study was to identify socioeconomic and demographic factors that affect farmers' decision to adopt fragrant rice varieties during the T. Aman season. To provide a detailed analysis of the adoption decision of aromatic cultivars, we applied a discrete choice probit model for binary responses (yes, no).

Profitability of aromatic variety in the study area

Table 1 shown the cost and return of producing fragrant rice per hectare in the Naogaon and Jashore districts. The production of aromatic rice is 3.239 tons per hectare on average; however, it is somewhat higher in the Jashore (3.293 tons/ha) than in the Naogaon (3.185 tons/ha) district. But compared to the farmers in the Jashore (Tk 1,65,099/ha) district, the farmers in Naogaon (Tk. 1,69,917.5/ha) obtained higher gross returns. The price is high in the Nagaon district because the demand for aromatic rice is higher, and many aromatic rice-producing mills are situated in the Neoga on district. The average net income is Tk. 43753.75/ha, where the net income of the Nega on district farmers is higher than Jashore. Overall, findings show that growing fragrant rice is a lucrative business and a crucial source of income for rural farm communities.

Table 1. Per hectare profitability of aromatic rice cultivation in 2021-22.

Item	Naogaon	Jashore	Average
Total costs (TK/ha) (2+3)	122632	124877	123754.5
Total variable costs (TK/ha)	69904	72557	71230.5
Total fixed cost (TK/ha)	52728	52320	52524
Yield (kg/ha)	3185	3293	3239
Market value of paddy (TK/ha) (4*11)	144917.5	141599	143258.25
Market value of straw (TK/ha)	25000	23500	24250
Gross benefit (GB) (TK/ha) (5+6)	169917.5	165099	167508.25
Gross margin (GM) (TK/ha) (7-2)	100013.5	92542	96277.75
Gross profit ratio ((GM*100)/GB)	58.86	56.05	57.46
Net return (TK./ha) (7-1)	47285.5	40222	43753.75
Cost of production (TK/kg)	38.50	37.92	38.21
Selling price of grain (TK/kg)	45.5	43	44.25
BCR (cash cost basis) (7/2)	2.43	2.27	2.35
BCR (full cost basis) (7/1)	1.38	1.32	1.35

Source: Field survey 2021-22

Outcomes of the probit model

Table 2 displays the estimated results from the binary probit models. The table shows the estimated coefficients and standard errors for the parameters that affected the farmers' choice to adopt or grow aromatic rice varieties.

At the 5% level of significance, the years of education variable was found positive and significant. As anticipated, this variable showed a positive and very significant result. Therefore, education has a significant impact on aromatic rice adoption. In other words, a minimum level of education helps farmers to acquire, understand and analyse information on new technology and thereby leads them to its adoption. The outcomes of marginal effect suggests that the probability of adopting aromatic rice cultivars would be increased by 3.5 percent in the study areas as one percent grew in farm size.

The findings demonstrate a clear relationship between the amount of farm holdings and the adoption of fragrant rice cultivars. The adoption of aromatic rice cultivars by farmers rose as the farm size increased, according to the significant and positive sign-on farm size. According to the marginal impact estimate, with every 1% increase in farm size, the likelihood of adopting aromatic rice cultivars will rise in the research regions by 5.28 percent.

The price of the paddy is always a bigger contributor to agricultural income. So, a major factor in the adoption of aromatic rice cultivars is the favorable and notable price differential that emerges between aromatic and other cultivars. The marginal impact calculation shows that a 1% rise in the price of paddy will increase the likelihood of adopting aromatic rice cultivars in the research regions by 6.39%.

Another essential factor is market demand. The adoption of aromatic rice cultivars will rise by 13.77 percent in the study region as a result of a 1% increase in market demand, according to the model's positive and significant coefficients. Similar results were observed by Rahaman et al. 2020.

Table 2. Estimation of probit model for determinants of adoption of aromatic rice varieties (n=100).

Variable	Coefficient	Robust standard error	Marginal effect
Age	0.0132	0.0102	0.0193
Education	0.0290**	0.0130	0.035
Occupation only farming	-0.0448**	0.0130	0.0686
Family size	0.0035	0.0252	0.0027
Family member involve in farming	0.0037	0.0345	0.0032
Ln farm size	0.0656**	0.0299	0.0528
Price difference	0.0792**	0.0321	0.0639
Market demand	0.1505***	0.0577	0.1377
Eating quality	0.1284**	0.0584	0.0893
Training	0.0303	0.0452	0.0312
Extension service	0.1120***	0.0328	0.0921
Distance to UAO	0.0632	0.2153	0.0567
Distance to local market	-0.0367	0.0300	0.0254
Credit	0.1182**	0.0543	0.1062
Yield difference	-0.0921***	0.0297	0.0785
Disease infestation	-0.0856	0.0769	0.0798
Constant	-0.8588	0.5366	
Log pseudo likelihood	-271.21		
Prob > F	0.000		
Pseudo R2	0.522		
Breush-pagan Heteroskdasticity			
chi2(1)	2.31		
Prob > chi2	0.1327		
Mean VIF	1.84		

** and *** indicates significance at the 5 and 1 percent levels.

Additionally, positive and significant coefficients show that the choice to adopt more fragrant cultivars is strongly influenced by the quality and taste of the rice. According to the findings of the marginal impact, an improvement in rice's flavor and quality of one percent would boost the adoption of aromatic cultivars by 8.9 percent.

The adoption of modern fragrant rice cultivars in the study area is heavily dependent on the DAE's agricultural extension programme. The marginal impact findings show that a one percent increase in extension services in the study region will contribute to a 9.21 percent increase in the cultivation of aromatic rice.

The introduction of aromatic cultivars has a beneficial and considerable impact on credit accessibility. The majority of the time, farmers use credit to buy the essential agricultural inputs they need, such as better and certified varieties, fertilizers, insecticides, and farm equipment. Farmers in Bangladesh have additional opportunities to adopt new rice varieties due to official and informal finance sources. According to the marginal effects, a one percent increase in loan availability would contribute to a 10.62 percent rise in the adoption of aromatic rice in the studied area.

On the other hand, only farming and the yield difference coefficient were found significant but negative. Most farmers who grow rice as their only income source do not want to accept new varieties or rice cultivars with lower yields. The leading cause of this is because they consider how they would feed their family with the lower produce. Since meeting their fundamental needs is a top concern. According to the findings, a 1% increase in farming as the sole profession would cause a 6.8% and 7.8% decline in the adoption of aromatic rice cultivars in the research region, respectively.

According to the profitability analysis, the output of aromatic rice is 3,239 kg per hectare. The farmers in Naogaon (Tk 1,69,917.5/ha) had greater gross returns than the farmers in the Jashore area (Tk 1,65,099/ha). Similarly, the average net return per hectare is Tk. 43,753.75; thus, farmers in the negron district have a larger net return than those in Jashore. The probit econometric model was used to identify the determinants of adoption. The empirical marginal effects results showed that education, farm size, price difference, market demand, eating quality, extension service, and credit are all positive and significant means increasing uses of these factors would boost in the adoption of more aromatic cultivars in the research region. While the adoption of aromatic cultivars is severely impacted by occupation-only farming and yield differences.

- M S Rahaman, M A Islam, M A R Sarkar, M C Rahman and M S Islam

UNDERSTANDING CLIMATE VARIABILITY, ADAPTATION AND MARKET INSIGHTS OF RICE IN *HAOR* ECOSYSTEMS

Bangladesh is characterized by agro-zones that are highly susceptible to drought, cyclones, flooding, and rising salinity, rendering Bangladesh one of the most vulnerable countries in the world to climate change. Changing courses of the river systems and frequent monsoon flooding in Bangladesh gives a diverse wetland, such as rivers, *baors* (resulting from loss of river flows), *beels* and *haors* (natural depressions), and flood lands. The *haor* basin in the Northeastern zone of Bangladesh is an important wetland ecosystem. A total of about 0.71 million ha of net cultivable land is available in haor area, which produces more than 5.25 million tons of paddy each year. Since *haor* goes under flooding (5-10 m) from late May to October, almost 80% of this area is covered by Boro rice, while only about 10% area is covered by T. Aman. Flood, especially flash flood causes severe damage to Boro rice just before harvesting almost every year. This study aims to dig out the understandings of farmers about climate change and their adaptation practices. Besides, this study also investigates into the marketing systems of rice in the studied areas.

Farm level data were collected from Khaliajuri and Mohonganj upazila of Netrakona district and Tahirpur as well as Sadar upazila of Sunamganj district during June 2022. Purposive sampling technique was applied to collect the data from 40 farmers and 10 traders from each upazila by structured questionnaire. Thus, the total sample size was 200 for the study where the total number of farmers and traders were 160 and 40, respectively. Besides, expert opinions were collected from respective extension personnel.

Table 3 demonstrates the perception of farmers about climate change and extreme events over the last 20 years in both the study areas. About 91% and 96% of respondent farmers stated that they have the perception of climate change in Netrakona and Sunamganj district, respectively. About 85% and 87% of the respondent farmers of Netrakona and Sunamganj district, respectively, reported about increased temperature over last the 20 years in their respective areas. Again, according to the 76% and 80% of the farmers from Netrakona and Sunamganj, respectively, the intensity of day time heat has increased over the last two decades. Besides, respondent farmers of both the areas mentioned that events like unpredicted rainfall, changes of monsoon season, occurrences of drought, long summer season etc has been increased in their respective areas over the last 20 years.

Table 4 presents the variety wise affected area and yield loss due to flood occurred in the study areas in 2020. It is apparent that varieties that have comparatively longer duration are more affected by the flood. Different hybrid varieties and BRRI dhan29 got severely affected in terms of area and yield in both the studied districts. It is to be noted that this year almost all of the cultivated varieties got rigorously affected by the early flood in the studied *haor* areas.

Table 3. Farmers' perception on climate change and extreme events over the last 20 years in *Haor* ecosystems.

	% farmers' response							
	Netrakona				**Sunamganj**			
	Increase	Decrease	No change	No response	Increase	Decrease	No change	No response
Perception of climate change	91				96			
Temperature	85	4	9	2	87	3	8	2
Intensity of day time heat	76	12	10	2	80	7	8	5
Rainfall	17	75	8	-	11	70	15	4
Unpredicted rainfall	59	11	9	21	63	14	10	13
Changes of monsoon season	42	20	28	10	36	12	21	31
Lack of surface water	33	26	29	12	29	28	35	8
Occurrence of drought	61	11	21	7	58	11	17	15
Downstream of flood	45	4	41	10	38	6	41	15
Short winter season	35	15	26	24	41	19	13	27
Long summer season	41	8	32	19	44	13	19	24
High cold	47	12	21	20	38	31	17	14

Source: Field survey 2022

Table 4. Yield loss due to occurrence of flood in the study areas in 2022.

	Transplanting date	Harvesting	% Affected area	% Yield loss
Netrakona				
BRRI dhan28	15-20 December	5-15 April	24.23	42.30
BRRI dhan29	10-15 December	8-20 April	26.92	89.13
Hybrid	10-28 December	7-22 April	27.85	92.10
Sunamganj				
BRRI dhan28	12-15 December	5-14 April	29.52	90.25
BRRI dhan29	6-12 December	10-22 April	32.26	95.56
Hybrid	5-20 December	10-25 April	31.22	96.85

Source: Field survey 2022

Table 5 demonstrates the years of flood occurrence along with the arrival date, specific stages of the crop that time, flood depth, duration and recession date over the last 20 years in the studied areas of Netrakona and Sunamganj. In both the areas, severe flood occurred in 2017 and 2022 during the last 10 years. In almost every case, flood arrived at the end of the March to mid of the April that were too much prolonged as the recession time were end of the October to mid of the November. It is to be noted that, this year only the areas of typical *haor* i.e. areas outside the embankments got affected by the early flash flood. Farmers also reported that most of the time the crops remain at panicle initiation, booting, flowering or ripening stage during the arrival of flood.

Farmers' Ranking of Adaptation Practices

Figure 1 shows the percentage of farmers adopting some common adaptation practices in the study areas. It is worth mentioning that taking loan is the most common adaptation practice in both the studied *haor* districts. About 52% and 43% respondent farmers of Netrakona and Sunamganj district, respectively, reported that they take loan to overcome from the crop loss or any natural disaster. It is to be noted that most of the cases farmers are taking loan the informal sources i.e. *mohajon* with high interest rate in both the studied districts. Migration is another common adaptation practices which is getting more height in recent time in all the studied villages. Beside these, respondent farmers also mentioned about fishing, duck farming, homestead gardening as their common adaptation practices.

Table 5. Yearly details about flood occurrence and crop stages.

Year	Arrival date	Crop stage	Flood depth (CM)	Duration (day)	Recession time (days)
Netrakona					
2017	20-24 Mar	Panicle Initiation, Booting	76-200	20-220	25 Oct-10 Nov
2022	25-30 Mar	Booting, Flowering	40-240	-	Still inundated
Sunamganj					
2017	21-23 Mar	Panicle Initiation, Booting	200-300	210	01-05 Nov
2022	28-31 Mar	Flowering, Ripening	60-180	-	Still inundated

Source: Field Survey, 2022

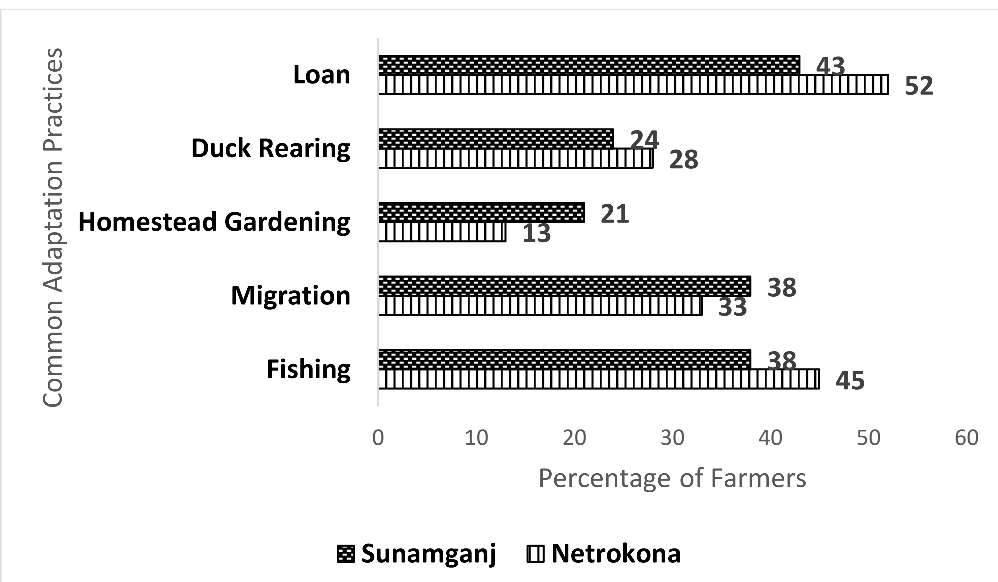


Fig. 1. Common adaptation practices implemented by farmers in Netrakona and Sunamganj.

Table 6 represents farmers' ranking of some adaptation practices which are predominantly related to agricultural practices in the studied areas. From the weighted average index (WAI) it is apparent that, shifting of harvesting maturity is the top most adaptation practice of rice farmers' in recent times. Respondent farmers reported that they harvest their paddy at 70-80% maturity whereas it was up to 80-90% maturity a decade before to avoid the loss of early flash flood especially in typical *haor* areas. Varietal diversification has been observed and also reported by the respondent farmers in the study areas. Adoption of different hybrid varieties is increasing day by day in *haor* areas which in results replacing the long duration varieties like BRRI dhan29 significantly. Besides these, early transplanting of seedling, short time migration, growing *rabi* crops and short duration varieties etc are found as popular adaptation practices in the studied *haor* areas.

Table 7 shows the percentage of total paddy being marketed through different paddy marketing channels in the study areas. Farmer-Bepari-Aratdar-Miller and Farmer-Bepari-Miller appeared as the most frequently used marketing channels in both the study areas. From Table 7, it is evident that about 26% and 31% of paddy of Netrakona and Sunamganj, respectively, being traded through Farmer-Bepari-Aratdar-Miller channel. Again, 38% and 30% of paddy of Netrokona and Sunamganj, respectively, being marketed through Farmer-Bepari-Miller channel. Due to the poor transportation facilities and remoteness the paddy marketing channels are comparatively shorter in those studied areas. Inadequate facilities of storage, poor transportation system force the farmers to sell their paddy from the field just after harvesting. Rest of the paddy are being sold to the nearest local markets where vans and boats are the most frequently used vehicle for transporting paddy. Farmers mentioned about poor transportation facilities, inadequate drying and storing facilities, lack of information, lack of rice mills and fewer number of buyers and processors, low price of paddy during harvesting as the main constraints in paddy marketing.

Table 6. Farmers' ranking of some adaptation practices in the study areas

Adaptation Practices	Lack of land (LL)	Lack of information (LI)	Shortage of labor (SL)	Lack of money (LM)	WAI	Rank
Shifting harvesting maturity	5	49	34	72	2.081	1
Varietal diversification	16	48	23	73	1.956	2
Early transplanting	11	55	28	66	1.931	3
Reduce number of livestock	55	5	6	94	1.869	4
Short time migration	60	10	8	82	1.700	5
Growing *rabi* crops	39	28	39	54	1.675	6
Short duration variety	11	82	18	49	1.657	7

Source: Field survey, 2022 and Authors' calculation

Table 7. Paddy marketing channel in the study areas.

Paddy marketing channel	% of Paddy	
	Netrakona	Sunamganj
Farmer-Bepari-Aratdar-Miller	26	31
Farmer-Bepari-Miller	38	30
Farmer-Aratdar-Miller	4	7
Farmer-Millers' Agent	0	9
Farmer-Faria-Aratdar-Miller	6	7
Farmer-Faria-Bepari-Miller	9	5
Farmer-Miller	0	4
Farmers-Bepari- Miller (Ashuganj)	16	7

Source: Field Survey, 2022

Limon Deb, S M M H Noman, S A Jui, A Chowdhury and M S Islam

The present study is aimed to find out the economics of rice seed production of both contract and non-contract growers during the Aman and Boro seasons.

Jashore Sadar and Chowgacha Upazila of Jashore district were purposively selected for the study as it is one of the largest contract seed growing zones of Bangladesh Agricultural Development Corporation (BADC). Sixty seed producing farmers were purposively selected and interviewed of which 30 were contract growers and the rest 30 were independent seed producing farmers. Boro and T. Aman seasons were taken into account as they two are the prime rice growing seasons of the country. Mainly, the descriptive statistical technique was applied to analyze the data, and tabular technique was used to present the results obtained from the analysis.

The demographic table revealed that the average education years of contract growers were higher than the non-contract growers as BADC tends to select quality farmers emphasizing on farming experience, knowledge about rice farming, and level of education Table 8. The average farm size of the contract growers and the non-contract growers was 1100 decimals and 272 which justifies that BADC select farmers with more cultivable land.

Table 8. Demographic profile of seed growers.

Particular	Contract grower	Non-contract grower
Family size (no.)	5	5
Age (year)	45	49
Experience (years)	24	27
Education (years)	10	8
Farm size (decimal)	1100	272
Annual Income	7,06,897	2,91,500
Occupation		
Agriculture	87	90
Business	7	10
Service	6	0

Source: Field survey 2022

Contract growers used more human labour as they had to do the intercultural operations (i.e., weeding, roguing, perching etc.) more intensively in contrast to non-contract growers in both the season Table 9. Moreover, having significantly larger farm sizes, CGs used more hired labour than the non-CGs. CGs used less seeds than the non-CGs in Boro and Aman seasons by 1 kg/ha and 6 kg/ha. To cultivate one acre of land CGs depend on BADC, but non contract growers buy private company seed.

Table 9. Input use pattern of seed growers in Boro and Aman season.

Input item	Boro		Aman	
	Contract grower	Non-contract grower	Contract grower	Non-contract grower
Seedling age	32	30	28	30
Transplanting date	20 Nov-15 Jan	10 Nov-05 Feb	10 Jun-01 Aug	16 Jun- 10 Jul
Human labour (man-day/ha):	163	159	175	149
Hired	47	34	28	43
Family	11	27	22	28
Hired contract	105	98	124	78
Seed (kg/ha)	27	28	27	33
Fertilizer (kg/ha):	833	981	775	860
Urea	307	349	324	303
TSP	170	183	168	165
MoP	140	165	136	134
DAP	114	129	89	116
Gypsum	86	141	45	128
ZnSo4	16	15	13	14
Sulphur	37	52	39	57
Magnesium	18	15	17	37

Source: Field survey 2021-22

Per hectare human labour cost by contract growers was Tk 81,671 and it was Tk 79,446 for non-CGs in Boro season. In Aman season, per hectare human labour cost was Tk 87,339f or CGs while it was Tk 74,670 for non-CGs. Per hectare human labour cost of CGs in both the seasons was higher due to dependency on hired labour and reluctance to use family labour. In both Boro and Aman seasons, fertilizer cost by non CGs was higher than the CGs. Total cost of contract growers and non-contract growers was Tk 2,05,237 and 2,07,054 respectively in Boro season while in Aman season it was Tk 1,94,965 and Tk 1,80,018 respectively Table 10.

Per hectare yield of CGs in Boro season was 6,768 kg and non-CGs was 6,917 kg. In Aman season, CGs per hectare yield was 5,645 kg while it was 5,579 kg for non-CGs. Gross margin for CGs in both the season was higher than the non-CGs. Price of per kg rice seed is determined by BADC in case of CGs after analyzing the costs and market price that's why CGs unit price is higher in both the seasons in comparison to non-CGs. Benefit cost ratio (full cost basis) was 1.56 for CGs and 1.31 for non-CGs in Boro season while benefit cost ratio (full cost basis) was 1.38 for CGs and 1.07 for non-CGs in Aman season Table 11.

Table 10. Input-wise per hectare cost in Boro and Aman season.

Input-wise cost (BDT/ha)	Boro		Aman	
	Contract grower	Non-contract grower	Contract grower	Non-contract grower
Seed	1581	2619	1595	2428
Seedling development	950	800	750	897
Land preparation	10007	11318	12599	10169
Human labour:	81671	79446	87339	74670
Hired	23511	17236	14216	21653
Family	5659	13289	11123	14096
Hired contract	52500	48922	61999	38921
Fertilizer cost	23003	25789	21403	25689
Irrigation	15626	18733	9117	7884
Pesticide:	11788	9724	10846	7228
Herbicide	1489	1211	1334	1095
Insecticide and fungicide	10299	8512	9512	6133
Power thresher	5509	3629	3849	3917
Total variable cost	144475	138769	136376	118785
Interest on operating capital	2709	2602	2557	2227
Land rent	52394	52394	44909	44909
Total fixed cost	60762	68285	58589	61233
Total cost	205237	207054	194965	180018

Table 11. Profitability analysis of rice seed production.

Item	Boro		Aman	
	Contract grower	Non-contract grower	Contract grower	Non-contract grower
Total costs (BDT/ha)	205237	207054	194965	180018
Total variable costs (BDT/ha)	144475	138769	136376	118785
Total fixed cost (BDT/ha)	60762	68285	58589	61233
Yield (kg/ha)	6768	6917	5645	5579
Market value of paddy (BDT/ha)	291018	228263	231438	156204
Market value of straw (BDT/ha)	28520	43544	36749	36801
Gross benefit (GB) (BDT/ha)	319538	271807	268186	193004
Gross margin (GM) (BDT/ha)	175063	133038	131811	74219
Gross profit ratio (GM*100)/GB	54.79	48.95	49.15	38.45
Net return (BDT/ha)	114301	64753	73221	12986
Unit price of grain (BDT/kg)	43	33	41	28
Cost of production (BDT/kg)	30.33	29.93	34.54	32.27
BCR (cash cost basis)	2.21	1.96	1.97	1.62
BCR (full cost basis)	1.56	1.31	1.38	1.07

Source: Field survey 2022

Major constraints faced by the contract and noncontract growers from which it is evident that unavailability of labour, high disease and insect infestation, and high wage rate of labour were the prime problems in the study area.

S M M H Noman, L Deb, A Chowdhury, S A Jui, M S Islam

SPATIAL PRICE DYNAMICS OF RICE IN BANGLADESH: AN EVIDENCE FROM TIME-SERIES ANALYSIS

Rice has a vast market in terms of both volume and participants that often remains at the center of controversy in Bangladesh. Bangladeshi rice market is characterized by a plenty of intermediaries who maneuver along the vertical and spatial supply chain. Therefore, integrity and efficiency of rice markets are prime concern in the rice sector of the country. Again, market integration, price transmission and volatility analysis have been considered as the effective signaling mechanisms to determine market efficiency by the economists. Policy makers also possess a keen interest on these issues for accordingly devise policies and strategies as these are the evidences from macro-economic aspects. Thus, this study aims to evident the pricing irregularities exist in the spatially separated rice markets for finding a way toward sustainable rice value chain in Bangladesh. The specific objective of this study is to analyze short-run and long-run spatial price relationships including market integration, price transmission and volatility among 12 major wholesale rice markets in Bangladesh.

Time-series data from secondary source has been used for the study. Weekly average wholesale price series of 12 major rice markets namely, Barishal, Chattogram, Dhaka, Khulna, Kushtia, Mymensingh, Naogaon, Rajshahi, Rangpur, Sherpur, Sunamganj and Sylhet considered for this study Table 12. Price series covering from 2012-2020 were considered and collected from the Department of Agricultural Marketing (DAM), Ministry of Agriculture, Government of the People's Republic of Bangladesh. Johansen co-integration model, Vector Error Correction model (VECM) and Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model were used for analyzing market integration, price transmission and volatility clustering, respectively. EViews 10 along with updated add-ins were used as analytical software.

Table 13 exemplifies the results obtained from Johansen co-integration test. For the multivariable model, the co-integration test is by using Johansen's maximum likelihood procedure based on two test statistics, namely, the trace and eigenvalue. The results of both Trace and Maximum-eigen statistic indicate the rejection of no co-integration as well as at least seven co-integrating equations among the 12 markets. This result implied that all the studied 12 major wholesale markets are co-integrated in the long-run. The price of those markets may vary to different levels in the short-run but they are expected to move together as a system in the long-run during the study period. This necessitated the estimation of the movement of price in the long-run and short run, using VECM.

Table 12. Descriptive statistics of spatial rice prices

	BARISL	CHATTO	DHAKA	KHULN	KUSHTI	MYMEN	NAOGA	RAJSHA	RANGPU	SHERPU	SUNAM	SYLHET
Mean	38.34	36.24	38.68	36.40	36.58	38.18	37.17	37.61	37.17	36.90	37.53	36.61
Median	37.66	35.00	37.30	35.16	35.68	37.85	36.75	36.41	36.93	37.00	37.50.	36.33
Max.	50.00	49.33	54.50	51.33	53.00	53.25	50.16	50.83	53.62	54.50	50.75	52.08
Min.	29.00	24.20	31.00	25.33	20.28	26.75	22.83	27.41	25.43	26.75	22.00	26.83
Observ.	471	471	471	471	471	471	471	471	471	471	471	471

Table 13. Spatial cointegration test result.

Co-integration rank (r)	λ_{trace}	λ_{trace} (95%)	λ_{max}	λ_{max} (95%)
H_0: $r = 0$ vs $H_1 = r \leq 1$	417.13***	285.14	74.65***	70.53
H_0: $r \leq 1$ vs $H_1 = r \leq 2$	342.48***	239.23	68.86**	64.50
H_0: $r \leq 2$ vs $H_1 = r \leq 3$	273.62***	197.37	60.27**	58.43
H_0: $r \leq 3$ vs $H_1 = r \leq 4$	213.35***	159.53	57.40**	52.36
H_0: $r \leq 4$ vs $H_1 = r \leq 5$	155.95**	125.61	43.90*	46.23
H_0: $r \leq 5$ vs $H_1 = r \leq 6$	112.05**	95.75	37.64*	40.08
H_0: $r \leq 6$ vs $H_1 = r \leq 7$	74.41**	69.82	28.25	33.88
H_0: $r \leq 7$ vs $H_1 = r \leq 8$	46.15	47.86	21.84	27.58

Table 14 demonstrates the results obtained from Granger causality test. This implies that price of Dhaka market leads the price of Sunamganj, Naogaon and Chattogram in the long-run during the study period whereas, Khulna leads Naogaon, Sherpur, Sunamganj and Chattogram market. Except those unidirectional relationships stated in the Table 14, all other market pair shows bidirectional relationships during the study period.

Table 15 Presents the results of price transmission among 12 spatially separated major wholesale markets obtained from VECM. It is evident from the table that Dhaka market shows poor adjustment to the price change in all the other 11 wholesale markets across the country in the long-run. It is to be noted that all the error correction terms (ECT) are negative and significant which confirm the convergence of all the markets in long-run i.e. the price of these markets may vary at the short-run but they show convergence to the equilibrium in the long-run. The highest ECT has been observed in case of Dhaka-Kushtia which is also lower in efficient market context, implies that Dhaka market adjust only 11% of price change in Kushtia market within a week.

Table 14. Granger causality test result

Causality Direction	
Dhaka Granger Causes Sunamganj	Naogaon Granger Causes Chattogram
Dhaka Granger Causes Naogaon	Kushtia Granger Causes Sylhet
Dhaka Granger Causes Chattogram	Kushtia Granger Causes Chattogram
Khulna Granger Causes Naogaon	Rajshahi Granger Causes Dhaka
Khulna Granger Causes Sherpur	Sherpur Granger Causes Rajshahi
Khulna Granger Causes Sunamganj	Sunamganj Granger Causes Rajshahi
Khulna Granger Causes Chattogram	Barishal Granger Causes Sherpur
Naogaon Granger Causes Rajshahi	Chattogram Granger Causes Sunamganj

Table 15. Price transmission result.

Market pair	ECT	t-Statistic
Dhaka-Barishal	-0.0440*	-1.80740
Dhaka-Chattogram	-0.0385**	-2.03543
Dhaka-Khulna	-0.0925***	-4.12671
Dhaka-Kushtia	-0.1162***	-4.28634
Dhaka.-Mymensingh	-0.0743***	-3.82864
Dhaka-Naogaon	-0.0312*	-1.86980
Dhaka-Rajshahi	-0.0784***	-3.78228
Dhaka-Rangpur	-0.0589***	-3.00645
Dhaka-Sherpur	-0.0428**	-2.44658
Dhaka-Sunamganj	-0.0178	-1.22791
Dhaka-Sylhet	-0.0214	-1.01816

Table 16 presents the result of GARCH (1,1) estimation the rice prices in 12 studied markets for analyzing the volatility scenario. All the constant terms in the equations are significant at 1% level which implies that the price of rice in all the individual market is dependent on the immediate past price of the respective market and a constant term. Moreover, the extent of volatility was found higher and persistent in Barishal market as the GARCH term is the highest and the sum of residual term and GARCH term (0.97) tends to 1 in that case. All the wholesale rice markets except Kushtia showed high extent of volatility as all the GARCH terms are significant and much higher.

Though the studied major domestic wholesale markets across the country are co-integrated in the long-run but that does not allow us to consider this system as an efficient one because of the presence of poor price transmission and high volatility in recent periods. Effective government intervention i.e. estimating demand and supply precisely, act with vibrant rules and regulations, effective import and procurement policies, assist in commercialization etc might play important role in that case. Processors and wholesalers should have brought under some regulations to refrain them from manipulating the market, minimum support price should be introduced. Market infrastructure should be developed more- Introduction of rice processing centers; central wholesale market or reference market could be probable solutions. Connectivity among spatially separated rice markets should be improved more by well-developed transportation systems. Commercialization of rice farms should be encouraged, and at the same time market monitoring should be strengthened more.

- Limon Deb and M S Islam

MARKET CONCENTRATION OF POPULAR RICE BRANDS IN BANGLADESH

Rice is a major dietary food for more than fifty percent of the world and accounts for more than twenty percent of caloric intake. Studies in the literature demonstrate that with economic progress and growth in the disposable income of households, income elasticities for rice are becoming smaller over time. This has led to a decline in per capita rice consumption in a number of high- and middle-income countries. There is evidence that an increase in consumer income led to more consumption of fine-grain rice by replacing ordinary-grain rice, with declining total rice consumption. The rice market in Bangladesh is rich in fine rice with some popular brand names. The most popular names are Minikit, Nazir, Katari, Zira, BRRI Dhan28, etc. Bangladesh is not producing the paddy of these brand names as much as the amount of clean rice found in the market. Some newspapers reported that over-polishing of medium-bold grain is the mechanism of manufacturing fine rice grain in the auto rice mills. Therefore, this study is designed to identify the available rice brands in Bangladesh and their market concentration.

Table 16. Results of the GARCH model for volatility clustering.

Market	Constant	RESID(-1)^2	GARCH
Dhaka	0.000201***	0.181281***	0.444299***
Barishal	3.71E-05***	0.178893***	0.792584***
Chattogram	0.000178***	0.167357***	0.407102***
Khulna	0.000133***	0.211842***	0.598653***
Kushtia	0.000592***	0.704080***	-0.025326
Mymensingh	0.000221***	0.307628***	0.543562***
Naogaon	0.000234***	0.067776***	0.734968***
Rajshahi	9.62E-05***	0.172274***	0.667259***
Rangpur	0.000251***	0.239777***	0.608500***
Sherpur	0.000223***	0.163700***	0.643302***
Sunamganj	2.24E-05***	-0.029093***	1.012654***
Sylhet	0.000140***	0.090655***	0.748819***

Sampling technique. This study employed a stratified random sampling technique to select the respondents from the rice markets. The rice traders are classified into large, medium, and small. The sample size is distributed proportionally according to the population of respective traders' classes in the markets. Data were collected through a structured interview schedule from May to August 2021.

Location. Eight Upazila markets of Sylhet, Jamalpur, and Kurigram districts and two city markets (Dhaka and Gazipur)

Empirical approach. The Herfindahl Index measures the size of firms or brands in relation to the industry or sector and indicates the amount of competition among them. It is named after economists Orris C. Herfindahl and Albert O. Hirschman. It is also known as Herfindahl–Hirschman Index, or HHI. An increase in the HHI generally indicates a decrease in competition and an increase in market power, whereas decreases indicate the opposite.

Market share and price of popular rice brands in the sampled upazila markets

In the upazila level markets, BR28 was the most popular rice brand contributing about 40% of the available rice, followed by Minikit (17.7%), Swarna (14.5%), BR29 (12.1%), Pajam (6.1%), Zira (3.1%), and Katari (2.4%) (Fig 2). Due to the quality and aroma, the average price of Chinigura was the highest (87.5 Tk/kg) in upazila markets. The most popular BRRI Dhan28's price was 51 Tk/kg, whereas the price of Minikit was 58.5 Tk/kg. Nazir and Katari were fine-grain premium quality brands, reflecting relatively higher prices (60 and 58 Tk/kg, respectively) in the market. However, few consumers purchase these brands due to the low accessibility for higher prices (Table 17).

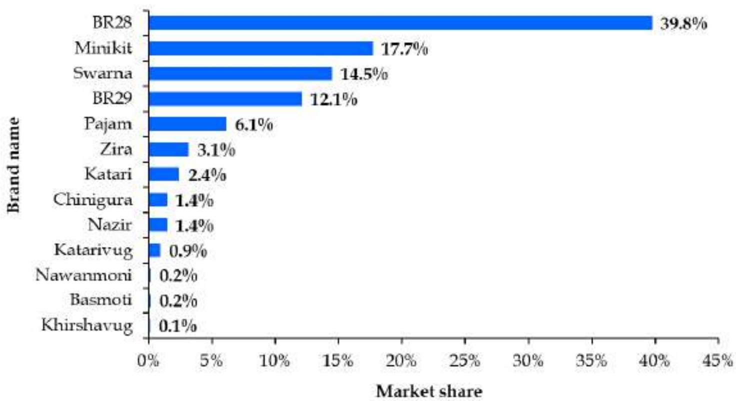


Fig 2. Market share of major rice brands in the surveyed upazilas. Note: Prepared by the authors based on the information from the market survey during 2020-21.

Table 17. Price (Tk/kg) of available popular rice brands in the upazila level markets in Bangladesh during 2020-21.

Brand name	Price (Tk/kg)			
	Mean	Maximum	Minimum	Standard deviation
Khirshavug	66.5	71	62	4.5
Basmoti	63	66	60	3
Nawanmoni	47	49	45	2
Katarivug	61.5	64	59	2.5
Nazir	60	64	56	4
Chinigura	87.5	95	80	7.5
Katari	58	61	55	3
Zira	60	64	56	4
Pajam	47.5	49	46	1.5
BRRI Dhan29	48	50	46	2
Swarna	44	46	42	2
Minikit	58.5	62	55	3.5
BRRI Dhan28	51	54	48	3

Market share and price of popular rice brands in the sampled city markets

The most popular rice brand in the city markets was Minikit which shares 33.5% of the available rice brands, followed by BRRI Dhan28 (19.4%), Zira (19.2%), Nazir (8.5%), and Katari (5.2%) (Fig 3). Because of the aroma and premium quality characters, the price of Chinigura was the highest (102.5 Tk./kg) in the market. The price of Basmoti was 68.5 Tk per kg. The price of imported Basmoti ranged from 250-300 Tk per kg. The most popular Minikit's price was 60.5 Tk per kg, whereas BRRI Dhan28 and Zira were sold for 54.0 and 64.5 Tk per kg, respectively. The price of Nazir and Katari were 65.0 and 63.5 Tk/kg, respectively (Table 18).

The market concentration of popular rice brands in Bangladesh.

The value of the HHI in the upazila level markets was more than 1800, indicating that the concentration of rice brands in the upazila markets was very high with very low competition. The market share of the top four was 97.33% (Table 19). That means the rice processors are highly concentrated on producing the top four brands.

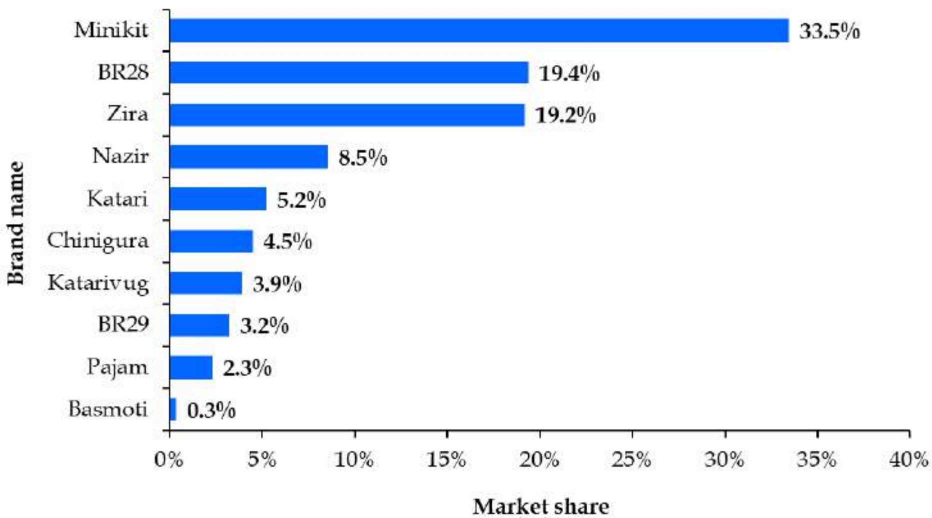


Fig 3. Market share of major rice brands in the surveyed cities. Note: Prepared by the authors based on the information from the market survey during 2020-21.

Table 18. Price (Tk/kg) of available popular rice brands in the city markets in Bangladesh during 2020-21.

Brand name	Price (Tk./kg)			
	Mean	Maximum	Minimum	Standard deviation
Basmoti	68.5	72	65	3.5
Pajam	50	52	48	2
BR29	51	54	48	3
Katarivug	66.5	70	63	3.5
Chinigura	102.5	110	95	7.5
Katari	63.5	66	61	2.5
Nazir	65	68	62	3
Zira	64.5	67	62	2.5
BRRI Dhan28	54	56	52	2
Minikit	60.5	63	58	2.5

Table 19. Popular rice brands on upazila level markets.

Brand name	Market share (%)	S^2	HHI	Share of HHI (%)	CR4	CR4 shares of HHI (%)
BRRI Dhan28	39.76	1580.81		68.14		
Minikit	17.89	320.07		13.80		
Swarna	14.50	210.15		9.06		
BRRI Dhan29	12.12	146.97		6.33		
Pajam	6.13	37.63	2319.97	1.62	2257.99	97.33
Zira	3.23	10.43		0.45		
Katari	2.41	5.81		0.25		
Chinigura	2.35	5.52		0.24		
Nazir	1.61	2.58		0.11		

Table 20. Popular rice brands on city markets.

Brand name	Market share (%)	S^2	HHI	Share of HHI (%)	CR4	CR4 share of HHI (%)
Miniket	33.70	1135.69		57.29		
BRRI Dhan28	18.90	357.21		18.02		
Zira	17.20	295.84		14.92		
Nazir	10.10	102.01		5.15		
Katari	6.70	44.89	1982.38	2.26	1890.75	95.38
Chinigura	4.00	16.00		0.81		
Katarivug	3.90	15.21		0.77		
BRRI Dhan29	3.20	10.24		0.52		
Pajam	2.30	5.29		0.27		

The value of the HHI indicates that the rice brands in the city markets were highly concentrated with low competition. The proportion of CR4 was 95.38% (Table 20). It means the rice processors are concentrated to produce the top four rice brands for the city markets of Bangladesh.

This study is the preliminary finding of '*Tracking Rice Varietal Authentication in Bangladesh: A Pathway from Farm to Market*' where the varietal sources of existing rice brands will be figured out. The findings reveal that both upazila and city markets were highly concentrated and the competition among the traders with rice brands was very low. The popular rice brands in Bangladesh are BRRI Dhan28, Minikit, Zira, Nazir, and BRRI Dhan29. The rice processors are highly concentrated to produce the top four brands that captured more than 95% share of the market. By the end of this study, the varietal sources of different rice brands and the causes of producing brandings would be identified.

M C Rahman, M A R Sarkar, M S Rahaman, M A Islam, and M S Islam

COMPARATIVE ADVANTAGE OF BRRI DHAN50 IN BANGLADESH

It is now commonly thought that Bangladesh may benefit from the commercial export of fragrant rice to gain important foreign currency. Even though the country has yet to develop a significant rice surplus, the case for exporting fragrant rice is compelling. The country will be able to earn foreign currency by exporting a specific amount of high-value fragrant rice. There have been intermittent attempts to export rice, with evidence of modest quantities of fragrant rice being exported to a number of places where nativars lived. However, whether or not a specific crop will be encouraged for production on a national/commercial level will be largely determined by its competitive advantage in the export or import substitution scenario.

For achieving sustainable aromatic rice production like BRRI dhan50 (*Banglamoti*) in *Boro* season, it is essential to investigate whether Bangladesh has a comparative advantage in *Boro* season aromatic rice (BRRI dhan50) production at import and export substitution in the short run. The specific objectives of the study were: i) to examine the prospect of production of export potential aromatic rice (BRRI dhan50) variety in terms of import and export substitution; and, iii) to draw some policy guidelines.

This study used cross-sectional data. A prominent aromatic rice-producing district namely, Jashore was selected purposively where BRRI dhan50 was grown specially. Two upazilas (Sadar and Monirampur) from Jashore district, two unions from each upazila and two villages from each union selected purposively with the help of the Department of Agriculture Extension (DAE) personnel where the BRRI dhan50 producers were concentrated. A structured questionnaire was used to collect data from May to June 2021. A total of 160 farmers were chosen randomly after collecting a comprehensive list of BRRI dhan50 producing farmers in each village. For this study, we use only the data for BRRI dhan50 aromatic rice variety growing in the *Boro* season to achieve the set objectives.

This study employed the domestic resource cost (DRC) ratio to measure the comparative advantage of export potential aromatic rice (BRRI dhan50) production at import and export substitution in Bangladesh.

In import parity situation, DRC value is less than one. It means Bangladesh has comparative advantage for producing export potential aromatic rice like BRRI dhan50 at import substitution. On the other hand, in export parity situation, DRC value is also less than one. It means Bangladesh has comparative advantage for exporting export potential aromatic rice like BRRI dhan50 at export substitution. These results are in line with the results of some earlier studies by Rashid (2009); Kazal *et al.* (2013; Tama et al, 2018).

Bangladesh has comparative advantage for producing and exporting export potential aromatic rice like BRRI dhan50 at import and export substitution. A plausible reason for these results is high prices of aromatic rice in the international market, higher per unit yield of aromatic rice and marketing spread of price between the wholesale to retail levels is a bit low. In accelerating comparative advantage in aromatic rice production in the long-run in Bangladesh, the following policy implication can be drawn: We know, marketing spread of price between the wholesale to retail levels has strongly influenced to DRC values. One of the reasons behind the wider price spread is the existence of market power of dominated millers and traders. So, the government can actively participate in the market to reduce the market power of the dominated millers and traders to refrain them from exercising price controlling power to earn excess profit that will minimize the price spread in the supply chain and increase the comparative advantage of the aromatic rice production at import and export substitution.

- M A Islam, M S Rahaman, M A R Sarkar, M C Rahman, and M S Islam

Agricultural Statistics Division

Summary

Among T. Aman varieties, BRRI dhan87 were found stable with stability index 2.00 while BR3, BR5, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan70, BRRI dhan77, BRRI dhan90 and BRRI dhan91 appeared to be below average stable. BR4, BR10, BR11, BR22, BR23, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan66, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan78, BRRI dhan79, BRRI dhan80, BRRI dhan93, BRRI dhan94, BRRI dhan95, BRRI hybrid dhan4 and BRRI hybrid dhan6 were found having average stability among T. Aman varieties. No entry was found as unstable varieties in T. Aman season. Among the aromatic rice BRRI dhan5, BRRI dhan34, BRRI dhan37 and BRRI dhan38 were found as below average stable in T. Aman season.

At 30% selection intensity four varieties BRRI dhan48, BRRI dhan82, BRRI dhan98 and BRRI hybrid dhan7 have been selected as highly stable variety based on multi-trait stability index (MTSI).

Reviewed and developed analytical skills on some of the key concepts, methods, software packages and databases used in bioinformatics with an emphasis on those relevant to rice research. So, we are capable to analyse DNA sequence data, search bioinformatics database, BLAST, phylogenetic tree, Sanger sequencing data, NGS data, check the quality of NGS data, Genome assembling etc., topic on bioinformatics.

Different statistical analys such as principal component analysis, factor analysis, cluster analysis the quantifies the perceived gain in experimental efficiency from using paired end rather than single end read data to provide reliable isoform specific gene expression estimates in RNA-Seq.

Most of the variety were found is a significant variation of the over estimation both sundry and oven dry sampled methods. The highest and lowest over estimations observed 6.51 and 18.16% respectively for sun dry methods. In oven dry method samples, the highest and lowest over estimations were 4.95 and 23.51% among the evaluated 46 Boro rice varieties.

In T. Aman season, BR11 and BR22 were recorded as the highest average grain yielder and ideal genotypes among long duration varieties. BRRI dhan94and BRRI dhan93 were the most stable genotypes with above-average yield in medium duration where BRRI hybrid dhan6, BRRI dhan87 were the most stable genotypes and above average yielder for short duration.

For reducing micro climatological risk factors weather-based rice advisory systems consider and manage the full spectrum of risks from weather extremes or climate variability. This novel approach can help rice growers in a better and more coordinated way in response to weather extremes or climate variability that exceeds their inherent coping capacity. This can significantly reduce the disaster risk of the rice farming communities, which is a major development challenge in Bangladesh.

In T. Aman season, BRRI dhan93 is suited in north and north-central regions of Bangladesh. Whereas BRRI dhan94 is suitable for western, north-central and south-east regions. BRRI dhan95 is appropriate for western, north-central and south-east regions of Bangladesh.

More or less, throughout the year eastern side of Bangladesh is prome to high rainfall and low temperature area and western side is low rainfall and high temperature area.

In a nut shell, the western side is suitable for cultivation of BRRI dhan90 and BRRI dhan92 which are suitable for all over the Bangladesh except the eastern side of Bangladesh.

The total area of rice grown in Aman 2021 was about 5.87 Mha. Total rice cultivation in the Boro 2021–22 season was estimated at 4.95 Mha.

Unfavourable area for Cold is 23,36,706.75 ha, drought is 10,62,338.46 ha, saline is 10,77,248.42 ha, ganges tidal floodplain is 79,51,76.31 ha, Haor is 2,87,407.64 ha, flood area is 31,40,094.13 ha and char land is 4,30,579.50 ha. Among these abiotic stresses flood area shows maximum and Char Land shows minimum unfavourable area for rice.

In the reporting year, two types of training were conducted under Capacity Building through Training programme. A total of 68 participants were trained

through the training programmes. The participants of these training were scientists and SA, FM and AFM of BRRI.

A computer programme using R has been developed to calculate the stability index of BRRI stability model. This program makes it possible to calculate the stability index of BRRI stability experiment data very easily and quicly.

Two new web applications have been developed for Budget Management System of BRRI and Quota Management System of BRRI. The applications have been hosted in the BRRI LAN and the related persons already started to use the applications. Also, updated different features as per user requirements of the existing Salary Management System, Labour Management System and Casual Leave Application Management System.

ICT cell of this division has developed sensor-based rice pest management through artificial intelligence (AI) technology ‘BRRI Rice doctor’ mobile and web apps both in English and Bengali version with the help of different divisions of BRRI. In has developed dynamic view connectivity, Bangla search and inner banner system for BRKB web apps. Besides, modified the RKB mobile apps disseminates of modern rice technology and its management information at the farmer door step. We have have developed Vehicle Requisition Management System **(**VRMS) of BRRI. So that, the requester informed through SMS on basis of demanding vehicle for official or personal purpose as well as driver get confirmation SMS for their upcoming duty. Also, we developed “BRRI Alapon” Telephone Directory Mobile App. We established video conferencing system (VCS) at BRRI to communicate with MoA and others government organization. We organized five day-long, two day-long, day-long ‘Public Service Innovation’ training workshops in the reporting year. A total of 400 participants were trained through the innovation including SPS trainings and e-Nothi in-house trainings. In addition, Cyber security system has been strengthened for BRRI.

STABILITY ANALYSIS OF BRRI VARIETIES

The main objectives of the study were to determine the stability index of BRRI released varieties, maintain season, year and location-wise database and identify the bio-physical and socio-economic factors causing instability. Experiments are being conducted in T. Aman season with BRRI released rice varieties since 2001 Gazipur and different regional stations. The collaborative regional stations in the T. Aman season are Rajshahi, Rangpur, Cumilla, Sonagazi, Barishal, Satkhira and Kushtia. In T. Aman the numbers of varieties were 47. The design was RCB with three replications and the effective plot size (harvest area) was 3×2 m^2, leaving the two-border row from each side. Recommended crop management practices were followed. Stability analyses of the experimental data were performed by using a newly developed model. The model deals with the performance of the genotypes across the geographical locations differing in land, soil and other biotic and abiotic factors over the years characterizing fluctuation of weather variable, floods, drought etc.

Table 1. Stability parameters of grain yield for T. Aman.

Variety	Stability parameter 2001-2020			Stability index	Stability rank	Nature of stability
	Si	Di	Pi	Gi	Ri	
Non-aromatic rice						
BR 3	18.282	-9.52	92	0.804	38	BAS
BR 4	12.792	0.5	84	1.23	22	AS
BR 10	13.773	9.09	72	1.326	17	AS
BR 11	13.946	7.827	83	1.36	14	AS
BR 22	14.084	6.781	82	1.319	18	AS
BR 23	15.796	2.252	83	1.126	29	AS
BR 25	15.597	-0.717	81	1.06	33	AS
BRRI dhan30	12.92	6.736	86	1.405	10	AS

BRRI dhan31	13.821	2.385	85	1.223	23	AS
BRRI dhan32	16.064	7.623	91	1.33	16	AS
BRRI dhan33	20.364	-11.249	80	0.634	40	BAS
BRRI dhan39	17.966	-1.697	75	0.915	36	BAS
BRRI dhan40	14.085	6.048	85	1.331	15	AS
BRRI dhan41	15.971	4.776	89	1.221	24	AS
BRRI dhan44	14.163	7.702	59	1.309	19	AS
BRRI dhan46	15.766	2.112	58	1.114	30	AS
BRRI dhan49	11.184	12.151	53	1.67	5	AS
BRRI dhan51	15.895	4.563	42	1.145	28	AS
BRRI dhan52	9.791	9.732	49	1.735	4	AS
BRRI dhan53	14.831	2.822	40	1.187	26	AS
BRRI dhan54	17.724	7.324	39	1.194	25	AS
BRRI dhan56	16.88	-4.753	43	0.938	35	BAS
BRRI dhan57	21.018	-19.502	42	0.424	43	BAS
BRRI dhan62	27.647	-20.438	35	0.315	45	BAS
BRRI dhan66	13.226	5.482	33	1.389	12	AS
BRRI dhan70	18.029	-9.569	24	0.705	39	BAS
BRRI dhan71	12.433	7.861	24	1.393	11	AS
BRRI dhan72	11.31	12.933	26	1.639	7	AS
BRRI dhan73	15.855	5.545	29	1.265	21	AS
BRRI dhan75	14.789	2.533	26	1.17	27	AS
BRRI dhan76	15.879	-3.323	31	1.064	32	AS
BRRI dhan77	13.959	-5.414	26	0.995	34	BAS
BRRI dhan78	10.95	5.244	18	1.479	9	AS
BRRI dhan79	9.416	9.162	16	1.665	6	AS
BRRI dhan80	9.185	3.665	16	1.542	8	AS
BRRI dhan87	11.45	20.721	17	2.00	1	S
BRRI dhan90	16.312	-9.524	9	0.864	37	BAS
BRRI dhan91	15.457	-37.39	9	0.094	47	BAS
BRRI dhan93	9.627	10.931	9	1.746	2	AS
BRRI dhan94	15.145	10.52	9	1.388	13	AS
BRRI dhan95	22.427	4.429	9	1.084	31	AS
BRRI hybrid dhan4	15.205	6.707	34	1.297	20	AS
BRRI hybrid dhan6	13.037	18.006	25	1.742	3	AS
Aromatic rice						
BR 5	19.02	-22.48	76.00	0.30	44	BAS
BRRI dhan34	18.94	-26.15	80.00	0.23	45	BAS
BRRI dhan37	17.52	-22.57	84.00	0.37	42	BAS
BRRI dhan38	16.34	-20.37	81.00	0.45	41	BAS

Note: AS=Average stable, BAS=Below average stable, Stable=S and Unstable=US

Among the T. Aman varieties, BRRI dhan87 were found stable with stability index 2.00 while BR3, BR5, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan70, BRRI dhan77, BRRI dhan90 and BRRI dhan91 appeared to be below average stable. BR4, BR10, BR11, BR22, BR23, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan66, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan78, BRRI dhan79, BRRI dhan80, BRRI dhan93, BRRI dhan94, BRRI dhan95, BRRI hybrid dhan4 and BRRI hybrid dhan6 were found having average stability. No entry was found as unstable varieties in T. Aman season. Among the aromatic rice BRRI dhan5, BRRI dhan34, BRRI dhan37 and BRRI dhan38 were found as below average stable in T. Aman season (Table 1).

IMPROVEMENT OF BRRI STABILITY MODEL BY INCORPORATING MULTIPLE FACTORS

The main objective of the study is to apply a novel stability model by incorporating multiple factors for evaluating the stability of rice genotypes. For this study an experiment was carried out for the evaluation of 13 T. Aus rice genotypes in a randomized complete block design (RCBD), with three replications in nine different locations of Bangladesh in 2021. The data inciuding GY: grain yield (ton/ha), GD: growth duration (days), PH: plant height (cm), TN: no. of tiller per hill, PN: no. of panicle per hill, PL: panicle length, GPP: no. of grain per panicle, UGP: no. of unfilled grain per panicle, TGW: thousand grain weight were used to perform the multi-trait stability index (MTSI) model for fulfil the study objectives. The statistical analyses were performed by using R software with the "metan" package (Olivoto and Dal'Col Lúcio, 2020). Results show that the interaction plot for agronomic and morphological traits exhibited non-crossover type interactions (Fig. 1). This kind of genotype-environment interaction (GEI) is expected due to high test site heritability and also low CV for all the test sites.

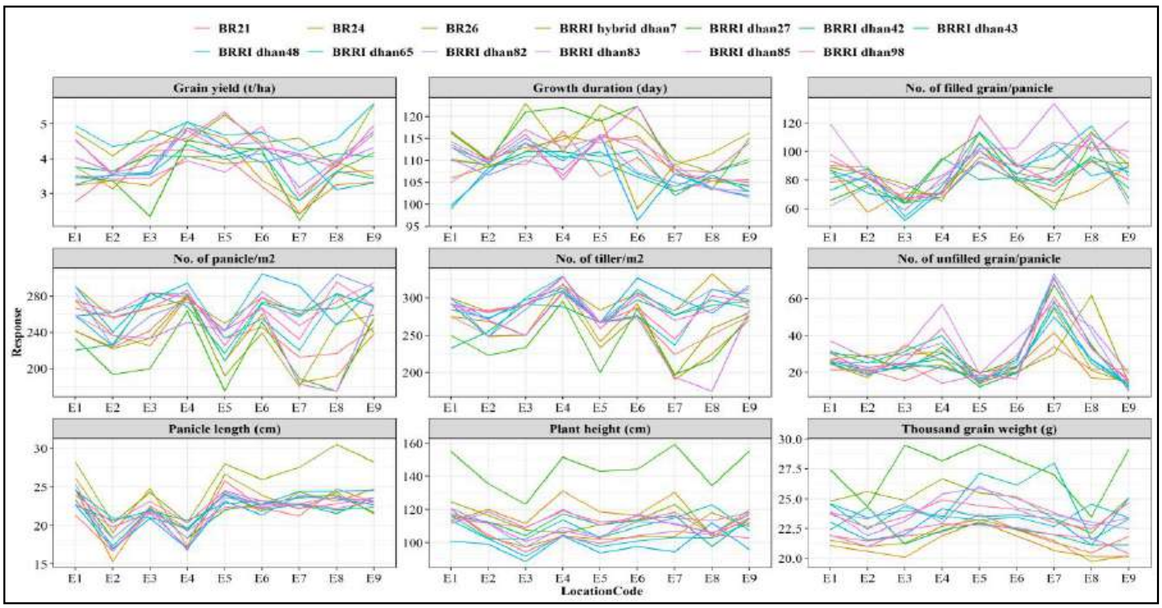


Fig. 1. Interaction plot for agronomic and morphological traits performance of 13 T. Aus rice varieties tested at nine environments in 2021. In the figure, x and y axis represent the response, respectively in short form.

Where, E1: Barishal; E2: Cumilla; E3: Gazipur; E4: Habiganj; E5: Kushtia; E6: Rajshahi; E7: Rangpur; E8: Satkhira; E9: Sonagazi

The LR test showed significant genotype-environment interaction for all traits. The overall grain yield of T. Aus rice varieties ranged from 2.0 ton ha^{-1} to 5.87 ton ha^{-1} while the environments mean yield was 3.98 ton ha^{-1}. The genotypic variance was higher than residual and GEI variance for grain yield, plant height, and thousand grain weight (Fig. 2). We have found for that yield, TGW, PH is mostly dominated by genotype effect. Growth duration is mostly regulated by both genotype and environment effects. The number of grain per panicle, number. of unfilled grain per panicle mostly influenced by residual factors than genotypes and environments interaction factor. High values of broad sense heritability were calculated for all traits under the study, the highest broad sense heritability of genotypic mean was plant height (97%) and the lowest was under. of unfilled grain per panicle (65%) (Table 2). The genotypic selection accuracy (Acc) values ranged from 0.80 (UGP) to 0.99 (PH). The highest CVg was recorded for no. of unfilled grain per panicle (11.72) and lowest was growth duration (2.09). The CV ratio was highest for plant height (1.99) followed by growth duration (1.56), thousand grain weight (1.37), grain yield (1.24), panicle length (0.83), number of tillers per hill (0.68), number of panicle per hill (0.66) and no. of filled / unfilled grain per panicle and (0.36) (Table 1). High extent of significant association was noticed between grain yield and grain per panicle (GP), number. of tiller per hill (TN) number. of panicle per hill (PN), growth duration (GD) and grain per panicle (GPP). Grain yield have found significant negative correlations on plant height (PH) and number. of unfilled grain per panicle (UGP) (Fig. 3).

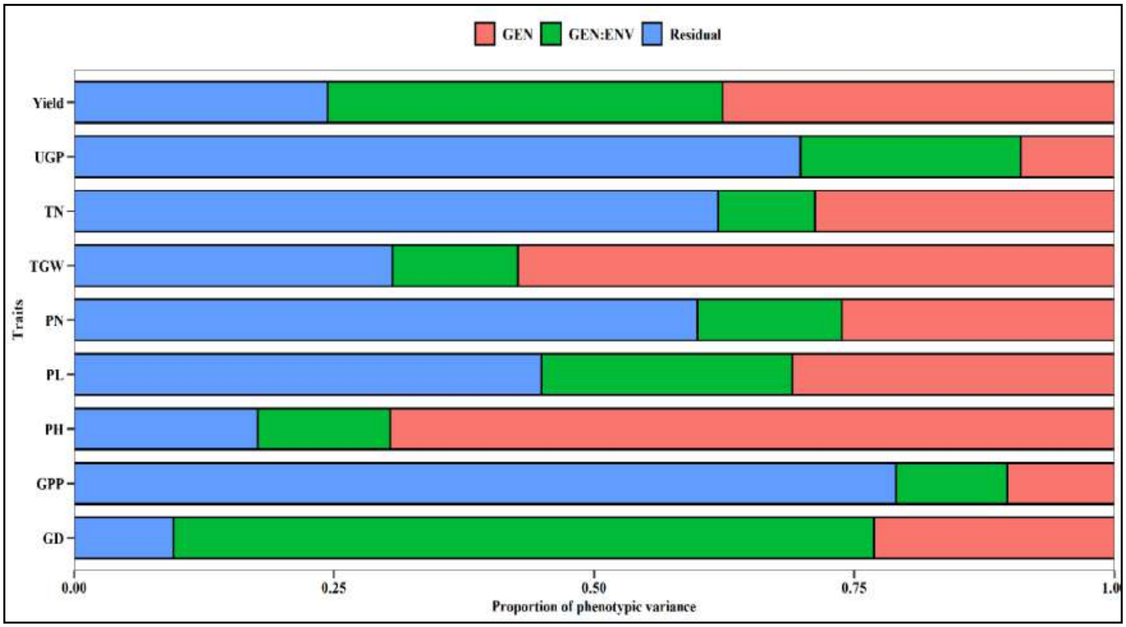


Fig. 2. Proportion of the phenotypic variance for 13 T. Aus rice traits assessed in nine different environments.

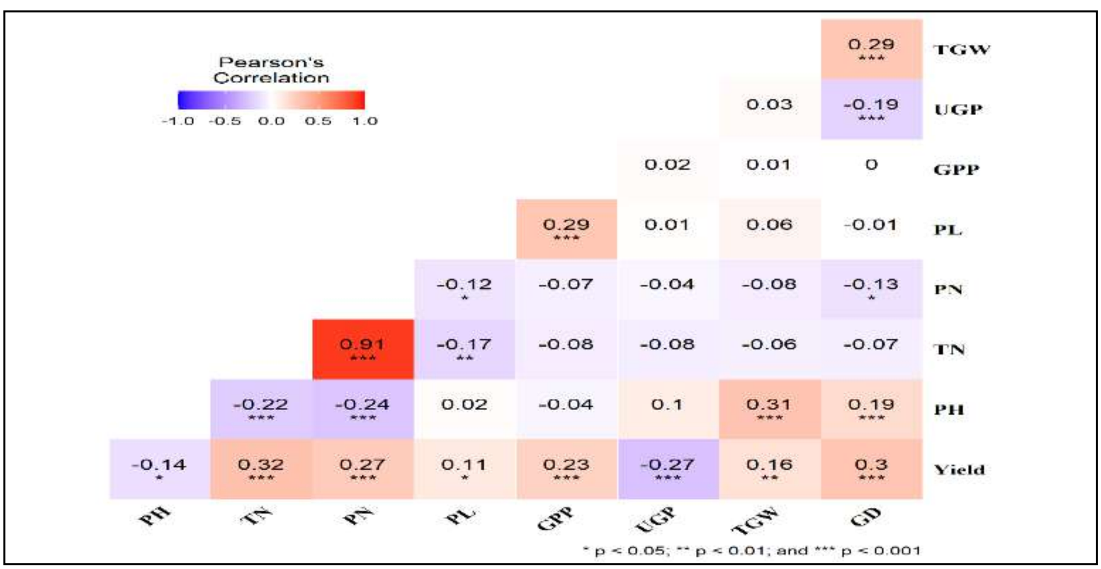


Fig. 3. Pearson's correlation matrix among 38 T. Aman rice traits evaluated in seven environments.

Table 2. Deviance analysis, genetic parameters and variance components for nine morphological and physiological traits evaluated in 13 T. Aus rice varieties.

Parameter	Yield	PH	TN	PN	PL	GPP	UGP	TGW	GD
Phenotypic variance	0.41	170.99	3171.46	2677.47	3.82	326.90	118.58	4.85	22.91
GEIr2	0.38	0.13	0.09	0.14	0.24	0.11	0.21	0.12	0.67
h2mg	0.88	0.97	0.90	0.87	0.88	0.71	0.65	0.96	0.75
Accuracy	0.94	0.99	0.95	0.94	0.94	0.85	0.80	0.98	0.86
rge	0.61	0.42	0.13	0.19	0.35	0.12	0.23	0.28	0.88
CVg	9.87	9.72	9.94	9.86	4.86	6.79	11.72	7.14	2.09
CVr	7.95	4.89	14.58	14.92	5.85	18.82	32.65	5.22	1.34
CV ratio	1.24	1.99	0.68	0.66	0.83	0.36	0.36	1.37	1.56

Note: Yield: grain yield (ton/ha), GD: growth duration (days), PH: plant height (cm), TN: no. of tiller per hill, PN: no. of panicle per hill, PL: panicle length, GPP: no. of grain per panicle, UGP: no. of unfilled grain per panicle, TGW: thousand grain weight, PV: phenotypic variance, GEI R2: GEI coefficient of determination, h2mg: heritability of genotypic mean, Acc: accuracy of genotype selection, rge, association among genotypic values across environments, CVg: genotypic coefficient of variation, CVr: residual coefficient of variation.

GENOTYPES SELECTION BASED ON MTSI AND CONTRIBUTION OF FACTORS TO THE MTSI

Nine principal components were maintained, and the variance in these first two factors accumulated was 51.66% (Table 2). After proper varimax rotation, mean communality (*h*) was 0.67signifying that higher ratio of each trait variance was influenced by the factors. The height and lowest communality have found for PN (0.74) and TGW (0.41), respectively. The nine attributes were clustered into the three different factors as: FA1: (PH, TGW and GD); FA2: (Yield, TN, PN and PL); FA3: (GPP and UGP) (Table 2). The strengths and weaknesses plot for varieties based on different factors using multi-trait stability index reveal the factor presenting the smallest contribution for variety indicating the most performer genotypes or vice versa. In case of FA1, the factor elements PH, TGW and GD; the BRRI dhan27, BRRI dhan82 and BRRI dhan83 are the most performer of those traits. BRRI dhan48, BRRI dhan82, BRRI dhan85, and BRRI dhan98 are the most performer for FA2 traits. GPP and UGP are members of FA3, and the best performers for this factor are BRRI hybrid dhan7, BR21, and BRRI dhan27 (Fig. 4). Hence, in upcoming research, it would be desirable to explore the performance of the varieties nearer or closer to the base point. The role of factor individually to the MTSI index is used to identify the strengths and weakness of genotypes. The less involvement of a FA, the nearer the characters within that factor are to the ideotype (Fig. 4). Overall, factor 2 (FA 2) contributions to MTSI are the highest for most of the genotypes. Thus, positive gains are desired for Yield, TN, PN and PL. This specifies that those were the high grain yielding variety out of the tested varieties (Fig. 4).

The values of the MTSI presuming 30% selection intensity for selecting highly stable variety (Fig. 5). Among 13 varieties BRRI dhan48 and BRRI dhan82 are the selected variety using MTSI at 15% selection intensity. If we increase the selection intensity then BRRI dhan48 and BRRI dhan82, BRRI dhan98 and BRRI hybrid dhan7 are the selected variety based on multi-trait stability index (MTSI). The MTSI value 5.45 presents the cut point (Fig. 5, red line). The variety BRRI dhan85 are closer to red line which possibly will explain desirable characters.

The selection differential (SD) for the WAASBY index was positive for the most of the traits under present investigation, suggesting that the technique was more proficient for selection of best performing and most stable advanced lines under diverse environments. The SD for the WAASBY index was 11.8%, 7.35% and 6.29% for GY, TN and PN respectively (Table 3).

Table 3. Selection differential, explained variance and communalities of the WAASBY index and selection gain (%) for different traits of 13 T. Aus rice varieties.

VAR	Factor	Xo	Xs	SD	SD perc	h2	SG perc	PC	Variance (%)	Com.	goal
PH	FA1	112	107	-5.73	-5.1	0.971	-4.95	PC1	30.66	0.68	0
TGW	FA1	23.4	23.7	0.381	1.63	0.959	1.56	PC2	21.11	0.67	100
GD	FA1	110	109	-1.32	-1.2	0.747	-0.898	PC3	15.31	0.68	0
Yield	FA2	3.98	4.45	0.47	11.8	0.88	10.4	PC4	10.38	0.74	100
TN	FA2	304	326	22.3	7.35	0.896	6.59	PC5	7.93	0.72	100
PN	FA2	268	285	16.9	6.29	0.874	5.5	PC6	6.26	0.69	100
PL	FA2	22.4	22.6	0.144	0.641	0.877	0.562	PC7	3.65	0.64	100
GPP	FA3	85.4	84.4	-0.992	-1.16	0.714	-0.829	PC8	3.02	0.41	0
UGP	FA3	27.9	27.9	0.0669	0.24	0.645	0.155	PC9	1.66	0.80	100

NOte: Xo: Mean for WAASBY index of the original population, Xs: Mean for WAASBY index of the selected genotypes, SD: Selection differential, SG: Selection gain, Com.: Communality.

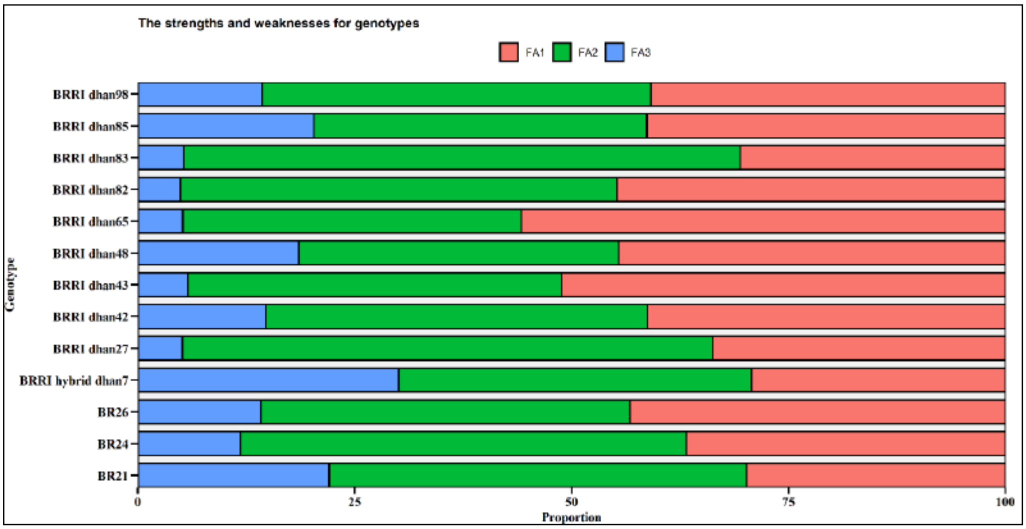


Fig. 4. The strengths and weaknesses view of selected genotypes.

The y-axis presents the ratio of each factor on the calculated MTSI of the selected genotypes. The minimum the proportions explicated by a factor, the nearer the traits within that factor are to the ideotype. Where G stands for genotype and FA stands for factor.

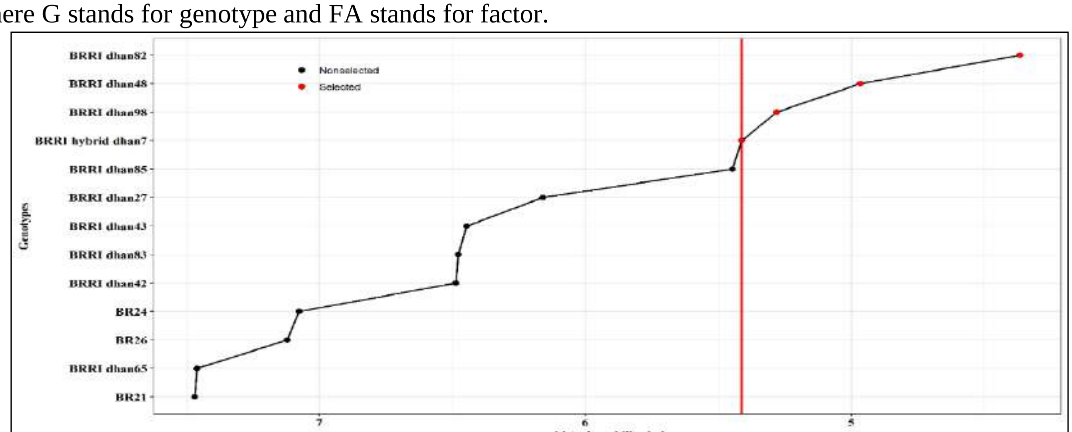


Fig. 5. Selection of highly stable variety on the basis of multi trait stability index considering 30 % selection intensity.

DEVELOP ANALYTICAL SKILLS ON THE SCOPES OF BIOINFORMATICS IN RICE RESEARCH

Bioinformatics plays an essential role in today's biological science. As the amount of molecular data grows exponentially, there is a parallel growth in the demand for tools and methods in data management, visualization, integration, analysis, modeling, and prediction. Now, many of our researchers are unfamiliar with the available bioinformatics methods, tools, and databases, which could lead to missed opportunities or misinterpretation of research findings. The main objective of the study is (i) To review the application of bioinformatics in rice research and (ii) develop analytical skills on the application of bioinformatics in rice research.

Under this study, we review some of the key concepts, methods, software packages, and databases used in bioinformatics, with an emphasis on those relevant to rice research and we found that Bioinformatics is an interdisciplinary research area. For more clearly defined, bioinformatics is the discipline of quantitative analysis of information relating to biological macromolecules such as DNA, RNA and proteins using appropriate tools (e.g., statistical, mathematical, biological database, etc.) with the aid of computers. The ultimate goal of bioinformatics is to better understand a living cell and how it functions at the molecular level.

Since the amount of molecular data grows exponentially in the world, the demand of Bioinformatics parallel growth with the molecular data. Also, the subfields of Bioinformatics increased day by day. Bioinformatics converts molecular OMICS data into information and knowledge that can improve/discover drugs/vaccine/varieties. In the year 2020-21, some of our divisional scientist successfully completed and participated in some workshop and training on bioinformatics arranged by BRRI and other organigation. Now we are capable to analyse DNA sequence data, search bioinformatics database, BLAST, phylogenetic tree, Sanger sequencing data, NGS data, check the quality of NGS data, genome assembling etc., bioinformatics related topic.

STATISTICAL MODELING AND RNA-SEQ DATA ANALYSIS

Statistical tests of the reproducibility of the non-uniformity of reads show a consistent sequence specific bias across biological and technical replicates of a gene. This effect could be due to bias in RNA fragmentation, bias in other biochemical sample preparation steps or boundary effects when a gene of fixed length is fragmented. The last cause of bias can be modeled using Monte Carlo simulations of a fixed length mRNA sequence subject to a Poisson fragmentation process and incorporated into the insert length model. Improvements to the model could be made by increasing the precision of the estimate of the probability mass function of read lengths, for example by simulating a fragmentation and filtering process by Monte Carlo and matching the output of the simulations to the empirical distribution function $q(\cdot)$. De novo discovery of isoforms from a sample is an important and difficult statistical problem that we have not addressed in this paper. Another shortcoming of the model is that in order to the statistical inference to be accurate, with the current short read technology, the number of isoforms should be relatively small. By using the classical statistical concept of minimal sufficiency, a computationally feasible solution to isoform estimation in RNA-Seq is conducted step by step. Different statistical analysis such as principal component analysis, factor analysis, cluster analysis quantifies the perceived gain in experimental efficiency from using paired end rather than single end read data to provide reliable isoform specific gene expression estimates

COMPARATIVE STUDY FOR RICE YIELD ESTIMATION BY ADJUSTING MOISTURE CONTENT

The moisture content of paddy grain decreases from different moisture (%) to 14% for safe storage of grains, and seeds should be dried to below 12 %. Ideal moisture content for milling is between 12–14%. (IRRI Rice Knowledge Bank, 2009). According to standard procedure for determining yield components at harvest, for the measuring final grain dry the samples to reduce moisture content to 10–16% (IRRI Rice Knowledge Bank, 2009). Differences in grain moisture content can result in a significant variation in the processing characteristics of the grain as well as estimation. During rice yield estimation, it is very much important to adjust the moisture content after crop cut. Reduce the estimation error a comparative study is needed for estimating the rice yield by adjusting moisture content. Hence, the objective of this study is to determine adjustment factors to estimate the paddy yield and develop a criterion for performing a reliable estimation, which can help to reduce the estimation for rice production. For this study, BRRI released rice varieties were used. The study has conducted in Boro seasons. The samples were manually cleaned to remove all foreign materials such as dust, dirt, small broken and immature kernels. The initial moisture content of the samples was determined by oven drying method at 70ºC for 48 h (Sacilik et al., 2003). In order to obtain desired moisture levels below the initial moisture contents, the samples were kept for natural drying (sun dry) and artificial drying (oven dry), both until the desired moisture contents of the samples were obtained (Yang et al., 2003). The data were analyzed statistically using programming R software and data preparation and compilation will be completed using Microsoft Excel software.

Results show that, the sample initial moisture content was observed ranging from 17.60 to 26.30% and 16.67 to 25.80% for the sun dry and oven dry methods, respectively. The used sample average initial moisture content had 21.29% for the sun dry method and 21.06% for the oven dry method. In the sundry method the reduced compared moisture (%) was14±0.08. Also, in the oven dry method the reduced compared moisture (%) was 13.93±0.06. It was Revealed that during yield estimation from crop cut samples, most of the cases had found significant overestimation (Figs. 1 and 2). There are two important things observed for overestimation one is the high range of moisture reduction and the other is dust removal (dust, dirt, small broken and immature kernels, no. of unfilled grain, a small portion of panicle, broken straw, etc.) (Figs. 8 and 9). There is a strong relationship between ranges of moisture reduction and dust. A significant positive correlation has been found between moisture reduction and dust with overestimation (Fig. 10a-10b). The highest and lowest overestimations observed were 6.51 and 18.16%, respectively for sundry methods. The average overestimation (%) for sun dry sample observed was 12.91± 0.24 and most of the variety found a significant variation of the overestimation (Fig. 6). For oven dry method samples, the highest and lowest overestimations (%) were 4.95 and 23.51 among the 46 Boro rice varieties (Fig. 7). Similarly, the overestimation for over dry method also significantly varied from variety to variety and the average overestimation (%) had 13.07±0.30.

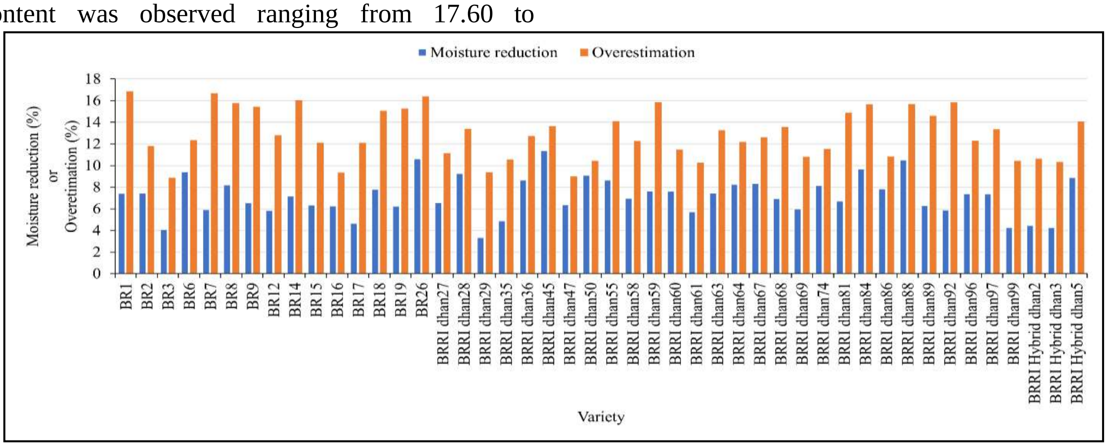


Fig. 6. Comparisons of moisture reduction and overestimation of different Boro rice varieties in sun dry method.

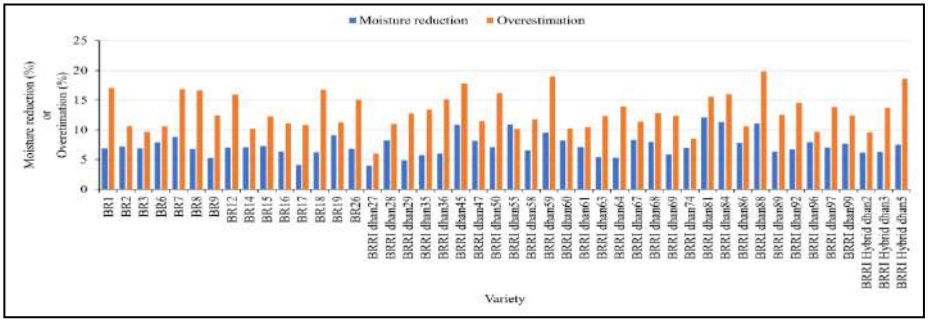


Fig. 7. Comparisons of moisture reduction and overestimation of different Boro rice varieties in oven dry method.

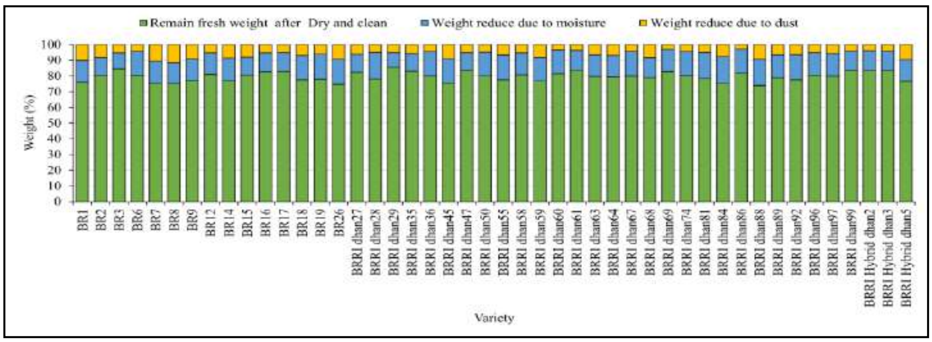


Fig. 8. Variety-wise remains/reduction weight from initial moisture to 14 % moisture content in sundry method.

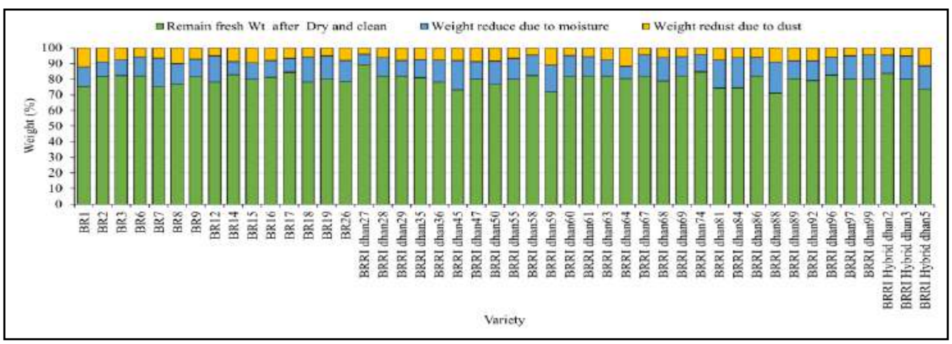


Fig. 9. Variety-wise remains/reduction weight from initial moisture to 14 % moisture content in oven dry method.

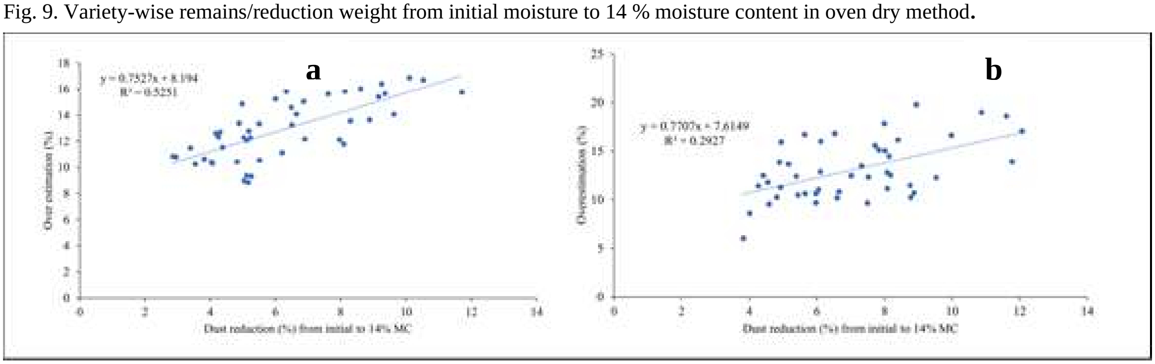


Fig. 10. Relationship between dust reduction on overestimation in sun dry (a) and oven dry (b) methods.

GENOTYPE × ENVIRONMENT INTERACTION OF BRRI VARIETIES

The development of rice varieties is affected by the environment, genotype and their interaction. Yield performance of different varieties varies across testing environments and its grain yield performance is a function of genotype (G), environment (E) and genotype × environment interaction (GEI). The structure of GEI is very important in plant breeding programmes, because a significant GEI can seriously impair efforts in selection of superior genotypes in relation to new crop introductions and cultivar development programmes leads to successful evaluation of stable genotype, which could be used for general cultivation. The major objective of the study was to identify BRRI released rice genotypes that have both high mean yield and stable yield performances across different environments for different ecosystem of Bangladesh. The experiment was conducted in multi-environment trials for T. Aman 2021. Forty-seven BRRI released T. Aman rice varieties were evaluated in nine environmental conditions of Bangladesh, such as Barishal (E1), Bhanga (E2), Cumilla (E3), Gazipur (E4), Kushtia (E5), Rajshahi (E6), Rangpur (E7), Satkhira (E8), and Sonagazi (E9). The experimental sites covered all ecosystems of Bangladesh. The experiments were carried out in randomized complete block design (RCBD) with three replications and evaluated for rice grain yield. Each experimental plot comprised of 3m × 2m. Standard agronomic practices were followed and plant protection measures were taken according to Adhunik dhaner chash, BRRI (2020). AMMI model was used to quantify the effect of different factors (genotype, location) of the experiment. The model further provides graphical representation of the numerical results (GGE biplot analysis) with a straight-forward interpretation of the underlying causes of G × E. The major objective of the present study was to identify BRRI released rice genotypes that have both high mean yield and stable yield performance across different environments for different ecosystems of Bangladesh.

ANOVA of combined analysis

The combined analysis revealed that the yield of rice genotypes was significantly influenced by environment and contributed 41.94, 30.35 and 30.11% of the total variation for medium, long and short duration respectively in the Aman season. Additionally, the relative contribution of genotype sum of squares was found 25.55, 23.02 and 14.92% for short, long, and medium duration respectively. Genotype by environment (G × E) contributed the most 25.4% to the total variation for long duration followed by 24.89% and 24.54% for short and medium duration (Table 4).

Greater portion of total variation was explained by environmental main effect indicating that the environments were diverse and a major part of variation in grain yield reflected from environmental changes. The highly significant genotype × environment interaction effects for grain yield confirmed that genotypes responded differently to the variation in environmental conditions. The yield variations could be attributed to the different environmental (climatic) conditions and to different edaphic conditions at different locations. In this case application of stability analysis for identifying widely and/or specifically adaptation of rice genotypes is essential.

Table 4. ANOVA of individual category (long, medium and short duration) Aman 2021.

SV	Long duration			Medium duration			Short duration		
	DF	MS	SS (%)	DF	MS	SS (%)	DF	MS	SS (%)
ENV	8	30.35**	38.21	8	17.49**	41.94	8	15.41**	30.11
REP (ENV)	18	1.09**	3.10	18	0.69**	3.70	18	1.70**	7.45
GEN	17	8.61**	23.02	12	4.15**	14.92	15	6.97**	25.55
ENV: GEN	136	1.19**	25.40	96	0.85**	24.54	120	0.85**	24.89
Residuals	306	0.21	10.27	216	0.23	14.89	270	0.18	12.00
CV (%)	9.29			10.15			11.35		
$LSD_{0.05}$	0.69			0.77			0.74		

Note: ENV=environment, GEN= genotype, DF = degrees of freedom; MS = mean sum square; SS (%) = explain % sum of squares; ** = significant at the 1% level.

Evaluation of test environments

Aman season: The GGE biplot explained 73.93%, 77.6%, and 74.69.94% of the total variation of the environments for long, medium and short duration respectively (Figs. 11-33). In long duration (Fig.11), there were three clusters of environments, one contains Barishal, Cumilla, Bhanga, and Sonagazi; another contains Gazipur, Kushtia, Satkhira and Rangpur; the other cluster contains only Rajshahi. Among them Barishal, Cumilla and Sonagazi were closely associated (Fig.11c). Bhanga, Rajshahi and Rangpur had the longest vector and hence was highly discriminating. Overall, the location Rangpur was highly representative and can be considered ideal environment for evaluating long duration genotypes (Fig.11c).

GGE biplot showed three distinct clusters in medium duration: one contains Barishal, and Bhanga; another cluster contains Rangpur, Gazipur and Rajshahi; and Cumilla, Satkhira, Kushtia and Sonagazi remain in the same cluster (Fig. 12c). The closest association were observed between the environments Kushtia and Sonagazi; and Barishal as well as Bhanga. The position of the location Gazipur is in the longest vector and showed week correlation with Satkhira, Kushtia and Sonagazi. The ideal environment was found in Rajshahi for (Fig. 12c). for testing medium duration genotypes with its appreciable discriminating ability and representativeness and position nearest to the circle point of AEA axis.

In short duration GGE biplot showed three distinct clusters (Fig. 13c). Barishal, Rajshahi, Rangpur and Sonagazi considered as one cluster and the second cluster contains Cumilla, Gazipur and Kushtia and the rest cluster contain only one location Bhanga as weii as Satkhira). Bhanga showed the longest vector, making it more discriminating than the other environments. Considering the criteria of ideal environment, Kushtia showed a smaller angle with the AEA and hence was highly representative environment (Fig. 13c) for testing short duration genotypes.

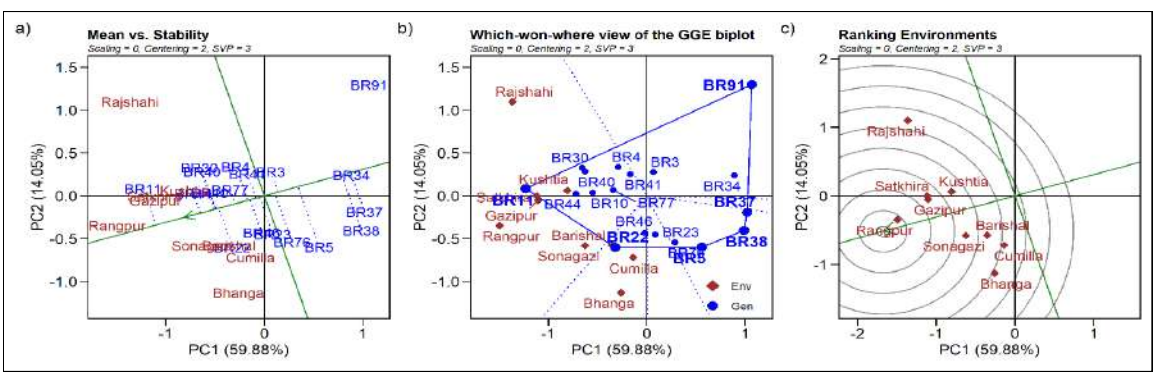


Fig. 11. GGE biplot of mean and stability (a), GGE biplot identification of winning genotypes and their related mega-environments (b) and association among the test environments (c) of long duration rice genotypes for yield and specific genotype × environment interactions in T. Aman 2021.

Performance and stability of rice genotypes across tested environments

Within a single mega-environment, genotypes should be evaluated on both mean performance and stability across environments. Figures 11a, 12a and 13a show average-environment coordination (AEC) views of the GGE biplot for grain yield of long, medium, and short duration. Figure 14 shows the yield performances and summary of ideal genotypes and genotypes with stable and high mean yields in different categories (long, medium and short duration). BR11 recorded the highest average grain yield (4.99 t/ha) in long duration (Fig. 11a). BR10, BR22, BRRI dhan40, BRRI dhan44 had the above-average yields. Thus, the BR11 and BR10 were the most ideal genotype with the highest mean yield and stability among the tested genotypes. The genotype BRRI dhan94 and BRRI dhan93 were the most stable genotype with above-average yield (5.34 t/ha) and (5.17 t/ha) in medium duration (Fig. 12a). BRRI dhan49 (5.09 t/ha), BRRI dhan52 (5.02 t/ha) BRRI dhan79 (4.92 t/ha) and BRRI dhan51 (4.86 t/ha) displayed the above-average yields. Other stable genotypes with above-average yields were BRRI dhan49 and BRRI dhan79. BRRI hybrid dhan6 (5.37 t/ha) and BRRI dhan87 (5.31 t/ha) recorded the highest average grain yield as the most stable and ideal genotype in short duration (Fig. 13a). Also, BRRI dhan95 (5.04 t/ha), BRRI hybrid dhan4 (4.93 t/ha), BRRI dhan72 (4.89 t/ha), and BRRI dhan75 (4.85 t/ha) were the moderately stable genotypes and above average yielder (Fig. 14).

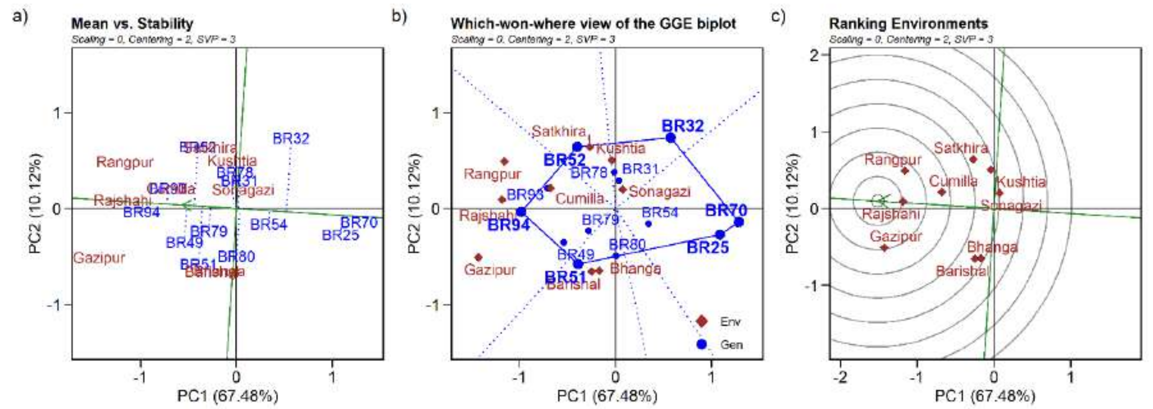


Fig. 12. GGE biplot of mean and stability (a), GGE biplot identification of winning genotypes and their related mega-environments (b) and association among the test environments (c) of medium duration rice genotypes for yield and specific genotype × environment interactions in T. Aman 2021.

Identification of which-won-where and mega-environment

One of the most attractive features of a GGE biplot is its ability to show the which-won-where pattern of a genotype by environment dataset. This plot consists of a polygon with perpendicular lines, called equality lines, drawn onto its sides. These lines divide the polygon into various sectors. Genotypes located on the vertices of the polygon are the best performers in one or more environments falling within a particular sector.

The biplot showed three sectors containing all the test environments in long duration and accordingly three mega-environments were identified (Fig. 11b). One mega-environment had four locations, Gazipur, Rangpur, Barishal and Sonagazi; the second consisting of three locations-Satkhira, Kushtia and Rajshahi; and the rest mega-environment contains Bhanga and Cumilla. Hence, the winning genotype in those environments was BR11 for first and second; BR22 closed to third mega environment (Fig. 11b). BRRI dhan91, BRRI dhan34, BRRI dhan37 and BRRI dhan38 were the low yielder of long duration genotypes.

In medium duration, the biplot grouped the test locations into four mega-environments (Fig. 12b). The first mega-environment had four locations, Cumilla, Rajshai, Rangpur and Gazipur. The second had two locations those were Kushtia and Satkhira. The third contained two locations Barishal and Bhanga. The fourth mega environment had only one location i.e., Sonagazi. BRRI dhan94 was the winning genotype in the first mega-environment while BRRI dhan52 was the winner in the second and BRRI dhan51 was the winner in the third and BRRI dhan32 in the last mega-environment.

The biplot was divided into three mega-environments in short duration (Fig. 13b). The first mega-environment had six locations-Bhanga, Cumilla, Gazipur, Kushtia, and Satkhira with BRRI dhan87, BRRI hybrid dhan4 and BRRI hybrid dhan6 being the winning genotypes. The second mega-environment had three locations-Barishal, Rajshahi and Rangpur BRRI dhan95 were the winner in this mega-environment. BRRI dhan90, BRRI dhan33, BRRI dhan57, BRRI dhan62 and were the low yielders of medium duration genotypes.

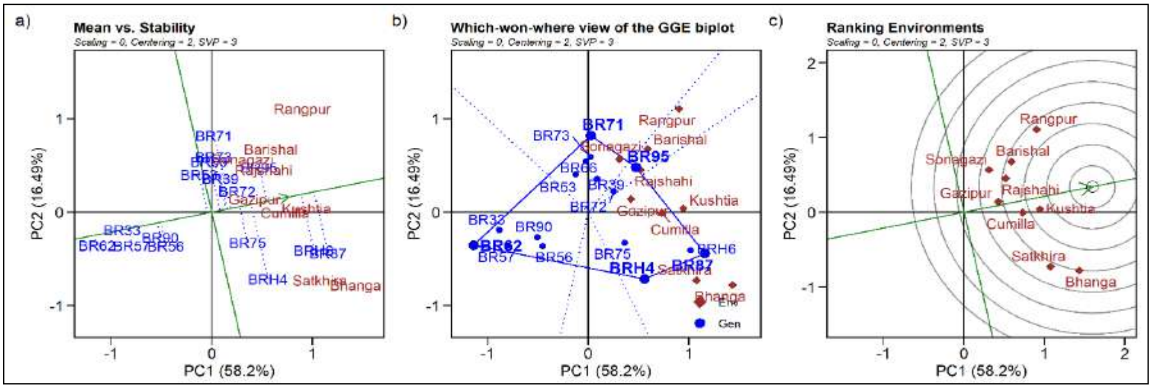


Fig. 13. GGE biplot of mean and stability (a), GGE biplot identification of winning genotypes and their related mega-environments (b) and association among the test environments (c) of short duration rice genotypes for yield and specific genotype × environment interactions in T. Aman 2021.

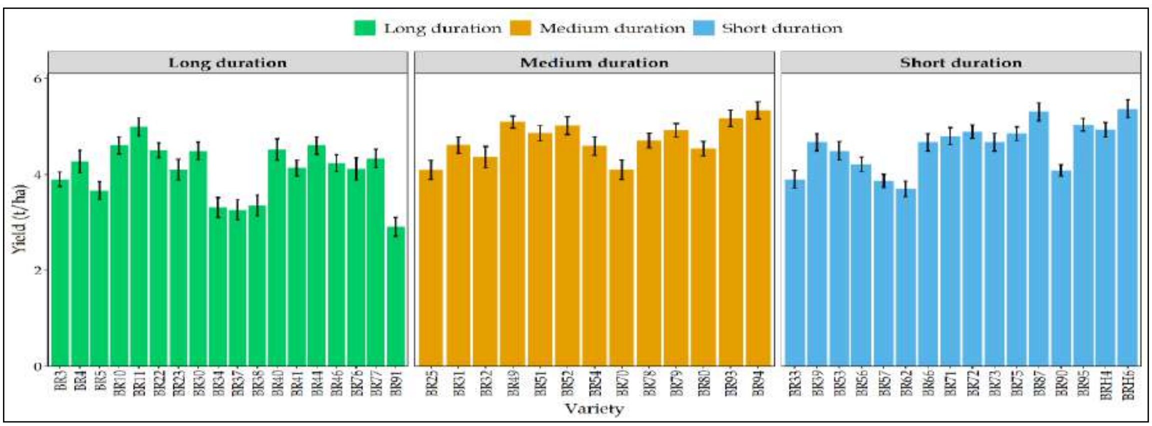


Fig. 14. Grain yield performance of BRRI released T. Aman rice varieties during 2021.

MAINTENANCE OF RICE AND RELATED DATABASE

Secondary data of rice and other important crops are collected periodically from Bangladesh Bureau of Statistics (BBS), Agricultural Marketing Directorate, Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB), Bangladesh Agricultural Development Corporation (BADC) and other sources and recorded accordingly. Databases are being updated regularly and uploaded at BRRI website.

MINIMIZING AGRO MICRO CLIMATOLOGICAL RISK FACTORS FOR MAXIMIZING SUSTAINABLE RICE PRODUCTION

The weather forecast and advisory service focused on food security and responsiveness to climate change in Bangladesh. Whereas, weather forecasts-based rice advisory system has potential for reducing poverty by increasing the rice yield, avoiding insect and disease outbreaks, efficient water management, labour and energy utilization, reduce losses and risks, reduce pollution with judicious use of agricultural chemicals through proper management in time and also provide guidelines for selection of the best-suited rice varieties according to the anticipated climatic conditions. This is how the system reduces the overall production costs and increases the farmers' income.

Considering this context, the objective of this study is to perform weather forecasts at weekly basis and validate forecast based rice crop management system through rice advisory generation in Boro season for sustainable rice production in Bangladesh. The seven-day basis weather forecast and rice advisory were generated in Boro season (Nov 2020 to May 2021) for BRRI HQ and eight regional stations of BRRI. A team comprising of multidisciplinary researchers (agronomist, plant pathologist, entomologist, soil scientist, plant physiologist, irrigation specialist, agricultural statistician, and agricultural economist) participated to generate location-specific weather forecast for six parameters, viz rainfall, relative humidity, wind speed, soil moisture, minimum and maximum temperature and prepared advisories using local language Bengali at different growth stages of Boro rice based on weather forecasts. Weather research and forecasting (WRF) model for forecasting, which is a next-generation mesoscale numerical weather prediction system designed to serve both atmospheric research and operational forecasting needs, were used for the weekly weather forecast (both English and Bangla). Tables 5 and 6 show how the weather forecast and advisory looks like as a sample.

Table 5. Weather forecast for BRRI HQ, Gazipur from 12 May 2022 to 18 May 2022

Agriculture weather element	12.03.2022	13.03.2022	14.03.2022	15.03.2022	16.03.2022	17.03.2022	18.03.2022
Total rainfall (mm)	0.0	0.0	0.0	0.0	0.0	0.04	0.06
Min. Tem. (^{0}C)	18.82	12.29	13.60	14.15	16.64	18.47	17.07
Max. Tem. (^{0}C)	33.38	33.91	35.11	36.17	36.84	34.28	33.72
Min. RH (%)	15.92	16.71	14.85	12.96	18.37	31.58	30.95
Max. RH (%)	38.97	64.86	58.45	56.02	76.22	100.0	98.91
Min. wind speed (m/s)	1.0	1.16	1.89	0.42	2.66	1.85	1.5
Max. wind speed (m/s)	3.86	3.85	3.60	3.39	3.80	3.4	2.83
Soil Moisture	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar Radiation	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 6. Weather forecast based rice advisories at BRRI HQ and different RSs in Boro.

Weather based Rice Advisories for coming 07 days

সম্ভাব্য বৃদ্ধির পর্যায়: কাইচ থোড়

কৃষিতাত্ত্বিক ব্যবস্থাপনা: এই সময়ে কোন সারের দরকার নাই। শামা ঘাস ও ফুস্কা ঘাস এই সময় ফুল বের হয়। শামা ঘাস ও ফুস্কা ঘাস থাকলে পরিস্কার করতে হবে।

সেচ ব্যবস্থাপনা: গাছের বৃদ্ধির এই পর্যায়ে পর্যাক্রমে ভিজানো ও শুকানো পদ্ধতিতে সেচ দেয়া যাবে না। ফুল ফোটার আগ পর্যন্ত এই সময় জমিতে ৫ সে.মি. দাঁড়ানো পানি রাখতে হবে। এইসময় পানির ঘাটতি হলে ধানের ফলন কমে যেতে পারে।

কীটপতঙ্গ ব্যবস্থাপনা: কাইচথোড় পর্যায়ে ধানে মাজরা, বাদামি গাছফড়িং, পাতা মোড়ানো পোকা, পামরী এবং ইঁদুরের আক্রমণ হতে পারে। জমিতে আলোক ফাঁদ (পামরি ব্যতিত) ব্যবহার করা, নিয়মিত জমি পর্যবেক্ষণ করা, ডালপালা পুঁতে দেওয়া, হাত জাল দিয়ে পোকা ধরা, ডিম ও কীড়া ধ্বংস করা, সর্বোচ্চ কুশি থেকে কাইচথোড় পর্যায়ে মাজরা এবং পাতা মোড়ানো পোকা নিয়ন্ত্রণের জন্য অনুমোদিত কীটনাশক যেমন কার্টাপ প্লাস, ভিরতাকো, ডায়াজিনন/কার্বোফুরান/মেলাথিয়ন/ডার্সবার্ন ইত্যাদি পরিমিত মাত্রায় ব্যবহার করা যেতে পারে। পামরী পোকার আক্রমণে শতকরা ৩৫ ভাগ পাতা ক্ষতিগ্রস্ত হলে মীশাল ২০ ইসি প্রতি লিটার পানিতে ১.৫ (দেড়) মিলিলিটার কীটনাশক মিশিয়ে জমিতে প্রয়োগ করুন। এ সময়ে জমির শতকরা ৫০ ভাগ গোছায় ২-৪ টি ডিম ওয়ালা স্ত্রী বাদামি গাছফড়িং বা ১০-১৫টি বাচ্চা পোকা বা উভয়ই দেখা গেলে এবামেক্টিন, সফসিন, মিপসিন ইত্যাদি কীটনাশক পরিমিত মাত্রায় স্প্রে-মেশিনের সাহায্যে গাছের গুড়ায় ব্যবহার করা যেতে পারে। ইঁদুরের গর্ত খুঁড়ে, বিভিন্ন ধরনের ফাঁদ ও বিষটোপ এবং বিভিন্ন ধরণের জৈবিক পদ্ধতির সহযোগিতায় ইঁদুর দমন করা যেতে পারে।

রোগবালাই ব্যবস্থাপনা: ধান গাছের এ পর্যায়ে এবং আবহাওয়ার বর্তমান এ অবস্থায় পাতাব্লাস্ট রোগ দেখা দিতে পারে। সেক্ষেত্রে রোগ দেখা দেওয়ার পর ট্রুপার ৮ গ্রাম ওষুধ ১০ লিটার পানিতে ভালভাবে মিশিয়ে ৫ শতাংশ জমিতে ৭ দিন ব্যবধানে পড়ন্ত বিকেলে দুই বার স্প্রে করতে হবে।

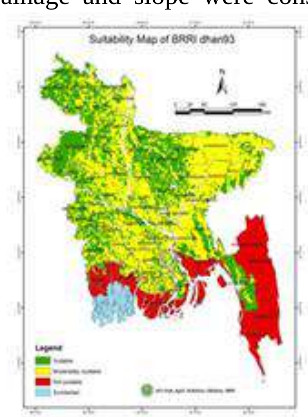
Suggestion: Contact nearby Upazilla Agricultural Officer for necessary help and suggestion.

SUITABILITY MAPPING OF BRRI RELEASED VARIETIES

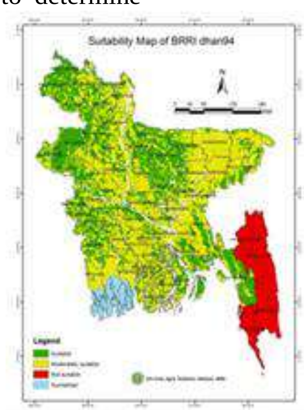
Our land is not homogenous all over Bangladesh. As we need to increase production with limited land, so it will be very helpful if we have variety-wise suitability map based on soil properties. BRRI dhan93 to BRRI dhan95 are very prospective varieties. So, the suitability maps of these varieties are very important. The objectives of the study were to construct edaphic suitability maps for newly released BRRI varieties and also find out variety-wise suitable areas for production.

Soil physical properties namely, land type, top soil texture, relief, soil consistency, soil moisture, soil permeability, soil reaction, soil salinity, drainage and slope were considered to determine areas suitable for growing respective rice varieties. The suitability scale 1 to 3 was assigned to each soil characteristic in relation to respective rice varieties cultivation: 1- for the suitable, 2- for moderate and 3- for not suitable. So, proactivity will increase if we cultivate rice varieties according to their suitable area.

In T. Aman season, BRRI dhan93 is suited in north and north-central regions of Bangladesh (Map 1). Whereas BRRI dhan94 is suitable for western, north-central and south-east regions, but not for its hilly regions (Map 2). BRRI dhan95 is appropriate for western, north-central and south-east regions of Bangladesh, but not for areas that are hilly or salty. Map 3 shows the suitability map of BRRI dhan95.



Map. 1. Suitability map of BRRI dhan93.



Map 2. Suitability map of BRRI dhan94.

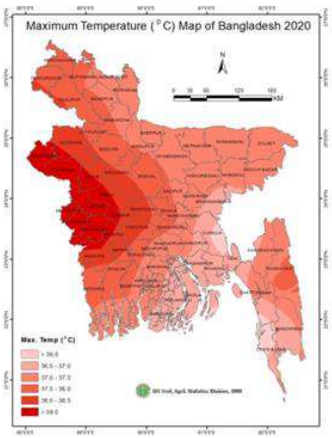
Map. 3. Suitability map of BRRI dhan95.

CLIMATE MAPPING OF TEMPERATURE AND RAINFALL OF BANGLADESH

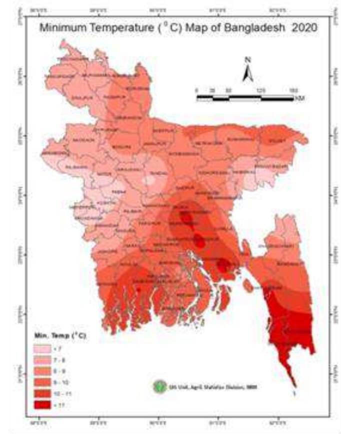
Data on daily maximum and minimum temperature and rainfall of 35 weather stations of BMD for 2020 were used for the study. Year and station-wise maximum value of maximum temperature and minimum value of minimum temperature and total rainfall were determined. Then by using geo-statistical tools of Arc GIS10.3 software maps were prepared. In the maps scenario of climatic factors were described.

In 2020, maximum temperature was high in central western part of Bangladesh and lower in south-eastern region. Map 4 shows the maximum temperature scenerio of Bangladesh for 2020. Minimum temperature was lower in central western and northern area and high in south eastern region. Map 5 shows the minimum temperature scenerio of Bangladesh for 2020. Total rainfall was the highest in north-east corner and south-east corner and lowest was central part of western area of Bangladesh. Map 6 shows the total rainfall scenriro of Bangladesh for 2020.

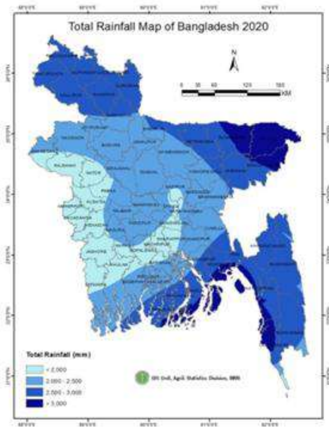
More or less throughout the year eastern side of Bangladesh is high rainfall and low temperature area and western side is low rainfall and high temperature area. Spatial distribution of minimum temperature and total rainfall are more or less same but maximum temperature is vice-versa to minimum temperature and total rainfall.



Map 4. Maximum temperature map of Bangladesh for 2020.



Map 5. Minimum temperature map of Bangladesh for 2020.



Map 6. Total rainfall map of Bangladesh for 2020.

ZONING OF BRRI RELEASED RICE VARIETIES

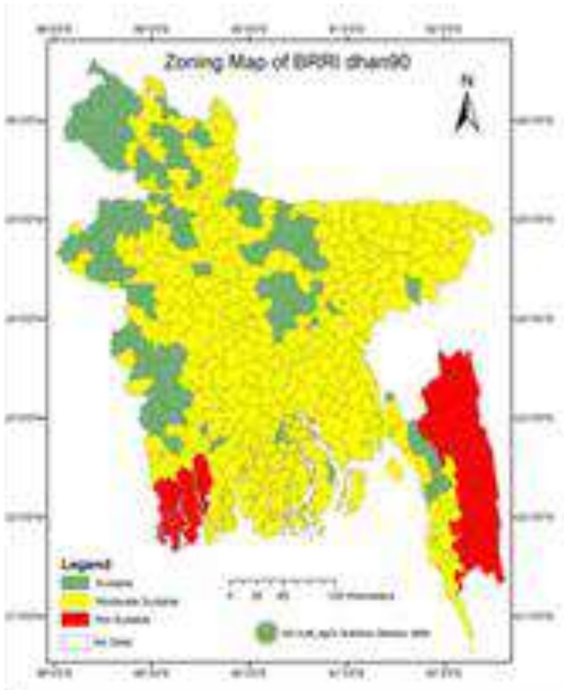
A major purpose of zoning is to put land to the use for which it is best suited. Some land is best left to be cultivated because of its unique soil characteristics. As every rice varieties has some unique characteristics, thus it has different suitable areas for cultivation. So, variety-wise rice zoning map is needed. BRRI dhan90 and BRRI dhan92 are very prospective varieties.

The whole process were carried out by two steps. Step 1: suitability mapping, step 2.: Zonal mapping. Step 1: Soil physical properties were considered to determine suitable area for growing particular rice varieties. The suitability scale 1-3 were assigned to each soil characteristic in relation to particular rice varieties cultivation. Input vector themes soil physical properties were converted into grid themes for analysis in the Model Builder environment using Arc GIS 10 Spatial Analyst Module. Then each input grid were weighted by the relative influence for suitability assessment. These weights were the values of "Percent Influence Field" in the weighted overlay table of the Model Builder. Then final suitability map were generated. To carry out step 2: upazila map were superimposed on suitability map and suitable area of each upazila was calculated by map algebra tool and finally the zonal map was produced.

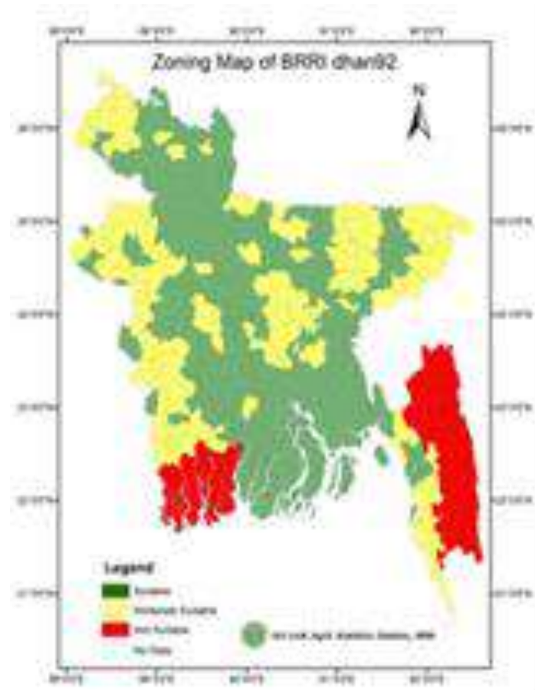
Mainly, western side and some central parts of northern areas are suitable for BRRI dhan90. Here total 464 upazilas are considered, among them 107 upazilas are found under suitable zone, 328 upazilas are found under moderate suitable zone and 28 upazilas are found under not suitable zone, and one upazila was found with no data. Map 7 shows the zoning map of BRRI dhan90.

BRRI dhan92 is suitable all over Bangladesh except western and eastern side of Bangladesh. In this context 464 upazilas were considered, among them 227 upazilas were found under suitable zone, 155 upazilas were found under moderate suitable zone, 31 upazilas were found under not suitable zone and one upazila was found with no data. Map 8 shows zoning map of BRRI dhan92.

In a nut shell, it can be said that the western side is suitable for cultivation of BRRI dhan90 and BRRI dhan92 is suitable all over the Bangladesh except western and eastern side of Bangladesh.



Map 7. Zoning map of BRRI dhan90



Map 8. Zoning map of BRRI dhan92

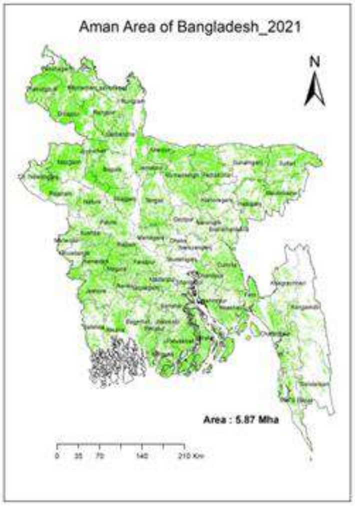
SEASON-WISE RICE AREA MAPPING OF BANGLADESH

Bangladesh is an agro-based country and rice is the main agricultural product. Rice contributes more than 80 percent to the total food supply. Now-a-days, remote sensing and GIS are considering as powerful tools for crop mapping, monitoring and yield forecasting. These tools are very much reliable, moreover, it is time, labour and cost effective. Identification of crop types and mapping are the first steps of satellite remote sensing-based crop monitoring and yield forecasting system.

Remote sensing and GIS are considering as powerful tools for crop mapping. Satellite images were collected from MODIS data portal of NASA. Time series and level three product images of Normalized Difference of Vegetation Index (NDVI), Effective Vegetation Index (EVI) and Land Surface Water Index (LSWI) were collected according to the respective rice growing season. Whenever rice crop is in initial stage i.e. transplanting time its vegetation index are very low and in peak vegetative stage i.e. PI or booting stage its vegetation index are very high and in ripening or harvest time its vegetation index become again low. This algorithm were applied in agriculture area of Bangladesh and threshold value developed by ground truth data collected through GPS reading of various rice field all over Bangladesh. Then season-wise rice maps (Maps 9 and 10) were prepared.

Then district-wise rice cultivated area were calculated.

The total area of rice grown in Aman 2021 was about 5.87 Mha. Total rice cultivation in the Boro 2021–22 season was estimated as 4.95 Mha.



Map 9. Aman cultivated area sketch of Bangladesh 2021.

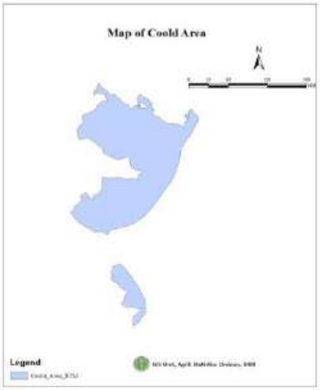
Map 10. Boro cultivated area sketch of Bangladesh 2021-22.

FAVOURABLE AND UNFAVOURABLE RICE CULTIVATION AREA MAPPING OF BANGLADESH

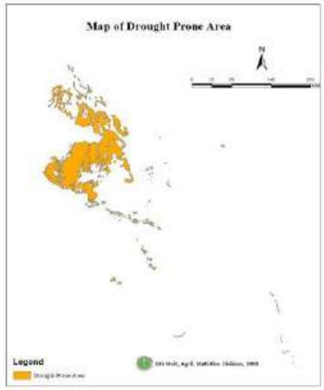
Bangladesh has diversified agro environment. Many areas are suffering from various abiotic stresses, for rice research policy an assessment of favourable and unfavourable environment is important. A GIS map can delineate rice growing environment conditions at a glance. Researchers and policy makers can get an idea at a glance about favourable and unfavourable areas for rice cultivation in Bangladesh which is helpful for decision taking.

Geo spatial data (Shapefile) drought, saline, ganges tidal floodplain, flood and char land were collected from Bangladesh Agricultural Research Council (BARC), Haor shapefile collected from CGIS and Cold shapefile is made by GIS unit of Bangladesh Rice Research Institute (BRRI). Spatial data are collected from BARC, Bangladesh country of Alumnus and various researches output from Agricultural Statistics Division, Irrigation and Water Management Division, Plant Physiology Division of BRRI. All stress prone area shapefile has been created in GIS platform. Also, stress prone area maps were prepared and finally district wise areas were calculated.

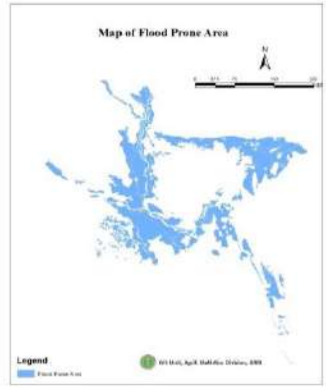
Map 11 shows the cold area of Bangladesh and total cold area found 2336706.75 ha, map 12 shows the drought area of Bangladesh and total drought area was found 10,62,338.46 ha, map 13 shows the flood prone area of Bangladesh and total flood area was found 31,40,094.13ha, map 14 shows the haor areas of Bangladesh and total haor areas were found 2,87,407.64 ha, map 15 shows the saline area of Bangladesh and total saline area was found 10,77,248.42 ha, map 16 shows the non-saline tidal area of Bangladesh and total non-saline tidal area was found 7,95,176.31 ha and map 17 shows the char land area of Bangladesh and total char land area were found 43,05,79.50 ha. Unfavourable area for cold is 23,36,706.75 ha, drought is 10,62,338.46 ha, for saline is 10,77,248.42 ha, Ganges tidal floodplain area is 7,95,176.31 ha, Haor is 2,87,407.64 ha, Flood prove area is 31,40,094.13 ha and Char land area is 4,30,579.50 ha. Among these abiotic stresses flood area shows maximum and char land shows minimum unfavourable area for rice.



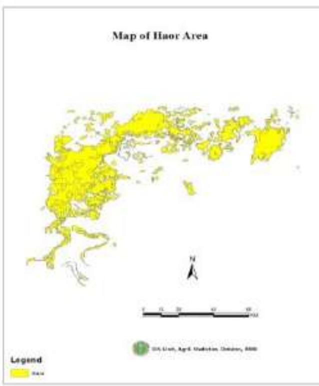
Map. 11. Cold area of Bangladesh.



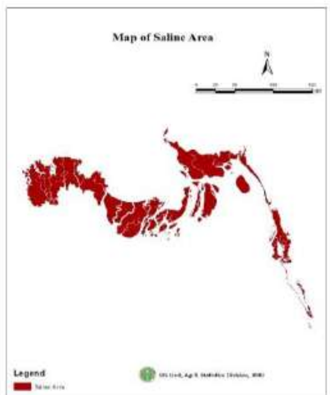
Map 12. Drought area of Banglades.



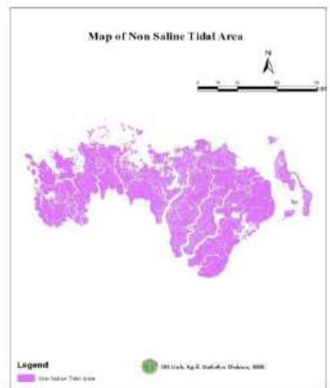
Map 13. Flood Area of Bangladesh.



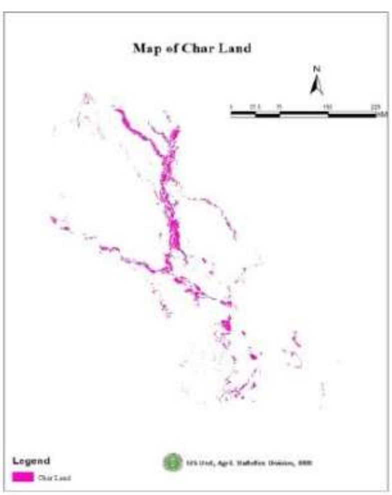
Map 14. Haor area of Bangladesh.



Map 15. Saline area of Bangladesh.



Map 16. Non saline tidal area of Bangladesh.



Map 17. Char land area of Bangladesh.

CAPACITY BUILDING THROUGH TRAINING

To set up the experiments, collecting, compiling, reporting, analyzing and presenting of the experimental data and increase the accuracy of the findings and developing skills on research, two types of training programmes were conducted in 2020-21. The topics were planning experiments, problem data, field experimentation, experimental design, factorial experiment, CRD, RCBD, LSD, SPD, Strip PD, SSPD, Strip SPD and augmented design in the training of 'Experimental Data Analysis'. Another topic was the 'Experimental field layout, data Collection and Data preparation' under this training programme.

A total of 68 participants were trained through the training programmes. Through the training on 'Experimental Data Analysis' eight participants were trained. The participants were CSO, PSO, SSO and SO of BRRI. The second training programme was 'Experimental Field Layout, Data Collection and Data Preparation'. A total of 60 participants including FA, AFM and SA were trained through this training

Develop A Computer Program Using R To Calculate the Stability Index for Brri Stability Model

In the variety development and release process stability analysis is one of the most important for the genotypes. Assuming this importance Agricultural Statistics Division of BRRI developed a Stability model that was a great achievement of the division. But the analytical procedure of finding the stability index of the genotypes was very laborious and time consuming. In this study, we want to develop a computer programme using R software. So that one can easily find out the stability index of genotypes within a minute. With this programme, user needs the updated version of the R software and the arrangement of the data in a specific format. At present, this programme is being used to calculate the stability index of BRRI varieties from the stability experiments for Aus, Aman and Boro season.

DIGITALIZED BUDGET MANAGEMENT SYSTEM OF BRRI

Finance and Accounts (F and A) Division of BRRI HQ has to manage the yearly budget of BRRI. For this, they collect budget from the ministry and distribute to the employees of BRRI according to the demand and preserve in a register book. After that they prepare budget related report from the register book manually but the procedure is quite difficult and time as well as labour consuming. In this circumstance, Agricultural Statistics Division developed "Digitalized Budget Management System" for BRRI. The web application was developed by using XAMPP, HTML, PHP, Javascript (JS) and JQuery. The system has already startd to used and the system is in live in the BRRI LAN (172.16.100.168/budget). The respected user can input the budget related information and can see all the report with printable format after login in the system. We have already prepared two reports by using this application.

Digitalized Quota Management System Of Brri

Employee recruitment is a contineuous process of an organisation. To recruite the new employee for the vacant post of the orgazisation, Administartion and Common Service Division contineously put their hard work for this management. Quota Management is one of the most important issue for new employee recruitment. Manually quota calculation is a very laborious and time-consuming work. In this circumstance, Agricultural Statistics Division developed "Digitalized Quota Management System" for BRRI. This is a web application and developed by using XAMPP, HTML, PHP, Javascript (JS) and JQuery. The system has already startd to used. Now the system is in live in the BRRI LAN (172.16.100.168/quota). The respected user can input the employee related information and can see all the report with printable format after login in the system.

Digitalized Salary Management System Of Brri

One of the most important work of Finance and Accounts (F and A) of BRRI HQ is to prepare the monthly salary of the employees. For this, they collect employee's salary related information and preserve in the salary register books. After that they prepare salary related report. Some of the reports have been prepared manually and some by using software. In this circumstance, Agricultural Statistics Division developed "Digitalized Salary Management System" for BRRI HQ employees. The web application developed by using XAMPP, HTML, PHP, Javascript (JS) and JQuery. Now the system is in live in the BRRI LAN (172.16.100.168/salary). The system included labour informations, attendance report, wages report and other reports with printable format. Many of the new features were included as the demand of the users.

DIGITALIZED LABOUR MANAGEMENT SYSTEM OF BRRI

Farm Management Division (FMD) of BRRI works for labour management to collect attendance information from all divisions and sections. After that FMD used to do the entry, updates, monitoring and reporting the information manually. So that, many of these existing practices and procedures took long time to prepare wages sheet per month. In this circumstance, Agricultural Statistics Division developed a updated version (LMSV1) of the digitalized labour management system (LMS) for BRRI HQ. The system is a web application and developed by using XAMPP, HTML, PHP, Javascript (JS) and JQuery. Now the system is in live in the BRRI LAN (172.16.101.17/lmsV1). The system included labour informations, attendance report, wages report and other reports with printable format. Labour attendence correction option was included as the demand of the users.

Digitalized Casual Leave Application System

Agricultural Statistics Division developed a web application of a casual leave (CL) using XAMPP, HTML, PHP, Javascript (JS) and JQuery. This is a very easy to access, accurate, consistent and most flexible casual leave (CL) application procedure with the usual system (hard copy application). Now, this system is ready to use only for the Agricultural Statistics Division and hosted in the BRRI LAN (172.16.100.168/cls). All kinds of reports related to casual leave can be generated by this web application whenever the authority needs.

INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) ACTIVITIES

Sensor-based rice pest management through artificial intelligence (AI) technology of BRRI

BRRI Rice Doctor mobile and web application has already been developed where BRRI released rice varieties, modern rice cultivation, insect & pest, disease and agricultural machinery technologies related information is included. But it is an interactive tool for farmers, extension workers, scientists/researches, teachers, students and other users when the hi-tech will be initiated. It has introduced hi-tech solution through artificial intelligence (AI) for controlling disease and insect by image analysis. The dynamic mobile and web application is automatically providing the required problem-solving solution of rice disease and pest related with proper management within minutes. So image data has been collected from at least three districts of different region (Gazipur Sadar, Rajshahi and Cumilla) for accurate result and it will be continuing. Already, 67% development of this programme has been completed (Fig.15).

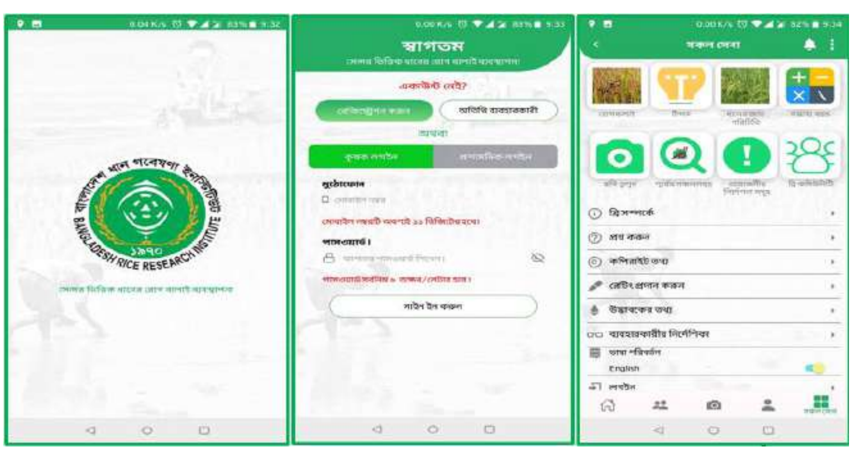


Fig. 15. Sensor-based rice pest management mobile app.

Development of new website for BRRI

A website is a collection of web pages and related content that is identified by a common domain name and published regulany by at least one web server. Hyperlinking between web pages guides the navigation of the site, which often starts with a home page. Some websites require user registration or subscription to access the content. Examples of subscription websites include many business sites, news websites, academic journal websites, gaming websites, file-sharing websites, message boards, web-based email, social networking websites, websites providing real-time data, as well as sites providing various other services. Bangladesh Rice Research Institute arranges national and international seminars and symposiums. Having a website makes it very easy for people to find information and also submit their papers, abstracts and posters for attaining national and international seminars and symposiums. Audiences can read up about BRRI, discover what BRRI does, and answers of a bunch of questions they have. By having a website people will be able to get information about BRRI when they search on a search engine like Google, Yahoo or Bing. The website has been used to get information and submit their papers, abstracts, posters and others. Development of the new website is going on (Fig.16).

Fig. 16. Coding of the website.

Strengthening cyber security system for BRRI

The cyber security system is the technique of protecting server, computer network, software, application, files, source code and database from unauthorized access, of the hacked or attacks. Virtual Private Network (VPN) provides a safe and encrypted connection over private and public networks that transports data securely. A virtual private network (VPN) protects data and identity over public networks by creating a private network from public internet connection. VPNs mask internet protocol (IP) addresses. So it is impossible to link it to online activity via IP detection. A VPN tunnel is an encrypted connection between the VPN client (local computer) and the server (VPN server). Since the connection is encrypted, nobody is able to intercept, monitor, or alter the communications.

Configuration of the Virtual Private Network (VPN), outer and inner tunnels are completed successfully. Configuration of remote connectivity is going on (Fig. 17).

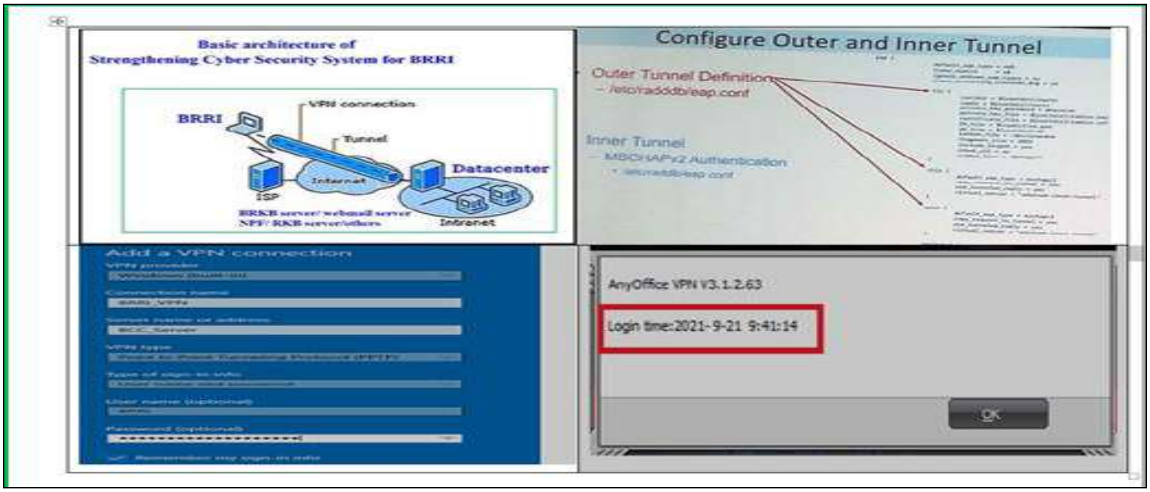


Fig. 17. Architecture of cyber security system and configuration of outer and inner tunnel.

BRRI Alapon Telephone Directory Mobile App

The BRRI Telephone Directory Mobile app named as *"BRRI Alapon"* has been developed according to the monthly progress review meeting of innovation team in September' 2020. This mobile app developed for BRRI officials to communicate with each other through this app like imo, Viber, Whatsup, WeChat etc. The app has features like chat, online calls, group messaging and location sharing. 'BRRI Alapon' is available in Apple's App Store (*iStore*) and Google play store for *Android* phone user. Anybody can call and exchange messages more securely using this app. App to app call, email and SMS is completely free for user. Database already has been developed for this app. All types of data have been collected from divisions, sections and regional stations of BRRI for developing the telephone directory mobile app.

Vehicle Requisition Management System of BRRI

Vehicle Requisition Management System (VRMS) is a transportation pool management activity of BRRI. It is a complex and tedious work for updating the allottee individually in time. The designated official of Transport Division is needed to work after office to manage the official vehicle requests and to convey the confirmation to the requesters and drivers over the phone. VRMS eases the allotment work using a simple requisition management system that doesn't require any advanced computing skills and the confirmation sent using SMS and email. So that, the requester informed through SMS on basis of demanding vehicle for official or personal purposees as well as driver get confirmation SMS for their upcoming duty. The database has already developed and architecture design has been finalized. The information of all vehicles of BRRI (driver's name, mobile number and vehicle reg. number etc.) has been collected from transport section.

Training on innovation, service process simplification (SPS) and e-Nothi management for enhancing capacity of BRRI employees

Innovation and Service Process Simplification (SPS) tool is essential to introduce the culture of innovative practices that would accelerate and simplify the BRRI research activities and service delivery process. Agricultural Ststistics Division has implemented all innovation activities and conducted various training on Public Service Innovation (PSI), Service Process Simplification (SPS), Simple implementation Project (SIP) and e-Nothi management as well as several annual innovation work plan of BRRI. Two day-long

‘Service Process Smplification (SPS)’ training has been completed on 28-29 May 2022 (Fig. 18) in spite of Covid-19 situation following social distance and health rules. In addition, ‘e-Nothi System’ in-house training has conducted from 31 May to 15 June 2021 for all division and sections of BRRI HQ.

Fig. 18. Innovation training programme at BRRI.

BRRI Rice Doctor mobile and web app

BRRI Rice Doctor mobile and web application has been developed for dissemination of is a rice varieties, modern rice cultivation practices, insect-pest and disease related dynamic diagnosis tools. It can also be useful for scientists, researchers, teachers, students and private input dealers. An English and Bengali version of Rice Doctor mobile app and web app has been developed to solve all the problems of rice cultivation. The apps also include a push notification and a Bangla text to speech option to facilitate users to view up-to-date information by sending text messages to specific problems. The 'Feedback' option has been added to provide the necessary advice to improve the quality of the app (Fig. 19).

Fig. 19. BRRI Rice Doctor mobile app.

Strengthening and dissemination of modern rice technology and its management information at the farmers’ door step through RKB Mobile App.

The mobile application of RKB (Rice Knowledge Bank) is a type of application software designed to run on a mobile device, such as a smart phone or tablet computer. RKB application has been developed with the information of BRRI released rice varieties, modern rice cultivation and agricultural machinery technologies, pest and disease management, soil and fertilizer management, irrigation and water management, quality rice seed production management, training and publications. It is available for android-based smart phone. So anybody can free download it from Google Play Store. Besides, this mobile app can be shared from other smart phones by 'SHAREit' software. RKB is being regularly updated with the latest rice-related information. For dissemination, we have trained 60 DAE officers in two batches. We have also developed a web page to get feedback from those DAE officers. All officers gave their feedback through the web page. We have participated in showcasing programme at Bangladesh Agricultural Research Council (BARC). Honourable senior secretary of cabinet division and honorable secretary of Agricultural ministry (MoA) were present in the programme (Fig. 20). A total of 17,543 users have already downloaded information from the play store.

Fig. 20. Training programme and shocasing programme on RKB mobile App.

BRKB website management

Bangladesh Rice Knowledge Bank (BRKB) is a hub of rice knowledge. This is a dynamic source of knowledge which is updated regularly to keep consistency with the latest innovations and users' feedback. BRKB Website has been managed, maintained and modified in collaboration with training, breeding and others research divisions. BRKB is updated regularly with the latest information. In this reporting year, we have developed 20 web and mobile based fact sheets. And all the fact sheets have been uploaded into BRKB website.

Dynamic view connectivity system and Bangla searching system for BRKB Website

We have developed Dynamic view connectivity and Bangla searching system for BRKB website. Dynamic view connectivity works dynamically between BRKB website and Facebook page. Bangla searching system has the ability to search both in Bengali and English languages. It searches and automatically characterizes Bangla and English content of BRKB website. About 900 research-related posts have been published in the dynamic view connectivity system and 10,432 users have got the service.

Web mail and group mail

We have created individual e-mail accounts in BRRI domain for all scientists and class-one officers as per requirement of MoA. We have updated the BRRI mail server from 8.8.15_GA_3928 FOSS version to 8.8.15_GA_4018 FOSS Mar 24, 2021 version (Fig. 21). Now, our mail server is more secure than the previous one. We provided 121 webmail related solutions in this reporting year. BRRI Web mail and Group mail have been hosted on BCC (Bangladesh Computer Council) server.

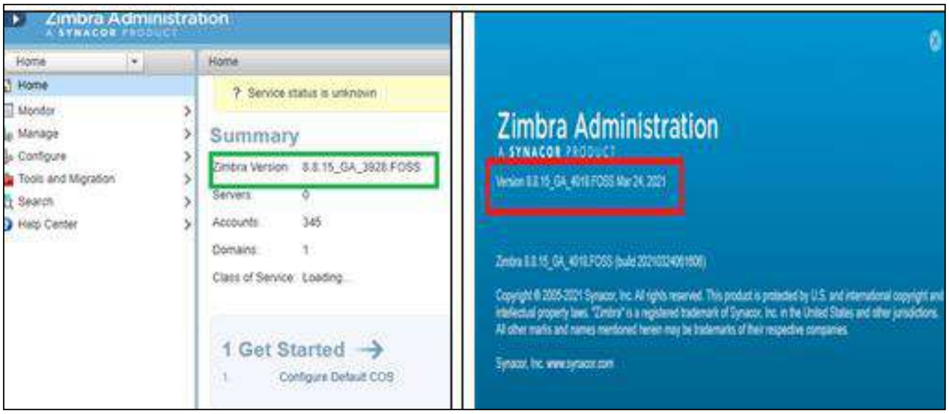


Fig. 21. Previous version and new version of the BRRI mail serkes.

Developing secure system for BRRI Web Mail and Group Mail

We incorporated the Secure Sockets Layer (SSL) in the BRRI web mail. Spamming filtering system (SFS) scans all users of BRRI web mail every other hour and find out the user who occurs spamming. When a web mail user creates some or heavy spamming, the automatic active and close system (AACS) automatically detects the user and also blocks the user. As a result, the whole system (BRRI web mail) is safe from the block of Gmail, Yahoo webmail or other e-mail servers. We have developed automatic active and close system (AACS) and also incorporated it in BRRI web mail. As a resulg our web mail is more secure. About 84 webmail users have created heavy spamming, AACS has detected those users and also blocked them so, the whole system has been saved from the block of Gmail, yahoo, webmail or other e-mail servers. SFS has scanned about 84 webmail accounts and solved all problems.

Online application system of BRRI

BRRI has started online application system for the first time since 23 May to 12 June 2019. It has already completed another online application process from 4 March to 24 March 2020. Applicants complete their application through this system and receive admit card, notification of written test date, result and all kinds of information through this online system and SMS based application. This system is developed by Teletalk Bangladesh Limited.

e-Nothi management system of BRRI

At present, hundred percent e-Nothi systems are being used in all divisions and sections of BRRI as well as regional stations. The in-house training on 'e-Nothi System' has been conducted for all divisions and sections as well as e-Nothi users of BRRI HQ from 31 May to 15 June 2021 for developing their skill. BRRI has issued 9,348 letters to Ministry of Agriculture (MoA) and different organizations as well as completed 26,135 notes from July 2021 to June 2022.

Management of BRRI local area network and internet connectivity

ICT network and internet connectivity of BRRI is managed and maintained by ICT Cell, Agricultural Statistics Division with the help of the Network developer company. We have increased our digital data network (DDN) bandwidth connectivity from 157 Mbps to 177 Mbps. We established new and high configured Router where internet speed capacity increased to 1000 Mbps; the internet speed capacity was 25 Mbps for previous device. We also established Local Area Network (LAN) connectivity at five regional stations i.e. Rangpur, Barishal, Sonagazi, Cumilla and Habiganj.

BRRI web portal management

BRRI web portal (*www.portal.gov.bd*) is developed, managed and updated by ICT Cell of Agricultural Statistics Division. BRRI web portal/website is being uploaded regularly by latest information. BRRI web portal is in Bangla and English languages. In this reporting year, we updated about 1,175 pages and uploaded about 6,280 documents like PDF, JPG, report, word and other files on the BRRI website. We sent twelve monthly website reports to the ministry of agriculture (MoA) on a regqular gasis.

BRRI networks update, maintenance and extension

BRRI Networks Facebook group is a big forum for all the scientists, officers and staffs of BRRI. ICT Cell created this Facebook group to post research related work for information sharing on noble work of rice and related activities, various problems and their solutions, official interactions in this forum. The Facebook group of "*BRRI Network"* link is https://www.facebook.com/groups/1409267722690061/. Thus, the *BRRI Network* is continuing with regular updating posted by everybody of this group. At present, more than 4,000 individuals have joined this group. It is increasing gradually. It has stored at least 700 and more photos of all national programme and research activities of BRRI HQ and all regional stations. It has also uploaded around 225 necessary pdf and word file document for all members.

Personal data sheet database

We have created Personal data sheet **(**PDS) database for all scientists, officers, clerks as per requirement of the Ministry of Agriculture (MoA). It has been increased up to 339 users in the BRRI PDS database. PDS database is updated regularly with the latest information. It is a routine work.

Video conference system

We have established video conferencing system (VCS) at BRRI to communicate with MoA and other government organizations. We have also, established Distance Communication Center (DCC) at BRRI with the help of Bangladesh Research and Education Network (BDREN) funded by University Grant Commission (UGC), which is similar to VCS. Besides, we have created Skype account for all divisional head and regional stations head. The communication between BRRI headquarter and other regional stations are being conducted by Video Conference System in every monthly co-ordination meeting. Monthly co-ordination Meeting, Sunday seminar, In-house training and workshops are being conducted by video conference system. Also, maximum meetings are being conducted by video conference system using Zoom Platform System (Fig. 22).

Fig. 22. Video conference system in action.

New version of Management Information System (MIS) of BRRI

A management information system (MIS) is a computerized database of information organized and programmed in such a way that it produces regular reports on operations for every level of management in an organization. It is usually possible to obtain special reports from the system easily. The MIS software of BRRI has nine modules (HRMIS, FMIS, PMIS, RMIS, LMIS, VMIS, TMIS, IMIS, Data Bank). The MIS Software will be developed under NATP-2 using PHP, JAVA, HTML, CSS, JAVASCRIPT and data will be managed by ORACLE.

Rice Pest Corner

We have developed "Rice Pest Corner" with information on insect and pest management and disease management. Rice Pest Corner has been developed for farmers, extension personnel, scientists, researchers, teachers, students and other users who want to learn and control insects and diseases and other problems that can occur in rice cultivation.

Heritage of BRRI

Heritage refers to something inherited from the past. So, ICT cell of Agricultural Statistics Division creates a menu titled as Heritage (*http://www.brri.gov.bd/site/page/cdf8a394-1652-4607-a1d1-b87de15b20f8*). It has created individual pages like former DG and Directors, CSO, PSO, SSO, Officers and Staff's etc. It has included almost all former scientists' personnel photo, short description as well as a link where anybody can find about their detail information. Thus, it has made the *Heritage*. Because "Heritage" in the broadest sense is that which is inherited. ICT cell of Agricultural Statistics Division provides ICT related support services to other divisions such as, updating data and uploading information to BRRI.

ICT AND RELATED FAIR

ICT Cell of Agricultural Statistics Division has been participated in several ICT and related fairs such as Digital World Fair, Development Fair, Tatha Mela and World Food Fair etc.

SUPPORT SERVICES

The scientists of this division are also engaged in helping scientists of other disciplines in planning experiments, statistical data analysis and interpretation of results. Sixty different types of analyses were performed during the reporting period. A number of maps were prepared using GIS and supplied to the scientists of other divisions whenever required.

Overall, ICT cell of Agricultural Statistics Division has taken initiative in accordance with government perspectives but BRRI Networks facebook group is first introduced among all National Agricultural Research System (NARS) and also first among all research institutes. The ICT cell of Agricultural Statistics Division provides e-Nothi management system, e-Tender and other internet related support services to other divisions and sections.

Farm Management Division

SUMMARY

Different kinds of research and development as well as management activities conducted by Farm Management Division can be discussed under three broad headings namely research, seed production and support services. Summary of these activities are described as follows-

An experiment was conducted at BRRI farm, Gazipur during T. Aman and Boro 2021-22 to find out the suitable management practice for yield maximization of rice and soil health. Seven treatments in RCB design with three replications were imposed and each treatment was assigned in 5m × 4m sized plot. Grain yield, tiller number, panicle number, plant height and grain number were significantly affected by the different Integrated nutrient management during both T. Aman and Boro seasons. This study indicates STB dose with one t ha^{-1}, poultry manure is better for rice yield. Further research may be needed to find out the suitable integrated fertilizer management.

An experiment was conducted at BRRI HQ farm, Gazipur during T. Aman and Boro, 2021-22 seasons to evaluate the efficacy of newly developed BRRI mechanical rice transplanter cum fertilizer applicator. No significant differences among the treatmets was found in growth parameters. Significant variations were recorded in case of yield. BRRI recommended practice and mechanical transplanting with 80% urea with other fertilizers produced very similar grain yield which was higher than the other treatments. From the results, it might be said that mechanical transplanting with 80% urea fertilizer can be recommended with BRRI recommended hand transplanting practice. Urea saving is additional benefit with low transplanting cost when transplanted with rice transplanter and fertilizer applicator.

An experiment was done at west byde of BRRI to investigate the effect of foliar application of silicon's aqueous solution on yield of aromatic rice. Silicon solution concentration of 0.0, 0.5, 1.0 and 1.5 percent was used as the mainplot treatment where time of spray (15 DAT and 30-35 DAT) were the subplot treatments. No significant differences were found among the treatments in all the variables in both T. Aman and Boro seasons. Therefore, we can say that silicon application might not have so significant effect on growth and yield of rice in Bangladesh situation.

A survey was conducted throughout the year to find out the labourers' wage rate at different locations around BRRI HQ and BRRI regional stations. The lowest wage rate was found in Habiganj, Satkhira, Sirajganj and Sonagazi areas (450-500 Tk per day). The highest wage rate was observed in Cumilla (800-850 Tk per day). Working hour was also different based on the location.

Performance of different BRRI released rice varieties were observed in seed production plots during 2021-22. Yield of the varieties ranged from 3.69 t ha^{-1} to 7.46 t ha^{-1} and 4.86 t ha^{-1} to 7.72 t ha^{-1} in T. Aman and Boro varieties, respectively. Among T. Aman varieties, BRRI dhan49 (7.46 t ha^{-1}) yielded the highest where as BRRI dhan89 (7.72 t ha^{-1}) yielded the highest among Boro varieties.

Farm Management Division produced about 13,837 kg TLS of which 1,837 kg, 5,083 kg and 6,917 kg was produced in Aus, Aman and Boro seasons, respectively. In addition, 150 kg non-seed and 4,005 kg mixed rice were produced during the reporting period.

A total of 7,855 kg breeder seed was produced under the supervision of FMD during T. Aman and Boro season of 2021-22. In total 2,718 kg breeder seed of three T. Aman varieties (BRRI dhan30, BRRI dhan49 and BRRI dhan98) and 5,137 kg breeder seed of two Boro rice varieties (BRRI dhan92 and Bangabandhu dhan100) was produced.

A total of 10,650 kg seed was distributed by FMD during the reporting period. In total 350, 1,150 and 9,150 kg seeds were distributed during Aus, T. Aman and Boro seasons, respectively. These seeds were distributed to DAE, researchers, different research divisions and regional stations of BRRI, seed producers, different agricultural organizations and agencies as well as farmers.

Including regional stations, BRRI had 717 labourers of which 497 regular and 220 irregular at the start of the reporting time (1 July, 2021). At the end of the reporting period (30 June 2022) the number of labourers reduced to 705 of which 487

were regular and 218 were irregular. The reduction of labourers were due to death, retirement.

Total labour utilization in different divisions was 1,91,869 man days of which 52.39%, 44.79% and 2.81% were utilized for research, support service and holidays, respectively in BRRI, HQ.

It was observed that total labour wages were Tk 11,19,61,815 of which Tk 5,85,67,775, Tk 5,01,53,440 and Tk 32,40,600 were paid to the labourers for research work, support service works, leaves and holidays, respectively.

A total of 82.44 ha of land were utilized by different research divisions in different season in BRRI HQ of which 6.17 ha in Aus, 37.46 ha in T. Aman and 38.81 ha in Boro season.

This division manages the BRRI flower garden to maintain the aesthetic view of the office campus, arrange beautification of BRRI premises and playground during different observation of national or international and organizational events, execute tree plantation and management of different fruit trees and other trees in BRRI. This division effectively carried out mosquito control activities, graveyard management activities, playground management, and help in other support service and management activities of BRRI.

DETAILED ACTIVITIES

The Farm Management Division (FMD) was established at the inception of BRRI in 1970. This division is one of the components of the Socio-economics and Policy Program Area of BRRI and carries out research as well as management and support services for the institute, such as, HYV rice seed production (breeder seed and truthfully labelled seed), fixing of labour wages, weed management methods and economics, water management (irrigation and drainage), maintenance of the BRRI office premises and field management, garden management and beautification of BRRI office areas, graveyard management, land and labour management for smooth conduct of field research at BRRI etc.

RICE PRODUCTION MANAGEMENT

Yield maximization of rice through integrated nutrient management

Md Mamunur Rashid CI: M R Manir, S Begum, M S Islam and M R Islam

This experiment was initiated on a permanent layout at the west byde of BRRI HQ farm, Gazipur during T. Aman 2021 to Boro 2021-22 to find out the suitable management practice for yield maximization of rice and soil health. Seven treatments in randomized complete block (RCB) design with three replications were imposed and each treatment was assigned in 5 m × 4 m sized plot. The treatment combinations were T_1 = Absolute Control (No nutrient supply), T_2 = BRRI dose N-P-K-S@83-17-53-12 kg ha^{-1} in T. Aman and 138-21-75-21 kg ha^{-1} in Boro season, T_3 = Soil test based (STB) Fertilizer Dose N-P-K-S @ 67-10-40-10 kg ha^{-1} in T. Aman and 134-16-75-10 kg ha^{-1} in Boro, T_4 = STB dose + 1 t ha^{-1} Cowdung, T_5 = STB dose + 1 t ha^{-1} poultry manure, T_6 = STB dose + 1 t ha^{-1} vermicompost and T_7 = STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC**.** Thirty-day-old seedling of BRRI dhan87 in T. Aman and 42-day-old seedling of BRRI dhan89 in Boro season were transplanted at 20 cm × 20 cm spacing in both seasons. All manures, soil and plant samples analysis were done by the help of Soil Science Division BRRI, Gazipur. Initial soil (0-15 cm depth) properties were: soil texture, clay loam; pH, 6.94; organic Carbon, 1.59%; Nitrogen, 0.18%; Phosphorus, 21.88 ppm and Potassium, 0.19meq/100g soil. Thirty-day-old seedling of BRRI dhan87 in T. Aman and 42-day-old seedling of BRRI dhan89 in Boro season were transplanted at 20 cm x 20 cm spacing. The flooded water level at 5-7 cm depth was maintained during rice cultivation, and drained out the water 21 days before rice harvesting. Yield and yield components were collected at harvesting time. Collected data were statistically analyzed using a standard statistical procedure (Crop stat 7.2).

Grain yield, tiller number, panicle number, plant height and grain number were significantly affected by the different nutrient management in both T. Aman and Boro season. Poultry manure related treatments and BRRI recommended dose performed better than the others in all the parameters except 1000-grain weight. On the other hand, absolute control (No nutrient supply) produced the lowest result. The details have discussed below.

Yield and yield Components in T. Aman

Plant height. In T. Aman season (BRRI dhan87), different nutrient management practices have significant effects in rice plant height. The tallest rice plant (125.69 cm) was found in the STB dose with 1 t ha^{-1} poultry manure, which is statistically similar with other nutrient management doses except absolute control. The smallest rice plant (121.27 cm) was found in the absolute control plot (Table 1).

Tiller number. Tiller production varies significantly among the different nutrient management practices in T. Aman season. STB dose + 1 t ha^{-1} poultry manure plot produced the highest tiller number. STB dose + 1 t ha^{-1} poultry manure produced the highest number of tillers m^{-2} (286) and the second highest STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC (273 tiller m^{-2}) whereas control plot produced the lowest number of tillers m^{-2} (207) among all the treatments. But BRRI recommended dose, STB dose + 1 t ha^{-1} VC used plot produced similar tillers m^{-2} (Table 1).

Panicle number. All the nutrient management during T. Aman season significantly affected in panicle production. Here, STB dose +1 t ha^{-1} poultry manure plot produced the highest panicles number. The highest number of panicles m^{-2} (271) found in STB dose + 1 t ha^{-1} poultry manure used plot. The lowest number of panicles m^{-2} (188) among all the treatments was observed in absolute control plot (Table 1).

Grain number and grain weight. In T. Aman season, the all nutrient management plots except the absolute control plot produced almost similar number of grains per panicle. STB dose + 1 t ha^{-1} poultry litter and STB dose + 1 t ha^{-1} vermicompost plot provided the highest number of grains per $panicle^{-1}$ (102) whereas control plot produced the lowest number of grains per $panicle^{-1}$ (95). In addition, there was no significant difference among the treatments in case of grain weight (Table 1).

Grain yield. During T. Aman 2021, grain yield was significantly affected by different nutrient management practices. STB dose + 1 t ha^{-1} poultry manure (5.81 t ha^{-1}) and BRRI recommended dose (5.59 t ha^{-1}) produced the highest and statistically similar grain yield followed by STB dose + 1 t ha^{-1} CD (5.42 t ha^{-1}), STB dose + 1 t ha^{-1} VC (5.39 t ha^{-1}), STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC (5.34 t ha^{-1}), and STB dose (5.20 t ha^{-1}). The lowest yield was observed in absolute control plot (3.23 t ha^{-1}) (Table 1).

Yield and yield components in Boro

Plant height. During Boro season STB dose, BRRI recommended dose, STB dose + 1 t ha^{-1} poultry manure, STB dose + 1 t ha^{-1} cowdung, STB dose + 1 t ha^{-1} vermicompost and STB dose + 0.33 1 t ha^{-1} CD + 0.33 1 t ha^{-1} PM + 0.33 1 t ha^{-1} VC used plot produced almost similar plant height which was statistically significant from control plot. STB dose with 1 t ha^{-1} poultry manure provided the tallest plant (103.82 cm) whereas control plot produced the smallest plant (94.37 cm) (Table 1).

Tiller number. Tiller production varies significantly among the different nutrient management in Boro season. STB dose + 1 t ha^{-1} poultry manure plot produced statistically the highest number of tillers followed by the other treatments. STB dose + 1 t ha^{-1} poultry manure produced the highest number of tillers m^{-2} (275) whereas control plot provided the lowest number of tiller m^{-2} (202) among all the treatments (Table 1).

Panicle number. Panicle production was significantly affected by all the nutrient management practices during Boro season 2021-22. Here, STB dose +1 t ha^{-1} poultry manure used plot produced statistically the highest panicle number. The highest number of panicles m^{-2} (250) was found in the STB dose + 1 t ha^{-1} poultry manure plot followed by 247 panicle m^{-2} in STB dose + 1 t ha^{-1} CD, 246 panicles m^{-2} in BRRI recommended dose and 246 panicle m^{-2} in STB dose + 1 t ha^{-1} VC used plot. Among all the treatments, the lowest number of panicles m^{-2} (182) was observed in control plot (Table 1).

Grain number and grain weight. In Boro season, STB dose + 1 t ha^{-1} poultry manure, BRRI dose, STB dose + 1t ha^{-1} cowdung STB dose + 1 t ha^{-1} VC, STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC and STB dose used plot provided almost similar number of grains per panicle which was statistically significant from control plot. STB dose + 1 t ha^{-1} poultry manure provided the highest number of grains per panicle (139.77) whereas the control plot produced the lowest number of grain (108.02). On the other hand, there was no significant difference among the treatments in case of grain weight (Table 1).

Grain yield. In Boro season, grain yield was significantly affected by different nutrient management practices. STB dose + 1 t ha^{-1} poultry manured plots produced the highest grain yield (7.02 t ha^{-1}). The lowest yield was observed in control plot (4.16 t ha^{-1}) (Table 1).

Grain yield, tiller number, panicle number, plant height and grain number were significantly affected by the different Integrated nutrient management during both T. Aman and Boro seasons In every parameter, poultry manure treatments performed the best. This study indicates STB dose with one t ha^{-1}, poultry manure is better for maximization of rice yield. Further research may be needed to find out the suitable integrated fertilizer management to maximize rice yield.

Efficacy of mechanical seedling transplanter and deep placement of mixed fertilizer on rice yield

PI: Setara Begum; **CI:** M M Rahman, M S Islam and M A Hossen (FMPHT)

The objectives of the study were to evaluate the efficacy of newly developed mechanical rice transplanter cum fertilizer applicator and to observe the yield and yield contributing parameters.

This experiment was conducted at the West Byde of BRRI HQ farm, Gazipur during T. Aman and Boro 2021-22 seasons to evaluate the efficacy of newly developed BRRI mechanical rice transplanter cum fertilizer applicator. Urea fertilizer along with TSP, MoP and Gypsum fertilizer can be placed and covered in 6-8 cm soil depth during mechanical transplanting using the developed rice transplanter. Randomized Complete Block (RCB) design was followed with three replications. Individual plot size was 8m × 5m along with 30 cm buffer spacing. Treatments of the studies were T_1 = Mechanical transplanting along with 100% fertilizer (Urea, TSP, MoP and gypsum) deep placement, T_2 = Mechanical transplanting along with 80% fertilizer (80% urea and 100% TSP, MoP and gypsum) deep placement, T_3 = Mechanical transplanting along with 70% fertilizer (70% urea and 100% TSM, MoP and gypsum) deep placement, T_4 = Mechanical transplanting along with 100% fertilizer hand broadcasting (TSP, MoP and Gypsum fertilizer as basal dose and urea fertilizer in three splits) and T_5 = Hand transplanting of same seedling of rice transplanter along with 100% fertilizer hand broadcasting (TPS, MoP and Gypsum in basal dose and urea fertilizer in three splits) and T_6 = BRRI recommended practice. In this experiment, BRRI dhan87 and BRRI dhan92 were used in T. Aman and Boro season, respectively. Twenty-day-old mat type seedlings were used in mechanical transplanting at 30 cm × 15 cm spacing whereas spacing of manual transplanting was 20 cm × 20 cm. All the intercultural operations were done according to BRRI recommendation those were same for all treatments. Yield and yield components data were taken at harvesting time. Growth data (plant height and tiller) were collected and statistically analyzed using standard statistical procedure.

Growth and yield contributing parameters such as tiller number, panicle number, filled grain, unfilled grain, and 1000 grain weight were not significantly affected by mechanical transplanting along with fertilizer deep placement and hand transplanting along with hand broadcasting of fertilizer. Mechanical transplanting with 80% urea fertilizer along with 100% TSP, MoP, and Gypsum fertilizer deep placement produed the highest yield in T. Aman season where as this treatment gave same yield compared to BRRI recommended practice during Boro season.

Plant height. Plant height was not significantly affected by mechanical seedling transplanting and deep placement of fertilizer in both T. Aman and Boro seasons (Table 2). Plant height of BRRI recommended practice plot were found taller due to higher seedling age (15 days older than mechanically transplanted seedlings) which was finally similar compared to the maturity stage (Fig. 1).

Tiller production. There were significant variations recorded in tiller production at different days after transplanting among the mechanical transplanting along with deep placement of fertilizer application and hand transplanting along with hand broadcasting of fertilizer during both T. Aman and Boro seasons (Fig. 2).

Panicle number. Number of panicle m^{-2} was not varied significantly with the mechanical transplanting along with deep placement of fertilizers and hand transplanting along with hand broadcasting of fertilizer (Table 2).

Filled grain per panicle and TGW. There were no significant differences among the treatments in case of number of filled grain $panicle^{-1}$ and 1000 grain weight (TGW). All the treatments produced statistically similar number filled grain $panicle^{-1}$ and TGW (Table 2).

Grain yield. Among different variables, only grain yield were significantly varied among the treatments (Table 2). In T. Aman season, T_2 (Mechanical transplanting along with 80% fertilizer deep placement) produced the highest grain yield (4.66 t ha^{-1}) followed by T_4, T_3 and T_1 (4.48, 4.38 and 3.31 t ha^{-1}, respectively). However, grain yield of treatment T_1 and statistically lower yield compared to the others. This might be due to the severe attack of criseck just after transplanting. Due to high amount of urea application at the transplanting time in treatment T_1 fostered the severity of creseck and ultimately yield was hampared.

On the other hand, during Boro season T_6 (BRRI recommended practice), T_2 (mechanical transplanting with 80% urea) and T_1 (mechanical transplanting with 100% urea) produced similar grain yield which was higher than the other treatments (Table 2).

It may be concluded that no significant differences among the treatmets were found in growth parameters. Significant variations were recorded in case of yield and BRRI recommended practice and mechanical transplanting with 80% urea with other fertilizers produced very similar grain yield. From these results, it might be said that mechanical transplanting with 80% urea fertilizer can be recommended with BRRI recommended hand transplanting practice. Urea saving provides additional benefit with low transplanting cost when transplanted with rice transplanter and fertilizer applicator.

Effect of foliar application of silicon on yield of aromatic rice

PI: Setara Begum; **CI:** MM Rahman, M S Islam, M M Rashid and MR Manir

The study was conducted to investigate the effect of foliar application of silicon's aqueous solution (sodium silicate) on yield of aromatic rice and to observe the disease and insect infestation.

This experiment was conducted at the West Byde of BRRI HQ farm, Gazipur during the T. Aman and Boro 2021-22 seasons to investigate the effect of foliar application of different concentrations of silicon solution on the yield of rice. BRRI dhan70 and BRRI dhan50 were used in T. Aman and Boro seasons, respectively. Transplanting were done maintaining spacing of 15 cm × 15 cm and 20 cm × 20 cm during T. Aman and Boro seasons, respectively. All intercultural operations were done according to BRRI recommendation and were same for all the treatments. Silicon was sprayed maintaining four concentration (0.0, 0.5, 1.0, 1.5 %) in two different times (20 DAT and 35 DAT). The experiment was done following split-plot design allotting silicon concentration in the sub-plot treatment and time of spray in the main plot treatment. Yield and yield components data were taken at harvesting time. Growth data (plant height and tiller) were collected and statistically analyzed using standard statistical procedure (Statistix 10).

T. Aman 2021. In T. Aman season, all the plots were lodged due to a depression and ultimately the yield was very low ranging between 2.05 and 2.67 t ha^{-1}. Low yield was observed in the control plots where silicon was not applied (Fig. 3). Yield differences among the treatments were not significant. No significant differences were found among the treatments in all the variables (Table 3). Plant height were very much close among the treatments along with the growth duration (Fig. 5).

Though the tiller production were little bit different in some stages, but the difference was very low and very similar at the maturity stage (Fig. 6). Since the plots were lodged resulting low yield and no significant differences were found among the treatments, therefore, we can see the effect one more season.

Boro, 2021-22. No significant variation was observed in the yield of BRRI dhan50 in different treated plots (Table 4). Yield ranged from 4.27 t ha^{-1} to 5.30 t ha^{-1}. Other growth and yield contributing parameters were also statistically similar among the treatments.

Therefore, we can say that silicon application might not have so significant effect on growth and yield of rice in Bangladesh situation.

LABOUR MANAGEMENT SYSTEM

Monitoring labour wage rate at different locations of Bangladesh

PI: M S Islam **CI:** M M Rahman, M R Manir, M M Rashid, M F Islam and S Begum

A survey was conducted throughout the year to find out the labourers' wage rate at different locations around BRRI HQ and BRRI regional stations. In addition, a conclusive survey was done in different locations around BRRI HQ such as Joydebpur, Chowrasta, Salna, Board Bazar and Konabari, Tongi area.

Laborer\s wage rate differs according to the location of the work. The lowest wage rate was found in Habiganj, Satkhira, Gopalganj and Sonagazi areas (450-500 Tk per day). The highest wage rate was observed in Cumilla (800-850 Tk per day) followed by Gazipur (700-800 Tk per day), Bhanga (700-850 Tk per day) and Barisal (750-800 Tk per day). Working hours were also different based on the location (Table 5). The working time (8 hrs day^{-1}) of labourers was more or less similar except Barishal, Bhanga, Cumilla and Satkhira. The average labour wage rate without food varied between Tk 350-700 and with food Tk 450-850 respectively at different locations surrounding of BRRI regional stations (Table 5).

In another study around BRRI HQ Gazipur (Joydebpur, Chowrasta, salna, Board Bazar, Konabari areas), the average wage rate per day (8.0 hrs work) was Tk 546-610 (Table 6). The highest wage rate of labourers was in May (Tk. 700-750 per day) due to harvesting and post-harvest operations of Boro rice and transplanting of Aus rice. Another higher rate was during July-August (TK 550-700 per day) due to harvesting and post-harvest operations of Aus rice and transplanting of Aman rice. The third higher wage rate was observed during December-January (Tk 550-620 per day) due to the peak period for harvesting and post-harvest operation of T. Aman rice and transplanting of Boro rice.

Rice Seed Production

PI: M S Islam **CI:** M M Rahman, M R Manir, M M Rashid and S Begum

Performance of different rice varieties in seed production plots during 2021-22.

In total 11 and 12 varieties were cultivated in BRRI research field for TLS seed production purpose during T. Aman and Boro seasons, respectively in 2021-22. The varieties were harvested at 80-90% maturity and yields (t ha^{-1}) were adjusted to 14% moisture content. Yield of the varieties ranged from 3.69 t ha^{-1} to 7.46 t ha^{-1} and 4.85 t ha^{-1} to 7.72 t ha^{-1} in T. Aman and Boro varieties, respectively (Table 7). Among T. Aman varieties, BRRI dhan49 produced the highest yield(7.46 t ha^{-1}) where as BRRI dhan89 yielded the highest yield (7.72 t ha^{-1}) among Boro varieties. During T. Aman season, BRRI dhan87 yielded the lowest (3.69 t ha^{-1}) due to lodging as a result of local storm and rain at dough stage.

Truthfully labeled seed (TLS) production. Rice seed production is one of the important mandates of FMD. This division produced two types of seeds, such as, breeder seed and truthfully labeled seed. In different rice seasons, the division produced about 13,837 kg TLS of which 1,837 kg, 5,083 kg and 6,917 kg was in Aus, Aman and Boro seasons, respectively (Table 8). In addition, 150 kg non-seed and 4,005 kg mixed rice were produced during this period (Table 9). This division also purchased 2,067 kg seeds of BRRI dhan87 from the farmers.

Breeder seed production. A total of 7,855 kg breeder seed was produced under the supervision of FMD during T. Aman and Boro seasons of 2021-22. In total 2718 kg breeder seed of three T. Aman varieties (BRRI dhan30, BRRI dhan49 and BRRI dhan98) were produced during T. Aman 2020-21 whereas 5137 kg breeder seed of two Boro rice varieties (BRRI dhan92 and Bangabandhu dhan100) was produced during Boro 2021-22 season (Table 9).

Seed distribution. For popularizing and dissemination of BRRI rice varieties, 10,650 kg truthfully label seed was distributed by FMD during the reporting period. In total 350, 1,150 and 9,150 kg seeds were distributed during Aus, T. Aman and Boro seasons, respectively. These seeds were distributed to DAE, researchers, different research divisions and regional stations of BRRI, seed producers, different agricultural organizations and agencies and also to the farmers.

Support Services

PI: M S Islam **CI:** M M Rahman, M R Manir and S Begum

Land and Labour Management. Including regional stations, BRRI had 717 labourers of which 497 regular and 220 irregulars at the start of the reporting time (1 July 2021). In BRRI HQ, total number of laborers was 444 of which 289 regular and 155 irregular labourers (Table 10). At the end of the reporting period (30th June 2022) the number of labors reduced to 705 of which 487 were regular and 218 were irregular. The reduction of labourers was happened because of death and retirement.

Soil health improvement. In order to improve soil health and productivity of BRRI farm, this division was also taken a series of activities such as incorporation of Dhaincha (as green manure) and rice straw, application of cowdung and compost etc.

Irrigation and drainage management. Irrigation and drainage management is one of the important managements carried out by FMD. Irrigation of the plots was done according to the land preparation schedule, cultivation schedule and the needs of the plots in all the seasons (Aus, Aman and Boro). In addition, drainage system is to be managed in all the year round, especially when heavy rain and depression occurs.

Labor utilization. Total labour utilization in different divisions was 1,91,869 man days of which 52.39 %, 44.79 % and 2.81 % were utilized for research, support service and holidays, respectively in BRRI HQ (Table 11). Among the research divisions, Plant Breeding Division utilized the highest laborers (16,540; 8.62%) followed by FMPHTD (8191; 4.26%) and GRSD (7955; 4.14%) for research purposes.

Labuor Wages. It was observed that total labour wages were 11,19,61,815 of which Tk 5,85,67,775**,** Tk 5,01,53,440 and Tk 32,40,600 were paid to the labourers for research work, support service works, leaves and holidays, respectively (Table 12). In addition, Tk 99,50,379 was paid as retirement benefits to18 labourers during the reporting period where 11 were in BRRI HQ and seven were in BRRI regional stations (Table 13).

Land utilization. BRRI has 286.33 ha of land of which 172.64 ha is cultivable (Table 10). A total of 82.44 ha of land were utilized by different research divisions in different season at BRRI HQ of which 6.17 ha in Aus, 37.46 ha in T. Aman and 38.81 ha in Boro season (Table 14). Among the research divisions, Plant Breeding Division utilized the highest amount of land (25.41 ha) followed by GRSD (12.95 ha) and Hybrid Rice Division (8.12 ha).

Garden management. This division manages the BRRI flower garden of the office campus. The office area and different gate areas and other beautification areas are managed maintaining the aesthetic view of the campus and producing visible flower garden during summer and winter seasons.

Beautification of BRRI. Beautification of BRRI premises and playground during observation of different national, international and organizational events are carried out by different means (such as embellishing, cleaning, arranging flower pots etc. Different management and organizing events are also done by Farm Management Division.

Tree plantation and management. Tree plantation and management of different fruit trees and other trees in the BRRI farm are another management work of FMD. Pruning, training and other management of the trees are done as regular basis.

Graveyard management. Farm Management Division conduct all activities related to graveyard management of BRRI. Graveyard is in the deep-water research area. A graveyard management committee headed by Head of FMD is working in this regard.

Mosquito control activities. FMD tried to control mosquito infestation by spraying insecticides in BRRI residential and office area during the reporting period. For effective control of mosquitoes, total community approach is to be considered along with this activity.

Play Ground management. BRRI has two playgrounds which are regularly maintained by FMD. Specially, maintaining of grass cover to the playground in suitable playing condition by cutting the grass regularly is a hard job. These playgrounds management are done by this division.

Sale proceeds. This division earns a total of Tk 69,555 by selling different farm products such as straw, dead tree and branches, green coconut, betel nut, jackfruit etc. and services (trolley use) (Table 15). The money was deposited to Accounts and Finance section for increasing government revenue.

Table 1. Yield and yield components of rice under different fertilizer management in T. Aman 2021 and Boro 2021-22.

Treatment	Plant height (cm)	Tillers m^{-2} (no.)	Panicles m^{-2} (no.)	Grain $panicle^{-1}$ (no.)	1000- grain wt. (g)	Grain yield (t ha^{-1})
T. Aman (BRRI dhan87)						
T_1	121.27	207	188	95	22.25	3.23
T_2	125.43	266	251	101	22.55	5.59
T_3	122.20	258	242	98	22.12	5.20
T_4	120.27	271	259	99	22.68	5.42
T_5	125.69	286	271	102	22.56	5.81
T_6	123.33	266	257	102	22.32	5.39
T_7	122.37	273	254	97	22.38	5.34
LSD (0.05)	3.33	10.95	7.58	4.31	0.65	0.21
CV %						
Boro (BRRI dhan89)						
T_1	94.37	202	182	108.02	22.30	4.16
T_2	103.27	274	246	139.54	22.46	6.78
T_3	101.60	258	237	139.28	22.47	6.37
T_4	101.33	270	247	138.98	22.49	6.48
T_5	103.82	275	250	139.77	22.56	7.02
T_6	102.93	268	246	139.28	22.53	6.65
T_7	102.17	264	240	140.15	22.57	6.47
LSD (0.05)	6.11	9.24	10.82	2.97	0.16	0.16

T_1 = Absolute control, T_2 = BRRI recommended dose N-P-K-S@83-17-53-12 kg ha^{-1}, T_3 = Soil test based (STB) Fertilizer dose N-P-K-S@67-10-40-10 kg ha^{-1}, T_4 = STB dose + 1 t ha^{-1} cowdung and T_5 = STB dose + 1 t ha^{-1} poultry manure. T_6 = STB dose + 1 t ha^{-1} vermicompost and T_7 = STB dose + 0.33 t ha^{-1} CD + 0.33t ha^{-1} PM + 0.33 t ha^{-1} VC.

Table 2. Yield and yield contributing parameters of rice as affected by mechanical seedling transplanting with deep placement of mixed fertilizer and hand transplanting with hand broadcasting in T. Aman and Boro 2021-22.

Treatment	Plant height (cm)	Panicle m^{-2} (no.)	Filled grain $panicle^{-1}$ (no.)	1000-grain wt. (g)	Grain yield (t ha^{-1})
T. Aman season (BRRI dhan87)					
T_1	127	225	152	23.38	3.31
T_2	130	218	153	22.33	4.66
T_3	133	234	157	23.35	4.38
T_4	131	218	167	23.33	4.48
LSD (0.05)	NS	NS	NS	NS	0.90
CV%	5.6	3	9	3.14	10.80
Boro season (BRRI dhan92)					
T_1	116	406	113	22.49	7.26
T_2	111	391	110	22.63	7.32
T_3	110	417	102	22.39	6.52
T_4	111	376	108	22.79	6.79
T_5	113	328	103	21.62	6.14
T_6	115	384	110	22.54	7.47
LSD (0.05)	NS	NS	NS	NS	0.59
CV%	2.36	7.75	2.57	4.23	4.77

T_1 = Mechanical transplanting along with 100% fertilizer (Urea, TSP, MoP and Gypsum) deep placement, T_2 = Mechanical transplanting along with 80% fertilizer (80% Urea and 100% TSP, MoP and Gypsum) deep placement, T_3 = Mechanical transplanting along with 70% fertilizer (70% urea and 100% TSM, MoP and gypsum) deep placement, T_4 = Mechanical transplanting along with 100% fertilizer hand broadcasting (TSP, MoP and gypsum fertilizer as basal dose and urea fertilizer in three splits) and T_5 = Hand transplanting along with 100% fertilizer hand broadcasting (TPS, MoP and Gypsum in basal dose and urea fertilizer in three splits). T_6 = BRRI recommended practice.

Table 3. Yield contributing parameters of BRRI dhan70 as affected by silicon spray during T. Aman 2021.

Time of spray / Silicon conc. (%)	Filled grain $panicle^{-1}$ 20 DAT	Filled grain $panicle^{-1}$ 35 DAT	Unfilled grain $panicle^{-1}$ 20 DAT	Unfilled grain $panicle^{-1}$ 35 DAT	Panicle m^{-2} 20 DAT	Panicle m^{-2} 35 DAT	1000-grain wt. (g) 20 DAT	1000-grain wt. (g) 35 DAT
0.0	102	71	36	29	249	261	21.53	20.45
0.5	87	99	48	41	236	252	20.83	21.22
1.0	83	85	37	32	249	248	20.63	21.10
1.5	94	92	44	45	238	249	21.12	20.77
Average	91	87	41	37	243	253	21.03	20.88
LSD for Silicon conc. (0.05)	NS		NS		NS		NS	
LSD for time of spray (0.05)	NS		NS		NS		NS	
LSD for interaction (0.05)	NS		NS		NS		NS	

Table 4: Yield contributing parameters of BRRI dhan50 as affected by silicon spray during Boro, 2021-22.

Time of spray / Silicon conc. (%)	Filled grain panicle^{-1}		Unfilled grain panicle^{-1}		Panicle m^{-2}		1000-grain wt. (g)	
	20 DAT	35 DAT	20 DAT	35 DAT	20 DAT	35 DAT	20 DAT	35 DAT
0.0	87	79	17	18	307	312	17.58	18.57
0.5	88	90	20	20	293	300	17.60	18.38
1.0	90	92	19	28	283	288	18.68	18.72
1.5	98	94	22	22	271	302	18.19	17.89
Average	91	89	20	22	289	301	18.01	18.39
LSD for silicon conc. (0.05)	NS		NS		NS		NS	
LSD for time of spray (0.05)	NS		NS		NS		NS	
LSD for interaction (0.05)	NS		NS		NS		NS	

Table 5. Labourer's wage rate with and without food at different locations of Bangladesh 2021-22.

Location	**Average wage rate (Tk) with food**	**Average wage rate (Tk) without food**	**Working time**
Habiganj	450-500	400-450	6.0am - 2.0pm
Rangpur	500-600	400-450	6.3am - 2.0pm
Rajshahi	500-550	400-450	6.0am - 2.0pm
Barishal	750-800	600-650	8.0am - 5.0pm
Sonagazi	450-500	400-420	6.0am - 2.0pm
Cumilla	800-850	650-700	6.0 am - 4.0pm
Satkhira	450-500	350-400	7.0am - 12.0pm
Kushtia	500-550	400-450	6.0am - 2.0pm
Bhanga	700-850	650-700	6.0am - 5.0pm
Gopalganj	450-500	400-450	6.0am - 1.0pm
Sirajganj	500-550	450-500	6.0am - 2.0pm
Gazipur	700-750	500-600	6.0am - 2.0pm
Average	389-436	543-614	-

Table 6. Labourer's wage rate without stuff at different places around BRRI HQ, Gazipur during 2021-22.

Month	Wage rate (Tk.)*	Remark
Apr	520-600	Normal period
May	700-750	Peak period. Harvesting and post-harvest operation of Boro rice and transplanting of Aus rice.
Jun	550-650	Normal period
Jul	550-675	Peak period. Harvesting and post-harvest operation of Aus rice and transplanting of
Aug	560-700	Aman rice.
Sep	520-550	Normal period
Oct	500-540	
Nov	550-600	
Dec	550-620	Peak period. Harvesting and post-harvest operation of Aman rice and transplanting of
Jan	550-620	Boro rice.
Feb	520-560	
Mar	500-540	Normal period
Average	546-610	

* Wage rate of each month is the average rate of different places such as Joydebpur, Chowrasta Salna, Board Bazar, Konabari area.

Table 7. Rice seed yield (t ha^{-1}) of different rice varieties from TLS production plots of FMD during Aman and Boro 2021-22.

Aman		Boro	
Variety	**Yield (t ha^{-1})**	**Variety**	**Yield (t ha^{-1})**
BRRI dhan22	4.64	BRRI dhan28	4.85
BRRI dhan30	6.05	BRRI dhan29	6.76
BRRI dhan46	5.25	BRRI dhan50	6.17
BRRI dhan49	7.46	BRRI dhan58	5.57
BRRI dhan52	5.11	BRRI dhan67	5.28
BRRI dhan71	4.76	BRRI dhan81	5.56
BRRI dhan75	3.87	BRRI dhan84	4.86
BRRI dhan87	3.69	BRRI dhan88	5.04
BRRI dhan95	4.81	BRRI dhan89	7.72
BRRI dhan98	7.23	BRRI dhan92	6.58
Bangabandhu dhan100	4.67	BRRI dhan96	5.33
		Bangabandhu dhan100	6.55

Table 8. TLS production of different varieties during 2021-22.

Variety	Season			Total (kg)
	Aus	Aman	Boro	
BR22	-	530	-	530
BR23	-	203	-	203
BRRI dhan28			580	580
BRRI dhan29			900	900
BRRI dhan34	-	425	-	425
BRRI dhan46	-	230	-	230
BRRI dhan48	195			195
BRRI dhan50			430	430
BRRI dhan52		250		250
BRRI dhan58			300	300
BRRI dhan67			250	250
BRRI dhan70		107		107
BRRI dhan71	-	300	-	300
BRRI dhan75	-	300	-	300
BRRI dhan81			450	450
BRRI dhan82	363			363
BRRI dhan83	183			183
BRRI dhan84			300	300
BRRI dhan85	40			40
BRRI dhan87	-	686	-	686
BRRI dhan88			270	270
BRRI dhan89			1040	1040
BRRI dhan92			1002	1002
BRRI dhan95	-	252		252
BRRI dhan96	-		270	270
BRRI dhan50				0
BRRI dhan98	1056			1056
Bangabandhu dhan100		1800	1125	2925
Seed (Total)	1837	5083	6917	13837
Non seed		-	150	150
Mixed rice	-	-	4005	4005
Grand total	405	2965	11072	17992

Table 9. Breeder seed production of different varieties during 2021-22.

Variety	Season			Total (kg)
	Aus	Aman	Boro	
BRRI dhan30	-	792	-	792
BRRI dhan49	-	958	-	958
BRRI dhan92	-		2770	2770
BRRI dhan98	-	1968		1968
Bangabandhu dhan100	-		2367	2367
Total	-	2718	5137	7855

Table 10. Land and labour strength of BRRI, in the date of 1 July 2021.

Station	Total land (ha)	Cultivable land		Labour (no.)						
		Area (ha)	% of total land	Regular			Irregular			Total
				Male	Female	Total	Male	Female	Total	
BRRI HQ, Gazipur	76.83	44.45	57.86	237	49	286	123	31	154	440
BRRI RS, Cumilla	24.68	16.03	64.95	13	1	14	12	1	13	27
BRRI RS, Hobiganj	35.03	25.90	73.94	25	2	27	11	0	11	38
BRRI RS, Sonagazi	45.77	35.90	78.44	33	2	35	4	0	4	39
BRRI RS, Barishal	41.10	10.74	26.13	22	3	25	3	0	3	28
BRRI RS, Rajshahi	13.24	8.92	67.37	22	3	25	6	0	6	31
BRRI RS, Bhanga	11.46	9.55	83.33	12	2	14	5	0	5	19
BRRI RS, Rangpur	6.07	4.05	66.72	28	1	29	4	1	5	34
BRRI RS, Satkhira	20.00	8.10	40.50	18	1	19	2	0	2	21
BRRI RS, Kushtia	4.05	3.0	74.07	11	0	11	1	0	1	12
BRRI RS, Sirajganj	4.05	3.0	74.07	2	0	2	7	1	8	10
BRRI RS, Gopalganj	4.05	3.0	74.07	-	-	-	6	0	6	6
Total	286.33	172.64	60.29	423	64	487	184	34	218	705

Table 11. Division /section wise labour utilization during 2021-22.

Division	Number of labour days utilized	
	Total	Percentage (%)
(A) Research		
Plant Breeding	16540	8.62
Hybrid rice	6442	3.36
Biotechnology	5452	2.84
Genetic Resources and Seed	7955	4.14
Entomology	4960	2.59
Plant Pathology	4170	2.17
Agronomy	4131	2.15
Plant Physiology	5302	2.75
Soil Science	6344	3.31
Rice Farming Systems	4199	2.19
Grain Quality and Nutrition	2416	1.26
Adaptive Research	4277	2.23
Training	1663	0.86
Agricultural Economics	1220	0.64
Farm Machinery and Post Harvest Technology	8191	4.26
Workshop Machinery and Maintenance	4158	2.17
Irrigation and Water Management	3020	1.57
Agricultural Statistics	2777	1.47
Farm Management a) Research	4681	2.44
b) Seed production	2639	1.37
Total	100537	52.39
(B) Support Service		
Farm Management		
a) Common Services	14089	7.35
b) Garden	11859	6.18
Building & Construction		
a) Caretaking	10456	5.45
b) Electrical	8104	4.22
Publication and Public Relation	796	0.41
Administration & Support Service		
a) Administration	9212	4.80
b) Audit	422	0.22
c)Transport	10275	5.37
d) Store	1828	0.95
e) Hostel	5808	3.02
f) Security	9055	4.72
g) Planning	423	0.22
h) Medical	757	0.40
Accounts & Finance	2842	1.48
Total	85925	44.79
(C) Leave		
a) Casual leave	2556	1.33
b) Govt. Holidays	2840	1.48
Total	5.398	2.81
Grand Total (A+B+C)	191869	100%

Table 12. Division /Section wise labour wages during 2021- 22.

Division/Section	Wages Incurred (Tk)
(A) Research	
Plant Breeding	96,06,535/-
Hybrid rice	37,53,240/-
Biotechnology	31,76,445/-
Genetic Resource and Seed	46,14,740/-
Entomology	28,89,795/-
Plant Pathology	24,29,525/-
Agronomy	24,06,,805/-
Plant Physiology	30,89,050/-
Soil Science	36,79,050/-
Rice Farming Systems	24,46,421/-
Grain Quality and Nutrition	14,07,610/-
Adaptive Research	24,91,865/-
Training	9,68,897/-
Agricultural Economics	7,32,000/-
Farm Machinery & Post Harvest Technology	47,58,543/-
Workshop Machinery & Maintenance	24,22,535/-
Irrigation and Water Management	18,12,000/-
Agricultural Statistics	16,17,940/-
Farm Management a) Research	27,27,245/-
b) Seed production	15,37,534/-
Total	5,856,7775/-
B) Support Service	
Farm Management a) Common Services	82,60,960/-
b) Garden	69,29,290/-
Building & Construction a) Caretaking	60,98,875/-
b) Electrical	47,32,282/-
Publication and Public Relation	4,71,600/-
Administration	53,74,186/-
a) Transport	59,86,420/-
b) General Store	10,65,029/-
c) Hostel	33,83,856/-
d) Security	52,46493/-
e) Planning & Evaluation	2,55,600/-
f) Medical	4,41,043/-
Accounts & Finance	16,55,806/-
Audit	2,52,000/-
Total	5,01,53,440/-
(C) Leave	
a) Casual leave	15,36,600/-
b) Govt. Holidays	17,04,000/-
Total	32,40,600/-
Grand Total (A+B+C)	11,19,61,815/-

* This expenditure excluded the temporary labourers engaged by the respective divisions.

Table 13. Retirement benefits given to labourers during 2021-22.

Working place	No. of retired labours	Retirement benefit given (Tk)
BRRI HQ, Gazipur	11	6003879/-
Regional Stations	7	3946500/-
Total	18	99,50,379/-

Table 14. Land utilization by different division/sections during 2021-22.

Divisions/section	Land area used (ha)			
	Aus	T. Aman	Boro	Total
Plant Breeding	2.83	11.29	11.29	25.41
Genetic Resources and Seed	0.11	6.17	6.67	12.95
Entomology	1.27	1.17	1.41	3.85
Soil Science	0.47	2.17	2.15	4.79
Biotechnology	0.40	1.30	1.13	2.83
Plant Physiology	-	0.61	0.73	1.34
Hybrid Rice	-	3.86	4.26	8.12
Agronomy	0.20	1.51	1.85	3.56
Plant Pathology	-	1.04	1.08	2.12
Rice Farming Systems	-	1.44	1.46	2.90
Adaptive Research	-	1.34	1.40	2.74
Grain Quality and Nutrition	0.11	0.68	0.98	1.77
Farm Machinery and Post Harvest Technology	-	0.53	0.34	0.87
Irrigation and Water Management	-	0.73	0.69	1.42
Agricultural Statistics	-	0.53	0.51	1.04
Farm Management: a) Research	-	0.40	0.49	0.89
b) Seed production	0.78	2.69	2.37	5.84
Grand Total	6.17	37.46	38.81	82.44

Table 15. Sale proceed of FMD during 2021-22.

Items	Amount (Tk)
Dead tree and branches	7100
Green coconut	435
Straw (green & dried)	56,500
Battle nut	3000
Trolley fare	1320
Jackfruit	1200
Total	69,555

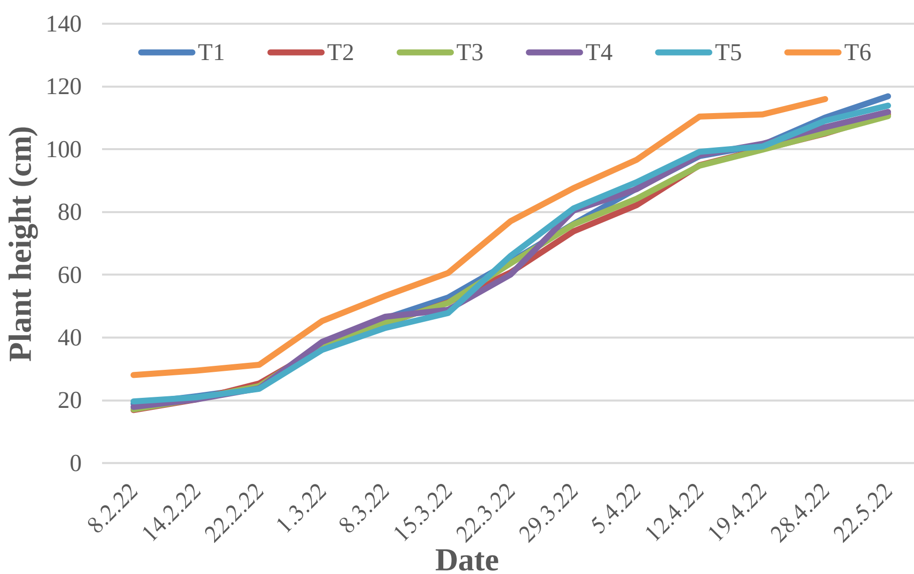


Fig. 1. Plant height in cm at days after transplanting as affected by mechanical seedling transplanting with deep placement of mixed fertilizer and hand transplanting with hand broadcasting in Boro 2020-21.

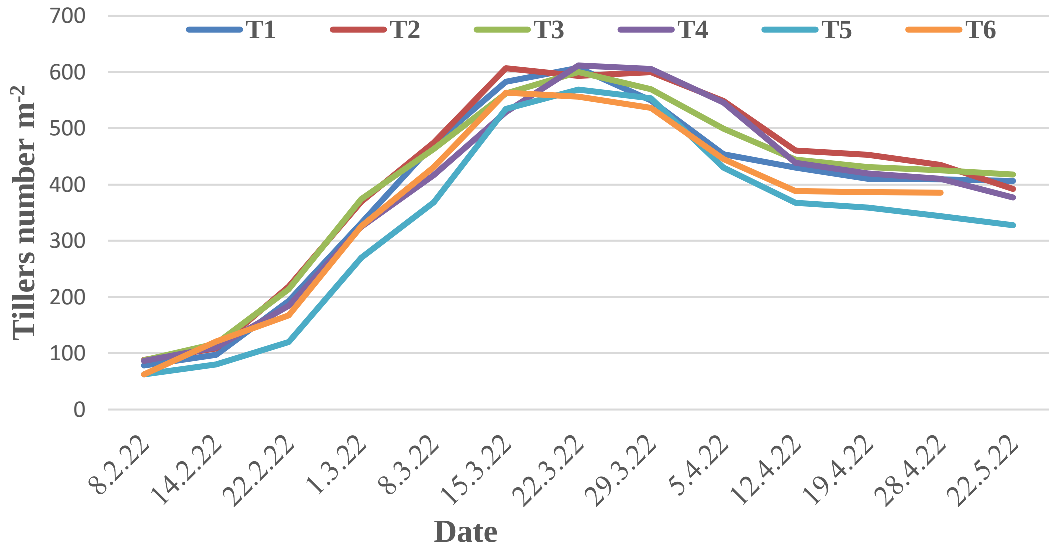


Fig. 2. Number of tillers m^{-2} at days after transplanting as affected by mechanical seedling transplanting with deep placement of mixed fertilizer and hand transplanting with hand broadcasting in Boro 2020-21.

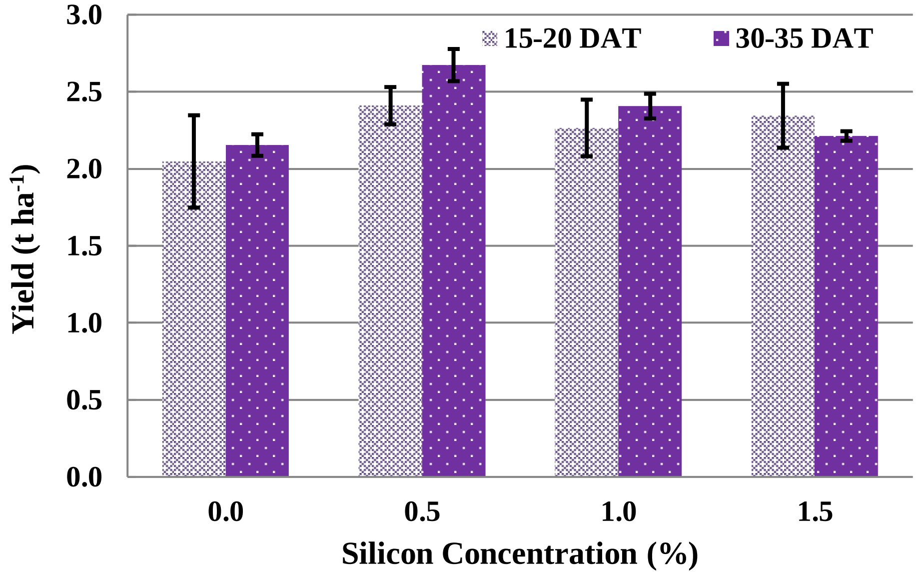


Fig. 3. Yield of silicon sprayed plots of BRRI dhan70 during T. Aman 2021 (bar represent standard error).

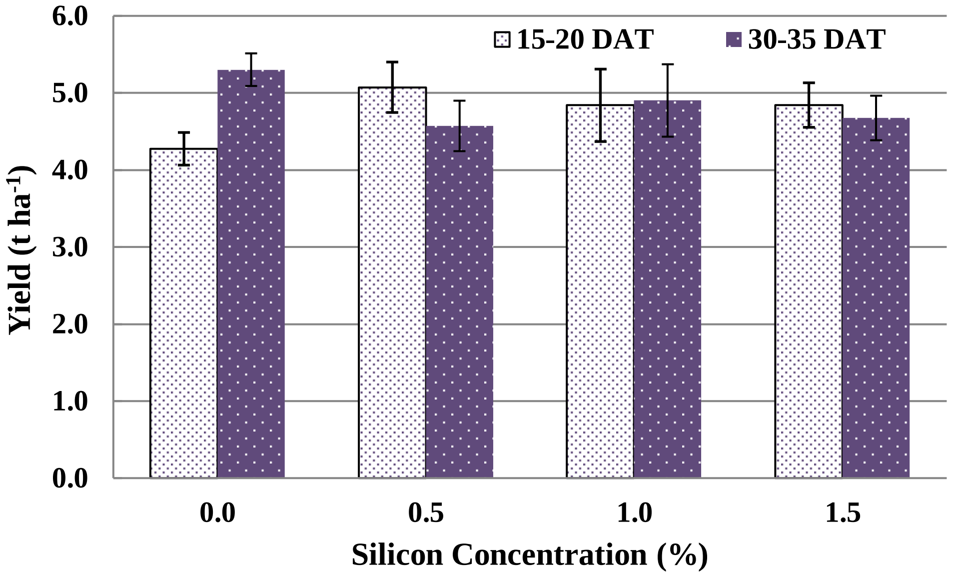


Fig. 4. Yield of silicon sprayed plots of BRRI dhan50 during Boro, 2022 (bar represent standard error).

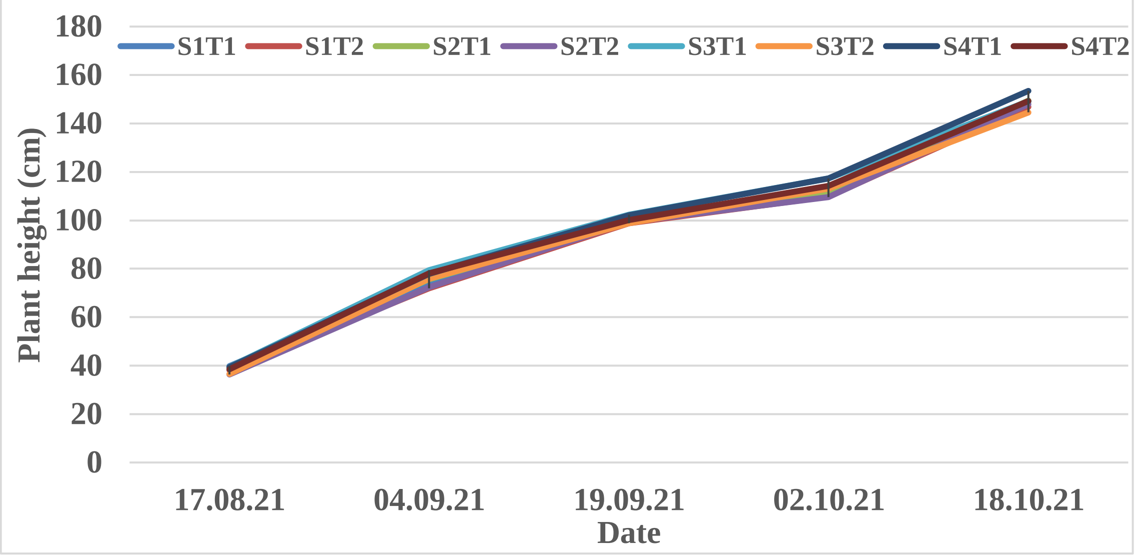


Fig. 5. Plant height of different silicon sprayed plots of BRRI dhan70 in T. Aman, 2021 season. [S1, S2, S3 and S4 represent 0.0, 0.5, 1.0 and 1.5 % silicon spray; T_1 and T_2 represent spray at 20 and 35 DAT]

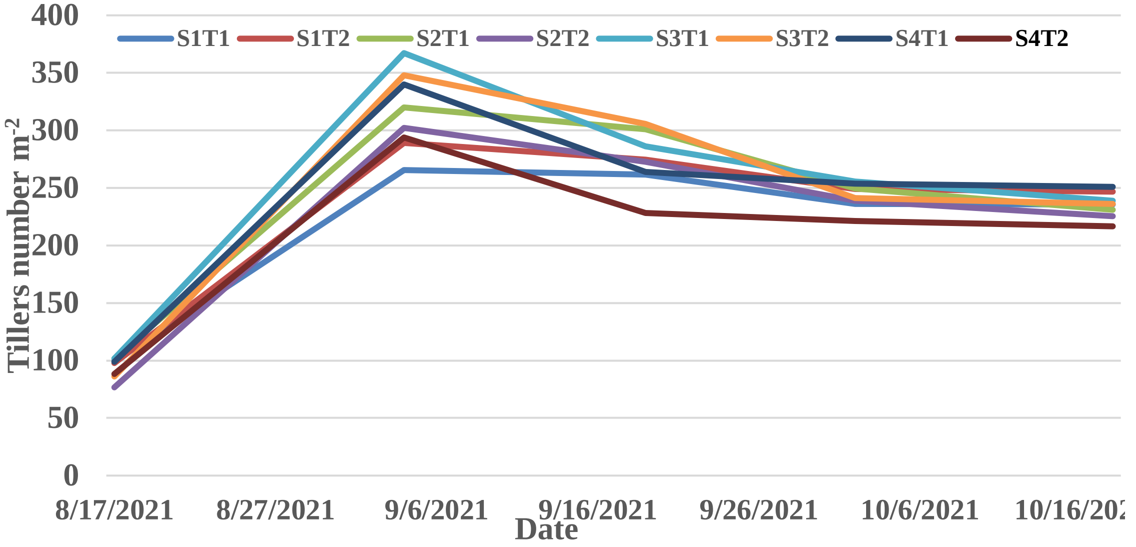


Fig. 6. Number of tiller production as affected by different silicon spray concentration in BRRI dhan70 during T. Aman, 2021 season. [S1, S2, S3 and S4 represent 0.0, 0.5, 1.0 and 1.5 % silicon spray; T_1 and T_2 represent spray at 20 and 35 DAT]

Farm Machinery and Postharvest Technology Division

+ Workshop Machinery and Maintenance Division

SUMMARY

The FMPHT division of BRRI Developed a basic, affordable, high-capacity prototype of combine harvester. The second prototype of the whole feed combine harvester has been made taking into account the problems with the first version of the combine harvester. Initial performance tests were done in Gazipur to determine capacity, travel speed, fuel consumption, grain output, and straw output. The harvesting capacity and fuel consumption were 0.288 to 0.309 ha/h (2.15-2.31 bigha/h), and 3.22 to 3.65 l/h respectively. The machine worked well at first, but after a few hours, it stopped because the crop conveyor's shaft twisted. In the research workshop, issues will be resolved. When this problem is rectified, the performance test will be repeated in the following season.

A manual forward-moving rice transplanter was made using local materials at the FMPHT divisional workshop. Field performance evaluation of the developed rice transplanter was conducted at the BRRI research field. The line-to-line spacing was set at 20 cm, although the plant-to-plant spacing varied between 18 and 20 cm. There were between 6.66 and 13 plants per hill. Percentage of missing, floating and buried hills were found 5.20%, 5.20% and 4.16%, respectively. Maximum transplanting efficiency was calculated as 85.41% and minimum was 31.25%. After transplanting, missing, floating, and buried hills were tallied and planting efficiency was assessed. About 5.2% of missing, floating, and buried hills were recovered. Maximum transplant efficiency was 85.4% and the lowest was 31.2%. For selected plots, field capacity was 0.14 ha/h and 0.10 ha/h. field efficiency was affected by the transplanter performance 77.08 to 44.62%. Break-even was determined by cost analysis. The transplanter breaks even at 1.14 ha/year.

A study was done to identify the seed rate of hybrid rice varieties for mechanical transplanting during Boro 2021-22 season at BRRI research field, Gazipur. The investigation employed BRRI hybrid dhan3, hybrid dhan5, dhan89, and hybrid dhan6. Mat type seedlings were grown in the same growth media on 280 x 580 x 25 mm plastic trays at 80, 90, 100, 110, and 120 g tray-1. During transplanting in the field, a walk-behind type four rows rice transplanter (Daedong, model-DP 488) was utilised with 140 mm plant-to-plant spacing and 300 mm line-to-line spacing. Seedling density grew linearly with seed rate, until 21 days after planting. All hybrids' seedling density rose with seed rate 21 days after planting, although BRRI dhan89's declined due to mortality. The BRRI hybrid dhan5 and dhan6 were taller than BRRI hybrid dhan3 and BRRI dhan89. Increased seed rate reduced seedling height after 21 days. 100, 110, and 120 g/tray produced the same amount of hills and plants per hill. Regardless of cultivar, increasing seed rate reduced missing hills. At 100 and 110 g/tray, BRRI hybrid dhan5 yielded substantially more than Ishpahani hybrid dhan6. BRRI hybrid dhan5 had the highest yield, followed by Ishpahani hybrid dhan6. BRRI dhan89 had the lowest yield, regardless of seed rate. 110 g/tray yielded much greater grain production than 80 and 90 g/tray.

The straw rope maker was designed to enhance the quality and efficiency of rope making. According to the design, the prototype of the machine was manufactured at the research workshop of the Farm Machinery and Postharvest Technology Division, BRRI using locally available raw materials. The rope-making capacity of the machine was observed at 55 mm s-1. The rope's tensile force and strength were determined to be 458.64±5 N and 7.20±0.5 MPa, respectively, with a rope diameter of 8.60±0.8 mm. The machine was simple to operate, using just 0.56 kW of electricity.

In Bangladesh, mat-type seedling is crucial for commercial rice transplanters. In recent years, hydroponics has gained interest. Hydroponics involves growing plants with their roots in mineral-rich water. Usually economically valued crops are produced using this approach in a controlled environment, although research is underway to create seedlings in grass and wheat. The use of hydroponic systems in rice production has not been researched. So, a research was undertaken to generate mat-seedlings for mechanical transplanting utilising hydroponics at WMM

Divisional lab, BRRI during Boro season 2021-22. BRRI dhan89 was used. M1:S2:R3 is preferable for producing mat-type seedlings for mechanical transplanting based on mat quality and strength.

In the FMPHT research workshop, a manual piston pressing briquette machine for small farmers was developed. Rice husk and ground maize stem will be utilised for briquettes.

Predicting drought is the best approach to reduce its effects. The present research tested the ability of additive regression (AR), random subspace (RSS), and M5P tree, and their hybridised variants, to predict the standardised precipitation evapotranspiration index (SPEI) on several time scales. Monthly rainfall and temperature data over 39 years were used to generate SPEIs (1980–2018). The best subset regression model and sensitivity analysis were used to find the best input variables from up to eight SPEI lags. The models were constructed in Rajshahi station and verified in four additional drought-prone regions. The presented models can reliably predict droughts at Rajshahi. M5P had the lowest mean absolute error (27.89–62.92%), relative absolute error (0.39–0.67), mean absolute error (0.208–0.49), root mean square error (0.39–0.67), and greatest correlation coefficient (0.75–0.98). The M5P model correctly predicted droughts in validation sites with varied time frames. Longer droughts are predicted more accurately.

A study has been ubdertaken to identifi the best land categorization map for Bangladesh combine harvesters. This research chose seven theme layers: soil texture (sand, silt, clay), bulk density, soil wetness, soil dry density, and water holding capacity. Weighted overlay analysis using GIS and machine learning was used to classify study area land suitability. Extra Tree Classifier model was used to estimate each thematic layer's relative weight. Preliminary study areas were selected at Kaliakoir upzila in Gazipur covering an area of 9.61 square kilometers (km2). It was found that 1.88 sq.km2 are highly appropriate, 4.16 sq.km2 are moderately suitable, 2.67 sq.km2 are low, and 0.86 sq.km2 are very low. The research will assist commercial combine harvester users, policymakers, and government employees to identify appropriate land in the study area.

Bangabandhu dhan100 rice milling characteristics have been determined using the BRRI-modified rubber roll husker and the MN-15 polisher. The customized rubber roll de-husker husked 90%, while the MNMP - 15 polisher recovered 64.5% milling recovery. The average head rice recovery from input paddy was 58.3%, indicating high-quality rice processing. For superior quality rice it is needed to replace a steel Engelberg huller with a rubber roll de-husker and a polisher. Rubber roll de-husker and friction polisher separate bran from husk. Husk and bran are utilized for briquettes and oil extraction.

Post-harvest aging increases paddy's shelf life and economic value. Age changes rice's physiochemical characteristics, affecting cooking and eating. Aged rice gives a greater milling yield, more volume expansion and water absorption during cooking, and harder, less sticky cooked rice. In the light of these issues, an experiment was undertaken to investigate the effect of aging on the premium BRRI variety's milling qualities. The trial used un-parboiled BRRI dhan50 and a semi-automatic rice mill at BRRI HQ. Rice was stored 9.3% moisture content (wb) at different structures such as Hermetic bag, plastic drum, painted motka. During the first 18 months of storage, milling quality was assessed in every three month. Each storage structure was tested seven times. The treatments were milling immediately after harvest, 3-month, 6-month, 9-month, and 12-month. 15-month T6=milling 18-month T7 milling. BRRI dhan50 has 10.52 percent moisture after harvest (wb). Milling yield, head rice recovery, and whiteness index were 63.25, 74.8, and 43.40.

The FMPHT Division of BRRI has developed a new solar-assisted paddy seed dryer with a central air distribution model (along the length of the drying chamber). Designing, manufacturing, and testing the prototype's performance were the aims of the study. The divisional workshop has developed the machine. To absorb more solar heat, a black-painted solar collector was developed. To identify the mechanical faults in the machine, the dryer performed a preliminary test at the FMPHT

Division. BRRI dhan50 seed germination rates of 92-98 percent were found using this solar-assisted dryer. The seed will be dry for more than 10 hours. The machine was found to be free of any major faults. In the upcoming season, a comprehensive performance test will be organized at the FMPHT Divisional research workshop. The improvement of the machine's functions will require additional prototype development.

In total, 56 batches of two-day-long residential training programme was conducted under financial and technical support of SFMRA project of FMPHT Division during the period of 2021-22. Participants of the training programme were from all BRRI regional station adjacent area and from its jurisdiction districts. Total 1154 numbers of participants were trained and among them 1085 were male and 69 were female. Participant were trained on operation, repair and maintenance of different agricultural machinery and technologies like transplanter, combine harvester, diesel engine, power weeder, prilled urea applicator, self propelled reaper, power tiller etc theoretically and practically in the threshing floor and in the main field. At the end of the training, a post-evaluation and trainee’s reactions regarding the training were collected. Certificates, leaflets and a set of tools were distributed among the participants. Trainees opined that they are now more confident about the use of the agricultural machinery.

AGRICULTURAL MACHINERY DEVELOPMENT AND TESTING

Development and fabrication of a whole feed combine harvester

It is difficult to get around the sparse, scattered acreage with the big, imported combines. When it comes to machinery and equipment, farmlands often lack roads. The prototype whole feed combine harvester was fabricated at the FMPHT divisional workshop at BRRI, Gazipur, using locally sourced and accessible parts and components. Cutter bar, reel, grain screw conveyor, feeding conveyer, threshing drum, blower fan, paddy conveyer, and driving power are all crucial components. As such, the combine harvester's grain storage tank and bagging mechanism had to be carefully thought out. The second generation combine harvester Plate 1 has been successfully manufactured by the FMPHT divisional workshop. Specifications, known first-version issues, and ideas were all taken into account throughout the design process. A preliminary performance test was done to find machine faults.

The whole feed combine harvester's mode of operation

The thresher of this combine harvester measures (L × W × H) 101 × 61 × 125 cm, and the machine is powered by a 32 hp diesel engine. V-belts transferred power from the engine shaft to the rest of the machine. The primary shaft produces 32 horsepower, and at 2200 revolutions per minute, the machine is operating at peak efficiency. The machine's pace changed based on the kind of crop being harvested and the state of the field. The thresher, cutter, blower for clearing debris, and driving wheel all received their share of power from the primary motor through a belt-pulley, perfect pulley, chain, and shaft. The combine harvester is depicted in its entirety in Plate 1; as the machine moves, the divider divides the crop for cutting, the reel picks up the laying or standing crops and pushes them to the cutting mechanism, and finally the reel pushes the cut crops down to the platform. The crop is thrown onto an inclined conveyor chain, which then feeds into the thresher, while the fingers retract. Crosswise transport is provided by the platform auger. The cylinder and concave assembly is crucial to the thresher's operation since it is responsible for sorting the crop into its component parts (seeds, chaffers that fall straight into the grain pan, or a conveyor). Straw and any leftover seed are directed into the straw carrier as the cylinder beater tends to remove the threshed material from the cylinder and assists in further separation at this stage. During the discharge process, the straw carrier shakes the load to remove any stray seeds or un-threshed heads. The chaffer sieve's front grain pan receives the material that has been separated from the straw through a grain return conveyor. When the threshed grain, along with some chaffer and tiny debris descends from the concave sieve, it is brought to a vibrating sieve, where it is cleaned with the help of a blower fan. A horizontal auger and a lifting auger are used to transport the cleaned grain from the cleaning area to the grain storage tank. When the threshing process is complete, the straw is released from the thresher and dropped to the ground via the straw exit. An opening in the bag or grain tank will allow the threshed and clean grain to flow out to the bagging platform.

Plate 1. The complete view of the whole feed combine harvester.

Machine performance evaluation

During Boro 2022 season, the performance assessment was done. The location was the BARI farm. The machine performed properly; but after a few hours of operation, it halted owing to a crop conveyor component's upper shaft twisting. In order to resolve this issue, adjustments were made by replacing the belt pulley with a chain sprocket. For this upgrade, the horizontal auger/speed screw has been raised relative to the old belt-pulley. After reconfiguration, the machine once again performed well. However, it observed some difficulty with the cutting bar slipping. Due to its slippage problem, the machine was unable to successfully chop the crop on the slope. This issue arose owing to the larger-than-expected gap between the machine's two cutting bars. For this reason, after harvesting the crop, some uncut tillers remained on the hill. By fixing and calibrating the cutting bar of the machine, it resolved this problem. The procedures of chopping, transporting, threshing, and cleaning performed adequately (Plate 2). However, it was discovered that poor engine performance was connected with smaller amounts of exhaust gases; hence, it is necessary to increase engine power to increase capacity. The range of the machine's fuel consumption was from 3.20 to 3.65 l/h, while the field's capacity was between 0.288 and 0.309 ha/h. Table 1 provides an overview of the machine field test performance statistics.

Plate 2. Field trial of the combine harvester at BARI farm, Gazipur.

Table 1. Field performance of BRRI fabricated whole feed combine harvester.

Place: BARI farm, Gazipur Sadar, Gazipur

Plot section no.	Duration of test (Working hrs.)	Travel speed (km/h)	Rate of work: Area covered		Rate of work: Grain output (kg/h)	Rate of work: Straw output (kg/h)	Fuel consumption l/h
			(bigha/h)	(ha/h)			
1	1.0	2.08	2.31	0.309	990.50	920.60	3.20
2	1.2	2.15	2.15	0.288	1010.65	890.40	3.40
3	1.5	2.10	2.27	0.304	1080.50	905.80	3.65
Average		2.11	2.24	0.3	1025.63	915.7	3.42

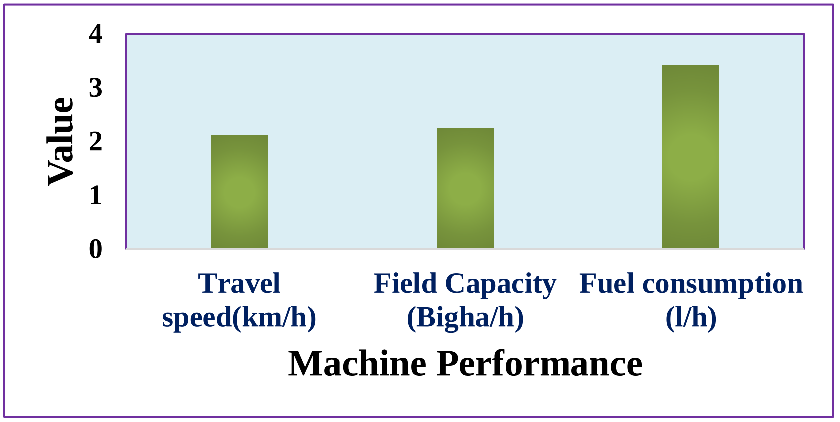


Fig.2. Travel speed, field capacity and fuel consumption of the machine.

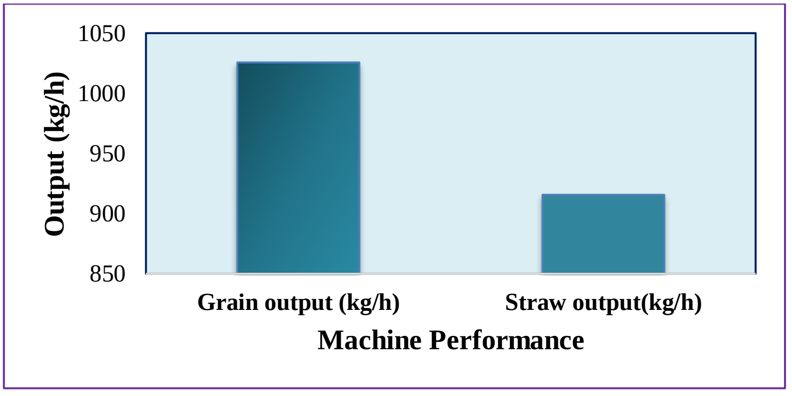


Fig.3. Grain output and straw output of the machine in different locations.

Figure 2 shows the machine's travel speed, field capacity, and fuel consumption are shown in Figure 2. The machine was run on the BARI farm at an average speed of 2.11 km/h. The machine's field capacity was measured at 2.24 (0.3 ha/h) bigha/h at the BARI farm, while its operational fuel consumption was measured at 3.42 l/h.

Figure 3 shows the output of the machine in terms of grain and straw is shown in figure 3 for the location at BARI farm, Gazipur. The machine's grain output was 1025.63 kg/h at the BARI farm location while it was running. Whereas, the machine's operational straw output was found to be 915.7 kg/h at the same location.

Identification of problems

Farmers, scientists, and machine operators were questioned mostly regarding their perceptions of the machine's overall performance while being used in the field. They provided positive comments and assessments of the developed machine's performance along with a focus on the issues and observations such as:

- ❖ More engine power is needed;
- ❖ Harvesting takes more time;
- ❖ During harvest, the shuttering loss of grain in the planted crop was observed;
- ❖ The machine is difficult to move over long distances.

Design, development and performance evaluation of a forward motion manual rice transplanter

A manually operated forward motion rice transplanter has been developed using locally available materials in the divisional workshop (Plate 3). Field performance evaluation of the developed rice transplanter was conducted at the BRRI research field. Line to line spacing 20 cm was fixed but plant to plant spacing was varied from 18 to 20 cm. Table 2 provides the detailed specification of the developed machine.

Performance evaluation at BRRI research field

Trial I. Twelve-day-old seedling of BRRI dhan46 was used in the first trial. The seedling height was 12.5 cm, seedling density was 5 per sq. cm. Soil thickness of mat type seedling was 1.5 cm.

Trial II. Fifteen-day-old seedling of BRRI dhan80 was used with height was 16 cm and seedling density 4 per sq. cm. Soil thickness of mat type seedling was measured 1.25 cm.

Trial III. Seedlings of BRRI dhan92 was used for Trial III. Three different mat thicknesses (1.45cm, 1.25cm, and 1cm) were used for this trial. Ten days old seedling of 14 cm height was used for trial III. Seedling density was counted as 3 per sq. cm.

[Seedling mat strength (tensile strength) was measured at laboratory by hanging from a bar adjusting with two C-clamp in both sides of the mat. Weight was added at one meter bottom of the clamp upto mat’s breaking point. A digital weight meter was used to measure the weight of hanging metals at the bottom clamp of mat. The seedling strength was measured in terms of Kilogram-force (Kg-f). Same procedure was followed for each type of seedlings.

Plate 3. Pictorial view of the rice transplanter.

Table 2. Specifications of studied manual operated paddy transplanter.

Item	Specification
Type	Manually operated four-rows transplanter
Overall dimensions	Length: 1900 mm Width : 1045 mm Height : 940 mm
Weight	30 kg
Adapted seedlings type	Mat type seedlings
Power source	Soil traction by ground wheel
Float	No. of floats: 2 Shape : Rectangular Size : 250 × 500 mm
Planting mechanism	Fixed fishing hook type fingers actuated by hand operated lever mechanism
No. of rows	4
Line to line spacing	200 mm
Effective width	800 mm
Seedling tray holder dimensions	425 mm × 210 mm
Number of persons required for operating machine	2 Nos.; One for operating machine and other for feeding nursery.

[Wheel traction area

The studied rice transplanter didn't give a satisfactory performance in the trial I and the trial II. For the trial III the rice transplanter showed a significant and successful performance. That's why wheel traction area was measured in the trial III. Wheel having different lug and stand size were used for trial III (Plate 4). Diameter of the wheel was same for all treatment. Trapezoidal shape lug area was calculated by following equation and added to area of rectangular stand to calculate whole traction area.

Lug area, (cm^2) = $\frac{(A+B)}{2}\ X\ h$ …..(1)

Where,

A and B = Length of two parallel sides (cm), and

h = Height (cm)

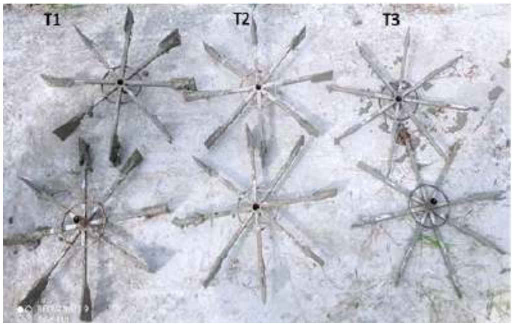


Plate 4. Wheels of different lug area.

Experimental design

The following treatments were arranged in a randomized complete block design (RCBD) with three replications.

Factor A (Wheel traction area, cm^2)	Factor B (Seedling strength, kg-f)
Larger lug type wheel (more traction area), T_1	Seedling mat type I, S_1
Medium lug type wheel (medium traction area), T_2	Seedling mat type II, S_2
Small lug type wheel (small traction area), T_3	Seedling mat type III, S_3

Trial I

Transplanter performance.

After completion the first trial seedling depth and plants per hill was not uniform over the field. A high number of missing hills was found and as a result planting efficiency was not satisfactory. The speed of operation was not acceptable to calculate theoretical and effective field capacity. It was counted that number of wheel rotation 17 instead of 32 for the specified field.

Identified problems.

The machine was not suitable for thick mats. Traction wheel depth was limited to 5 inch which caused power crisis in experimental field followed by low picker strength. Number of wheel rotation was not balanced because of high soil traction force as a result operator's height and physical condition was an important factor.

Improvement of the rice transplanter after Trial I: The traction wheel depth was increased upto 12 inch and mud gut was released to reduce frictional losses of wheel.

Trial II

The transplanter showed minimum number of losses in comparing to first trial. An average number of missing and buried hills was found as 8 and 2 respectively. Operator felt comfortable to pull the machine as the traction wheel depth was increased. Speed of operation was acceptable significantly. The theoretical and effective field capacity was found 0.09 ha/hr and 0.045 ha/hr respectively. Hence the field efficiency was calculated as 50%.

Identified problems.

Seedling was not placed to 90 degree angle on field because the guarder of picker was not provided on two sides like other rice transplanter**.** Seedling's regulator diameter was large that's why picker faced problem to step seedling properly.

Improvement of the rice transplanter after trial II. Mud guarder of the picker was added at both sides of planter and seedlings regulator diameter was reduced to adjustable range and prepared for next trail.

Trial III

General description.

The operation was successful in Trial III (Plate 5). The operator height was 64 inches and weight was 58 kg. Temperature of the experimental day was 32^0 C. Blood pressure of the operator was slightly fall after one hour of operation. That's why two operators were engaged during the experiment. One operator was pulling the transplanter and second operator helped first operator in bringing seedlings and assisting in turning of the manual rice transplanter. Plough pan depth of the field was 16 to 20 cm. The number of hills per sq. meter was counted 32 during transplanting. Seedling mat strength were measured 3.5 kg-f, 7 kg-f and 11.5 kg-f for seedling mat type I, II, and III respectively. Wheel traction area was largely depended on its lug size and diameter of each type wheel was same as 57cm. Wheel traction area were calculated 74 cm^2, 64 cm^2 and 30 cm^2 for large, medium and small lug type of wheel respectively.

Plate 5. Trial III (Transplanting capacity of the machine).

Plant to plant distance

Two-way interaction of seedling mat strength and traction area showed significant effect on plant to plant distance (Table 3). After analyzing, the highest plant to plant distance was observed 20 cm at S_2 when transplanted by T_3. S_3 also showed 20 cm plant to plant distance when transplanted by T_1 followed by T_2 and T_3. The lowest plant to plant distance was counted 18 cm when S_1 was transplanted by T_1 as well as in S_2 when transplanted by T_2. This fluctuation was because of penetration of wheel in the puddled soil. Transplanter wheel may face force against rotation and puddled soil might clog the picker gear. High mat thickness may be another cause of variation. As a result, picker of the transplanter picks the seedling in a slight variation.

Transplanting depth

Transplanting depth was measured after the completion of transplanting. Two-way interaction of seedling mat strength and wheel traction area showed significant effect on transplanting depth (Table 4). The maximum depth was observed 8 cm at S_1 while transplanted by T_3. S_2 showed the high depth of seedlings 7.66 cm when transplanted by T_1. Minimum depth was observed 3.66 cm from S_3 when transplanted by T_3 followed by T_2 in the same type of seedling mat.

Table 3. Interaction effect of seedling strength and wheel traction area on plant to plant distance (cm) in transplanting.

Seedling mat strength	Traction area			Mean
	T_1 *(74 cm^2)*	T_2 *(64 cm^2)*	T_3 *(30 cm^2)*	
S_1 *(3.5 kgf)*	18.00	19.00	19.33	18.77
S_2 *(7.0 kgf)*	19.66	18.00	20.00	19.22
S_3 *(11.5 kgf)*	20.00	19.67	19.67	19.77
Mean	19.22	18.88	19.67	-
% of CV value		2.78		
LSD $_{0.05}$	TA= 0.53	SS = 0.53	TA*SS = 0.92	
LoS	*	**	**	

Note: SS- Seedling strength, TA- Traction area of wheel, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, NS-Not significant.

Table 4. Interaction effect of seedling strength and wheel traction area on transplanting depth (cm).

Seedling mat Strength	Traction Area (cm^2)			Mean
	T_1 *(74 cm^2)*	T_2 *(64 cm^2)*	T_3 *(30 cm^2)*	
S_1 *(3.5 kgf)*	7.33	7.66	8.00	7.66
S_2 *(7.0 kgf)*	7.66	6.33	6.66	6.88
S_3 *(11.5 kgf)*	6.00	4.66	3.66	4.77
Mean	7.00	6.22	6.11	-
% of CV value	2.78			
LSD $_{0.05}$	TA= 0.80	SS = 0.80	TA*SS = 1.39	
LoS	**	**	*	

Note: SS- Seedling strength, TA- Traction area of wheel, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, NS-Not significant.

Plants per hill

Smooth rotation of wheel showed a uniform number of plants per hill. Two-way interaction of seedling strength and wheel traction area showed significant effect on seedling height ($p<0.01$) (Table 5). The highest number of plants per hill was found 13 on S_3 while transplanted by T_3 whereas minimum was observed 6.66 in S_1 and S_2 when transplanted by T_2.

Percent of missing hill

The missing hills were counted in terms of the failure of picking and placing of the seedling in the position of one sq. meter transplanting area. Two-way interaction of wheel traction area and seedling strength showed significant effect on missing hill of manualy operated rice transplanter ($p<0.05$). Maximum missing hill was observed 19.792% in S_3 while transplanted by T_3 (Table 6). S_1 showed the minimum missing hill 5.20% when transplanted by T_1 followed by T_2 at the same seedling (7.292%). Because of high degree of puddling, puddle soil attach in the head of picker, where picking seedling resulting in a resistance of the placement of seedling.

Percent of floating hill

Irrigation water and operator foot print that contain water influenced the floating hills of transplanting under the selective conditions. The interaction showed significant effect on floating hill. Maximum of floating hill was counted 19.79% in S_3 when transplanted by T_3 whereas minimum was observed 5.20% in S_1 while transplanted by T_1 (Table 7).

Table 5. Interaction effect of seedling strength and wheel traction area on plants per hill.

Seedling mat Strength	Traction area			Mean
	T_1 *(74 cm²)*	T_2 *(64 cm²)*	T_3 *(30 cm²)*	
S_1 *(3.5 kgf)*	7.00	6.66	7.33	7.00
S_2 *(7.0 kgf)*	7.66	6.66	8.66	7.66
S_3 *(11.5 kgf)*	8.00	9.33	13.00	10.11
Mean	7.55	7.55	9.66	-
% of CV value		12.54		
LSD $_{0.05}$	TA= 1.06	SS = 1.06	TA*SS = 1.84	
LoS	**	**	**	

Note: SS- Seedling strength, TA- Traction area of wheel, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, NS-Not significant.

Table 6. Interaction effect of seedling strength and wheel traction area on missing hill per sq. meter.

Seedling mat strength	Traction area			Mean
	T_1 *(74 cm²)*	T_2 *(64 cm²)*	T_3 *(30 cm²)*	
S_1 *(3.5 kgf)*	5.20	7.29	10.41	7.63
S_2 *(7.0 kgf)*	7.29	10.41	10.41	9.37
S_3 *(11.5 kgf)*	10.41	13.54	19.79	14.58
Mean	7.63	10.41	13.54	-
% of CV value	17.37			
LSD $_{0.05}$	TA= 1.82	SS = 1.82	TA*SS = 3.16	
LoS	**	**	*	

Note: SS- Seedling strength, TA- Traction area of wheel, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, NS-Not significant.

Table 7. Interaction effect of seedling strength and wheel traction area on floating hill per sq. meter.

Seedling mat strength	Traction area			Mean
	T_1 *(74 cm²)*	T_2 *(64 cm²)*	T_3 *(30 cm²)*	
S_1 *(3.5 kgf)*	5.20	7.29	10.41	7.63
S_2 *(7.0 kgf)*	8.33	10.41	10.41	9.72
S_3 *(11.5 kgf)*	10.41	13.54	19.79	14.58
Mean	7.98	10.41	13.54	-
% of CV value	16.47			
LSD $_{0.05}$	TA= 1.75	SS = 1.75	TA*SS = 3.03	
LoS	**	**	*	

Note: SS- Seedling strength, TA- Traction area of wheel, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, NS-Not significant.

Percent of buried hill

Two-way interaction of wheel traction area and seedling strength did not show significant effect on burried hill of the studied manualy operated rice transplanter. Maximum percentage of buried hill was found 29.16% and this experiment showed the minimum number of buried hill 4.16% (Table 8).

Transplanting efficiency

Transplanting efficiency of the studied rice transplanter was calculated in terms of seedlings placement. Planting efficiency influenced by missing, floating and buried hills. Two way interactions between seedling mat strength and wheel traction area effect significantly on planting efficiency. S_1 showed the maximum transplanting efficiency 85.41% when transplanted by T_1. Minimum was 31.25% on S_3 when transplanted by T_3 (Table 9).

Field efficiency

Field efficiency depended on effective field capacity. In interaction, S_1 showed the maximum field efficiency 77.08% when transplanted by T_1. When S_3 was transplanted by T_3 that showed the minimum field efficiency 44.62% (Table 10).

Table 8. Interaction effect of seedling strength and wheel traction area on burried hill per sq. meter.

Seedling mat strength	Traction area			Mean
	T_1 *(74 cm^2)*	T_2 *(64 cm^2)*	T_3 *(30 cm^2)*	
S_1 *(3.5 kgf)*	4.16	11.45	15.62	10.4
S_2 *(7.0 kgf)*	9.37	16.66	21.87	15.97
S_3 *(11.5 kgf)*	13.54	23.95	29.16	22.22
Mean	9.02	17.36	22.22	-
% of CV value	14.13			
$LSD_{0.05}$	TA= 2.88	SS = 2.28	TA*SS = 3.96	
LoS	**	**	NS	

Note: SS- Seedling strength, TA- Traction area of wheel, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, NS-Not significant.

Table 9. Interaction effect of seedling strength and wheel traction area on planting efficiency (%).

Seedling mat strength	Traction area			Mean
	T_1 *(74 cm^2)*	T_2 *(64 cm^2)*	T_3 *(30 cm^2)*	
S_1 *(3.5 kgf)*	85.41	73.95	63.54	74.30
S_2 *(7.0 kgf)*	75.00	62.50	57.29	64.93
S_3 *(11.5 kgf)*	65.62	48.95	31.25	48.61
Mean	75.34	61.80	50.69	-
% of CV value	7.12			
$LSD_{0.05}$	TA= 4.45	SS = 4.45	TA*SS = 7.72	
LoS	**	**	*	

Note: SS- Seedling strength, TA- Traction area of wheel, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, NS-Not significant.

Table 10. Interaction effect of seedling strength and wheel traction area on field efficiency (%).

Seedling mat strength	Traction area			Mean
	T_1 *(74 cm^2)*	T_2 *(64 cm^2)*	T_3 *(30 cm^2)*	
S_1 *(3.5 kgf)*	77.08	73.70	69.89	73.56
S_2 *(7.0 kgf)*	70.36	64.48	60.55	65.13
S_3 *(11.5 kgf)*	60.31	54.51	44.62	53.15
Mean	69.25	64.23	58.35	-
% of CV value	3.12			
$LSD_{0.05}$	TA= 1.99	SS = 1.99	TA*SS = 3.45	
LoS	**	**	*	

Note: SS- Seedling strength, TA- Traction area of wheel, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, NS-Not significant.

In case of calculating fixed cost, salvage value was considered 10 percent of purchase price and tax, insurance was considered 3.5% of purchase price of the machine (Hossen, 2016). The fixed cost of rice transplanting was found Tk 39.37 Tk per hr whereas the variable cost during only transplanting was Tk 541.11 Tk per hr for the studied rice transplanter. It was noticeable that the total variable cost of the transplanter was more due to high labour and seedling cost. Therefore, the total operating cost of transplanting rice, sum of fixed and variable cost was calculated 581.11 tk per hr.

Break even analysis

Operational cost of a forward motion manual operated rice transplanter was figured out for several number of ha coverage during the experiment, as the cost per ha varies with the number of ha coverage in a year of the machine. Figure 4 shows the variation of cost per ha with number of ha of usage per year is shown in Figure 4.

In three rice seasons, the average annual utilization of a transplanter was 40 days, including 10 days in Aus, 15 days in Aman, and 15 days in Boro. In case of six working hours per day, the annual utilization in hours per year is 240. Using an average effective field capacity of 0.094 ha per hr, the maximum potential covered area of 22.56 ha per yr was calculated. The cost of transplanting through manual rice transplanter was 15,170.64 TK per ha as against 14,000 TK per ha (assumed based on local status) in case of traditional transplanting at the highest annual area coverage. The cost of machine transplanting was gradually decreased for the depreciation of the machine. The cost of manual transplanting would break even at 1.14 ha of consumption per year, according to traditional transplanting costs of 14000 TK per ha. The cost of transplanter operation would be higher than traditional operating if the equipment was used for less than 1.14 ha per year.

Considering the economic situation of farmers, a self-propelled transplanter is prohibitively expensive. The newly developed forward motion manual rice transplanter was put through its paces. While employing a lighter strength mat in the field, the missing hill was kept to a minimum and the row-row gap was kept to a minimum of 20 cm. The number of hills per square meter, as well as the number of seedlings per square meter, is appropriately maintained, with 32 hills per square meter being discovered. For standing water of 20 to 30 mm, field efficiency for the planned transplanter is 77.08 percent, and transplanting efficiency is 85.41 percent. It is highly appreciated that, the studied manually operated rice transplanter is a solution of marginal and small farmers after further improvement.

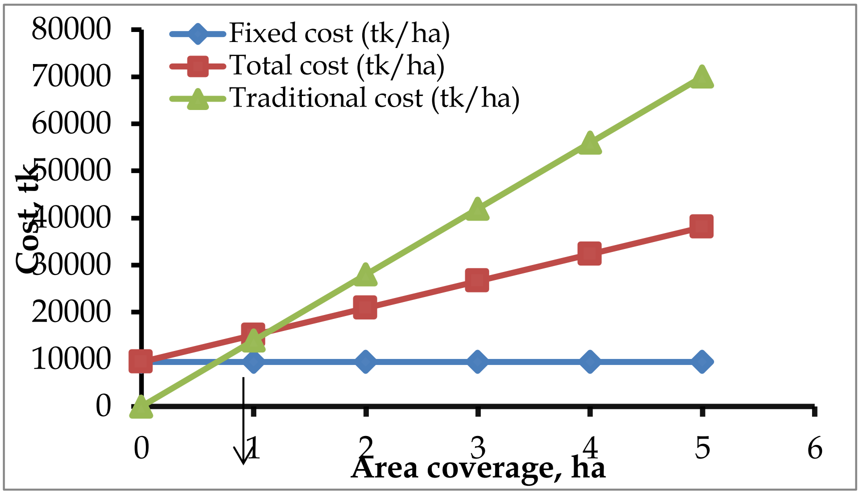


Fig. 4. Break-even analysis of the developed machine.

Development of BRRI straw rope maker

The most widespread and abundant rice-related product is rice straw. Heavy precipitation during the rainy season diminishes both the quantity and quality of available straw. Straw may be twisted into rope using either hand tools or a machine intended for the task. The purpose of designing and developing the BRRI straw rope maker was to increase the quality and efficiency of rope manufacturing. The planned hypothesis was a rope with a helix angle between 25^0 to 30^0 and a diameter between 4 and 20 mm. According to the design, the prototype of the machine was manufactured at the research workshop of the FMPHT BRRI using locally available raw materials (Plate 6). During design, lightweight, structural stability, and diameter uniformity were addressed. As the amount of twisting influences the strength of the rope, the diameter of the funnels entrance was set at half the rope's diameter. Laboratory and on-farm testing of the newly created rope maker was done. The rope maker consists of an A-frame, a wool basket, a rope splitter, two twisting funnels, two tiny stone pounds, a reel, and a gear mechanism. MS angle bar, cast iron, nylon plastic, and plain sheet were used to manufacture the rope maker. The twisting machinery consists of two plain-sheet twisting funnels, a wool basket rope divider, a rope mouth, and a tiny stone pound made of cast iron. The rope maker makes collecting and unloading rope straightforward. The rope-making capacity of the machine was observed at 55 mm s^{-1}. The rope's tensile force and strength were determined to be 458.64±5 N and 7.20±0.5 MPa, respectively, with a rope diameter of 8.60±0.8 mm. The machine was simple to operate, using just 0.56 kW of electricity. The operational concept of the BRRI straw rope maker was user-friendly, and its overall performance was suitable for creating rope. The straw rope maker was effective at continually generating high-quality rope with the specified diameter. The farmer may use this equipment to produce rope that is simple, rapid, and of great quality.

Determination of optimum seed rate for Hybrid rice variety for mechanical transplanting

A study was conducted to identify the seed rate of hybrid rice varieties for mechanical transplanting during Boro, 2021-22 season at BRRI HQ research field, Gazipur. BRRI hybrid dhan3, BRRI hybrid dhan5, Ishpahani hybrid dhan6 and BRRI dhan89 were used in the study. The same growth medium was used to establish mat type seedlings on plastic trays (280 x 580 x 25 mm) at seed rates of 80, 90, 100, 110, and 120 g $tray^{-1}$. Walk-behind type four rows rice transplanter (Daedong, model-DP 488) was used during transplanting in the field at the set of plant to plant spacing 140 mm while line to line spacing was fixed to 300 mm.

Experimental design and treatments. The following treatments were arranged in a two factor Completely Randomized design (CRD) with three replications. Rice varieties as main factor (4 varieties) whereas seed rate (g $tray^{-1}$) as sub-factors were 80 (S_1), 90 (S_2), 100 (S_3), 110 (S_4) and 120 (S_5) g per tray.

(a) (b) (c)

Plate 6. BRRI straw rope maker a) A complete view of straw rope maker b) Opeational view of rope maker c) Produced rope.

Statistical analysis. Data will be analyzed as a 2-way factorial design (variety x seed rate) according to Gomez and Gomez (1984) using Crop Stat 7.2 software (IRRI, 2007). Means will be compared with least significant difference (LSD) test using Statistix 10 programme (Statistix 10 software, 2013). Simple correlation analysis will carried out with Excel to determine the relationship of grain yield to yield attributes.

Mat type seedlings of the studied varieties were transplanter at 22 days after sowing. Field duration of the Ishpahani hybrid dhan6 was more compared to the BRRI hybrid rice varieties (Table 11).

Physical parameters

Table 12 presents physical parameters of the four selected varieties as well as germination percentage those were measured. Germination percentage of the selected varieties were similar while seed thickness of all hybrid varieties were more compared to the BRRI dhan89.

Density

Seeds density was measured immediate after sowing while seedling density was measured at 7, 14 and 21 days after sowing (Figures 5-8). Seedling density increased linearly with the increase of seed rate irrespective of variet except 21 days after sowing. At 21 days after sowing, seedling density of all hybrid varieties increased with the seed rate while seedling density of BRRI dhan89 decreased after the seed rate of 100 g/tray because of mortality.

Table 11. General information of the study.

Seeding	Transplanting	Harvesting date and duration (days)			
		BRRI hybrid dhan3	BRRI hybrid dhan5	Ishpahani hybrid dhan6	BRRI dhan89
29 Dec 2021	20 Jan 2022	12 May 2022 (134)	12 May 2022 (134)	14 May 2022 (136)	23 May 2022 (145)

Table 12. Physical parameters and germination percentage of the varieties.

Treatment	Germination rate (%)	Seed length(mm)	Seed thickness (mm)
V_1	93%	8.4	2.2
V_2	95%	9.2	2.4
V_3	95%	9.3	2.2
V_4	92%	9.7	2.1

Note: V_1 : BRRI hybrid dhan3, V_2:BRRI hybrid dhan5, V_3: Ishpahani hybrid dhan6 and V_4: BRRI dhan89 (V_4)

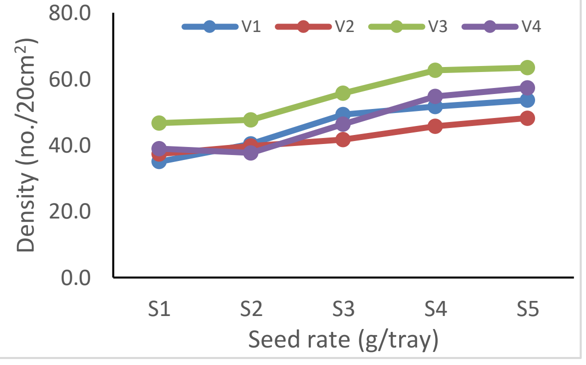


Fig. 5. Seed sensity after immediate after sowing.

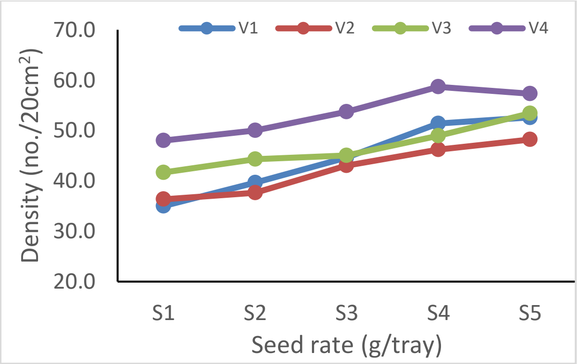


Fig. 6. Seedling density after 7 days of sowing.

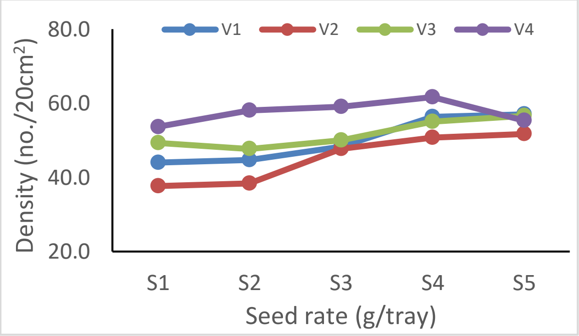


Fig. 7. Seedling density after 14 days of sowing.

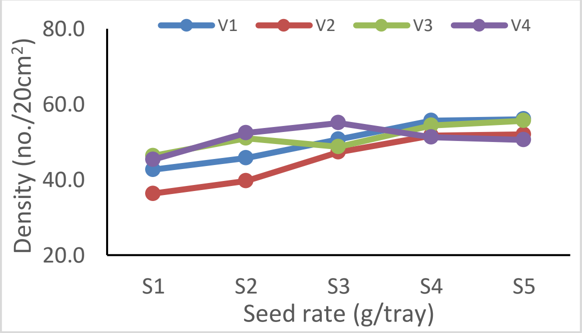


Fig. 8. Seedling density after 21 days of sowing.

Note: Variety: V_1 : BRRI hybrid dhan3, V_2:BRRI hybrid dhan5, V_3: Ishpahani hybrid dhan6 and V_4: BRRI dhan89 and Seed rate: S_1: 80 g/tray, S_2: 90 g/tray, S_3: 100 g/tray and S_4: 110 g/tray

Seedling height

Seedling height measured at 7, 14 and 21 days after sowing (Fig. 9-11). At seven days after sowing, seedling height only varied significantly with the varieties while at seven and 21 days after sowing, it was varied with the both variety and seed rates. Seedling height of the BRRI hybrid dhan5 and Ishpahani hybrid dhan were significantly more compared to the BRRI hybrid dhan3 and BRRI dhan89. At 21 days after sowing, seedling height gradually decreased with the increase of seed rate.

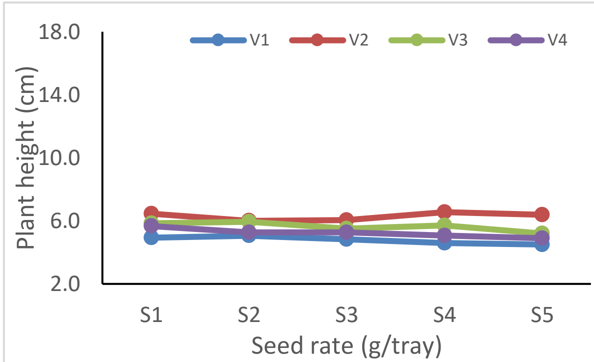


Fig. 9. Seedling height after seven days of sowing.

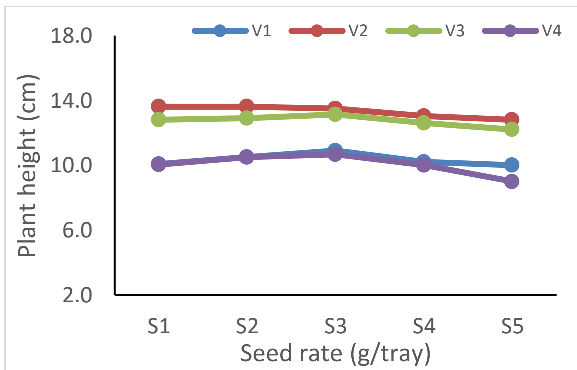


Fig. 10. Seedling height after seven days of sowing.

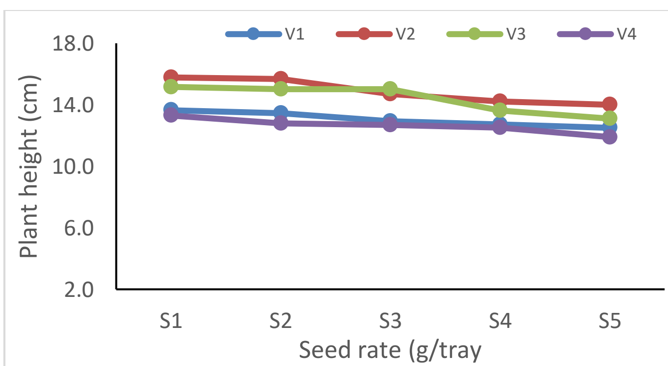


Fig. 11. Seedling height after 7 days of sowing

Note: Variety: V_1: BRRI hybrid dhan3, V_2: BRRI hybrid dhan5, V_3: Ishpahani hybrid dhan6 and V_4: BRRI dhan89 and Seed rate: S_1: 80 g/tray, S_2: 90 g/tray, S_3: 100 g/tray and S_4: 110 g/tray

Transplanting parameters

Number of hills per unit area. Two-way interaction of varieties and seed rate did no show significant effect on number of hills/m^2 while variety and seed rate individually showed significant effect on number hills/m^2. Higher number of hills per unit area were observed for Ishpahani hybrid dhan6 and BRRI dhan89. Contrary, 120 g/tray produced significantly higher number of hills per unit area which is similar with

110 g/tray while lower number was observed for 80 g/tray followed by 90 g/tray (Fig. 12).

Number of plants per hill. Two-way interaction of varieties and seed rate did no show significant effect on number of plants per hill while only seed rate showed significant effect on number plants per hill (Fig. 13). There have no significant variation of plants per hill among the seed rate of 100, 110 and 120 g/tray while lower number of plants per hill was observed for the seed rate of 80 and 90 g/tray.

Percent of missing hills. Interaction of variety and seed rate did not affect significantly on the percentage of missing hills while seed rate individually influenced the percentage of missing hills (Fig. 14). Percentage of missing hills decreased significantly with the increased of seed rate irrespective of the varieties.

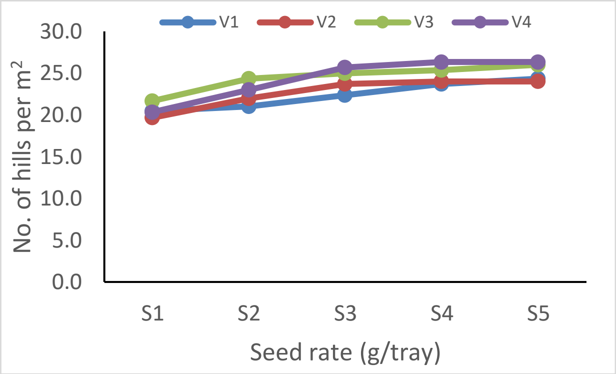


Fig. 12. Number of hills per m^2 .

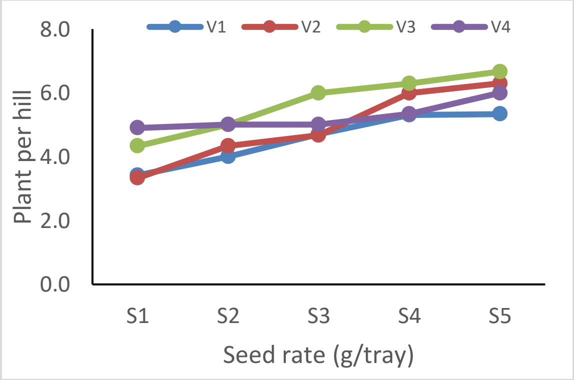


Fig. 13. Number of plants per hill.

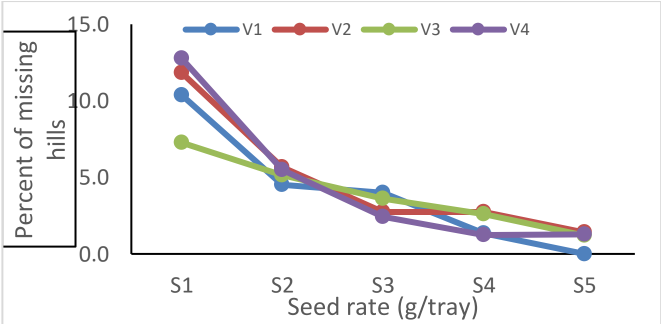


Fig. 14. Percent of missing hills as affected by variety and seed rate.

Yield and yield parameters

Grain yield (t/ha). Two-way interaction of variety and seed rate per tray was found significant effect on yield as were single effect of variety and seed rate. Significantly higher yield was observed for the variety of BRRI hybrid dhan5 under the seed rate of 110 g/tray while it was similar for the Ishpahani hybrid dhan6 under the same seed rate and BRRI hybrid dhan5 under the seed rate of 100 g/tray (Fig. 15). Among the four verities, BRRI hybrid dhan5 produced higher yield followed by Ishpahani hybrid dhan6 while BRRI dhan89 showed lower yield compare to the hybrid varities irrespective of the seed rate (Fig. 16). Contrary, seed rate of 100 g/tray produced significantly higher yield followed by 120 g/tray while 80 g/tray produced lower yield followed by 90 and 100 g/tray (Fig. 17).

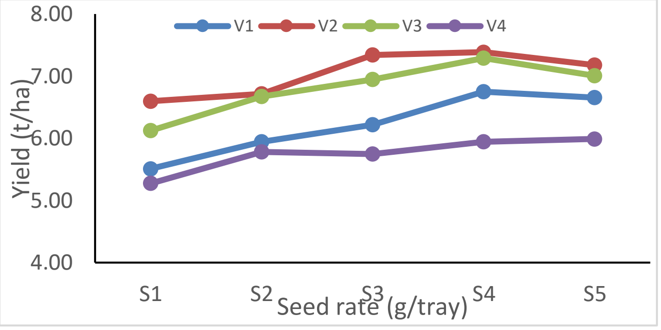


Fig. 15. Effect of variety and seed rate on yield (t/ha) where S×V: $p<0.01$.

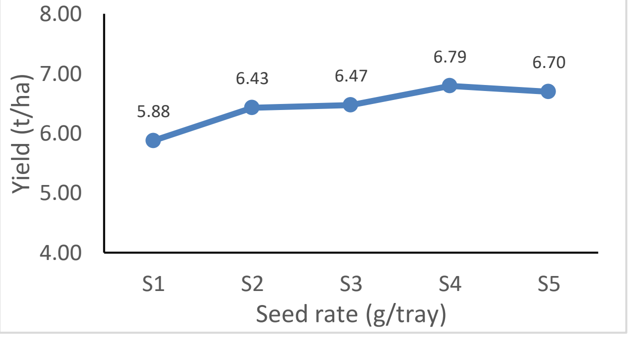


Fig. 16. Effect of seed rate on yield where S: $p<0.01$.

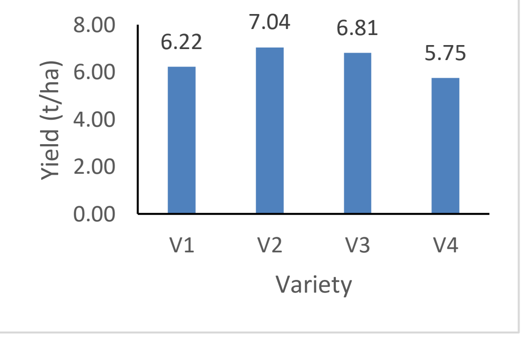


Fig. 17. Effect of variety on yield where $p<0.01$.

Note: Variety: V_1: BRRI hybrid dhan3, V_2: BRRI hybrid dhan5, V_3: Ishpahani hybrid dhan6 and V_4: BRRI dhan89 and seed rate: S_1: 80 g/tray, S_2: 90 g/tray, S_3: 100 g/tray and S_4: 110 g/tray.

TGW (t/ha). Two-way interaction of variety and seed did not show significant effect on 1000 grain weight while variety and seed rate individually showed significant effect on TGW (Figs. 18 - 20). Significantly higher TGW was observed for the variety of BRRI hybrid dhan5 under the seed rate of 110 g/tray while it was similar under the seed rate of 120, 100 and 90 g/tray. Among the four varieties, TGW was more for BRRI hybrid dhan5 followed by BRRI hybrid dhan3 and Ishpahani hybrid dhan6 while lower TGW was observed for BRRI dhan89 (Fig. 19). Significant effect also observed for seed rate on TGW. Higher TGW was counted for the seed rate of 110 g/tray while it was similar for 120g/tray/ Lower TGW was observed for 80, 90 and 100 g/tray (Fig. 20).

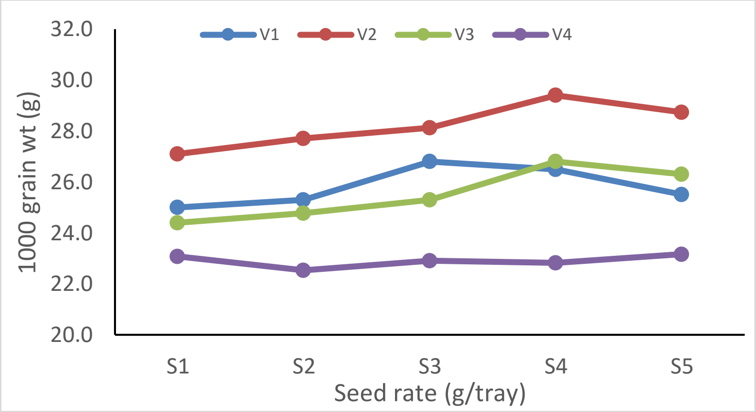


Fig. 18. Effect of variety and seed rate on TGW (g) where S×V: p>0.05.

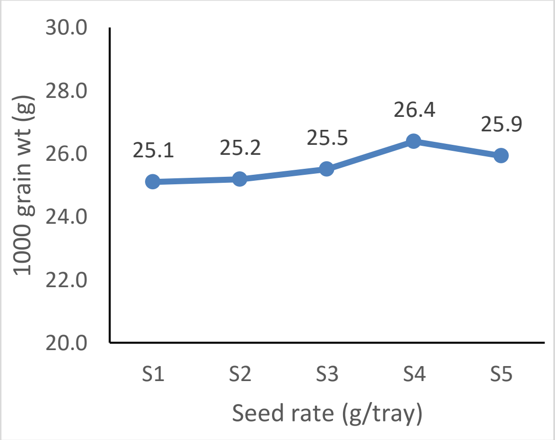


Fig. 19. Effect of seed rate on 1000 grain weight (g) where S: p<0.01.

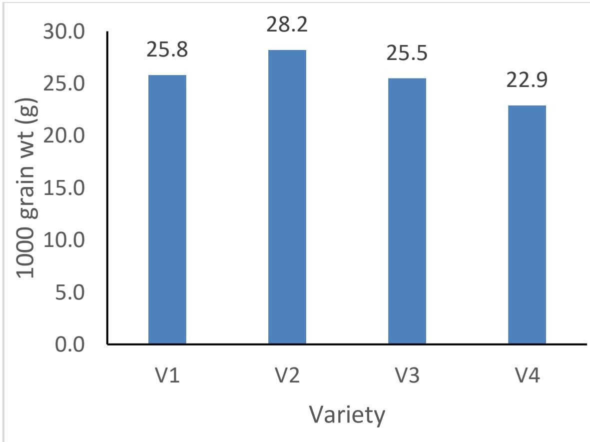


Fig. 20. Effect of variety on 1000 grain weight (g) where $p<0.01$.

In Bangladesh, hybrid rice is currently being transplanted mechanically. In order to maximize crop yield while maintaining seed rate of high values hybrid seed, optimal seed rate identification is crucial need for mat type seedling raising. Regardless of the seed type, 100 to 110 g/tray of seeds might be used for mat type seedling growing of hybrid rice, taking into account seedling density, seedling height, mat quality, number of hills per unit area, number of plants per hill, missing hills, as well as yield of grain.

Development of mat-type seedling using hydrophonic technique

In Bangladesh, mat-type seedling is crucial for mechanical rice transplanters. A mat-type seedling is nurtured on a polythene sheet with a thin layer of soil and farm yard manure (FYM). The polythene stops seedling roots from reaching the soil, forming a mat. A machine transplant requires this sort of nursery. The mat is tailored to suit the transplanter's trays. The soil situation will affect tray seedling output. Mat type is also prone to soil-born seedling blight. The usage of diseased soils or upland agricultural soils (pH>5.5) enhances disease incidence at low temperatures. In recent years, hydroponics has gained interest. Hydroponics involves growing plants with their roots in mineral-rich water. Usually economically valued crops are produced using this approach in a controlled environment, although research is underway to create seedlings in grass and wheat. To build a labour-saving rice transplanting method, a 6-m-long, 28-cm-wide mat of hydroponically produced rice seedlings was created. Hydroponic rice cultivation has not been widely investigated. So, there is inadequate data on the effects of liquid fertiliser dosage, seed rate, and root mat strength. So this subject is workable.

Seedling preparation and management. Sun-dried seeds were cleaned to remove impurities and immersed in the water before incubation to remove unfilled grain and other impurities. To protect seedlings from seed-borne diseases Atostin (*i.e.* Carbendazim) powder mixed water treat was used. Seed germination percentage was checked (>95%). Healthy seeds were picked by a specific gravity method. The pre-soaked seeds were weighed according to treatment, soaked in water overnight before sowing, and the partially sprouted seedling trays were put in the wet nursery two days after incubation. The trays were covered by the net to protect them from birds and insects (Plate 7)

Plate 7. Tray setup.

Experimental design and treatments. Three factors: media (Factor A), solution rate (Factor B) and seed rate (Factor C) were arranged in a randomized complete block (RCB) design with three replications (Table 12). Yoshida solution was sprayed at three doses (1X, 2X and 3X) at 6 hr intervals.

Table 12. List of the three main factors characters of the experiment.

Media (Factor A)	Solution rate (Factor B)	seed rate (Factor C)
Without any media (M1)	X1	120 gm
Rice husk (M2)	X2	150 gm
	X3	180 gm
		210 gm

Data collection. The agronomic characteristics of seedling density per unit area, leaf length (Only the top leaf length was measured under this study), and steam thickness were measured after ten seedlings were randomly selected by hand from each treatment combination. Vernier caliper was used to measure the stem thickness of a 25-day-old seedling. The rolling quality of the seedling mat was measured in terms of scored 10 for excellent (no crack during rolling), 8 for good (single and minor crack), 6 for medium (more than one crack but possible to roll up: medium crack), 4 for bad (more than one crack and difficult to roll up: major crack), 2 for very bad (more than one and large size crack and very difficult to roll up: extreme crack) and 1 for not possible to roll up in any way. Mat strength was measured by the pulling capability which was expressed by Kg. **Plate 8** shows the data collection procedure.

Table 13 displays the seedling height (cm) at different media (M1 and M2) with different solutions and seed rates. The seedling height of 12 cm is recommended for mechanical transplanting. In most cases, seedling height was increased with increased seed rate and solution rate. Highly significant effect was found for all single effects, but there was no combined effect.

Plate 8. Data collection mat type seedling using hydrophonic technique.

Table 13. Seedling height using hydrophonic technique.

Treatment	M1			M2		
	S1	S2	S3	S1	S2	S3
R1	13.62^{l}	13.71^{kl}	13.82^{ijk}	19.03^{g}	19.04^{fg}	19.25^{cde}
R2	13.68^{kl}	13.79^{jk}	13.92^{hij}	19.11^{ef}	19.24^{cde}	19.38^{abc}
R3	13.70^{kl}	13.97^{hi}	13.97^{hi}	19.16^{def}	19.32^{bc}	19.46^{ab}
R4	13.75^{kl}	13.78^{jk}	14.0^{lh}	18.90^{fg}	19.28^{cd}	19.51^{a}

Table 14. Seedling stem thickness using hydrophonic technique.

Treatment	M1			M2		
	S1	S2	S3	S1	S2	S3
R1	1.75^{ghij}	1.82^{cdef}	1.87^{abc}	1.86^{bcd}	1.90^{ab}	1.92^{a}
R2	1.74^{ghij}	1.76^{fghi}	1.81^{cdef}	1.81^{efgh}	1.87^{abcd}	1.87^{abcd}
R3	1.69^{jk}	1.72^{ijk}	1.80^{efg}	1.78^{efgh}	1.83^{cde}	1.83^{cde}
R4	1.66^{k}	1.67^{k}	1.74^{ghij}	1.74^{ghij}	1.76^{ghij}	1.78^{efgh}

Table 14 presents the M1 had the thickest stems, followed by M2. The highest steam thickness was observed at 1.92 by M2 with seed rate R1 and solution S3 and the lowest steam thickness was observed at 1.66 by M1 with seed rate R4 and solution S1. It was observed that stem thickness decreased as the seed rate increased and steam thickness increased as the solution rate increased.

Table 15 shows the highly significant effect of seed rate for mat type seedling. The density of seedlings increased with the increase in seed rate. The highest result was found at 10.06 by the seed rate R4 with solution rate 2 at media 2. No combined significant effect was found in this case.

Table 15. Seedling density using hydrophonic technique.

Treatment	M1			M2		
	S1	S2	S3	S1	S2	S3
R1	5.73[de]	5.80[de]	5.73[de]	5.66[de]	5.66[de]	5.93[d]
R2	7.13[c]	7.13[c]	7.26[c]	7.13[c]	7.40[c]	7.60[c]
R3	8.26[b]	8.60[b]	8.33[b]	8.33[b]	8.53[b]	8.60[b]
R4	9.80[a]	10.00[a]	9.86[a]	9.80[a]	10.06[a]	9.86[a]

From Table 16, mat quality increased with an increase in the seed rate except for seed rate R4 in the case of media 1. At media 2, mat quality increased with an increase in the seed rate in all cases. Mat strength was increased with an increase in the seed rate and better results were found for M1 compared to M2 (Table 17). Based on mat quality and mat strength, M1:S2: R3 combination was found better for raising mat-type seedlings suitable for mechanical transplanting.

Table 16. Mat quality using hydrophonic technique.

Treatment	M1			M2		
	S1	S2	S3	S1	S2	S3
R1	3.33[g]	4.00[fg]	4.66[efg]	4.66[efg]	4.00[fg]	4.66[efg]
R2	5.33[def]	6.00[cde]	6.66[bcd]	4.66[efg]	6.00[cde]	6.00[cde]
R3	7.33[abc]	8.66[a]	8.00[ab]	6.00[cde]	6.00[cde]	6.66[bcd]
R4	7.33[abc]	8.00[ab]	7.33[abc]	6.66[bcd]	6.66[bcd]	6.66[bcd]

Table 17. Mat strength using hydrophonic technique.

Seed Rate	M1			M2		
	S1	S2	S3	S1	S2	S3
R1	.98[kl]	1.13[jk]	1.15[jk]	.92[lm]	.76[m]	.98[kl]
R2	1.57[efg]	1.63[ef]	1.68[de]	1.04[k]	1.23[ij]	1.29[i]
R3	1.94[bc]	2.16[ab]	2.06[bc]	1.49[gh]	1.51[gh]	1.50[gh]
R4	2.10[ab]	2.23[a]	2.12[ab]	1.65[ef]	1.72[d]	1.69[de]

Design and development of a manually operated briquetting machine

A study was conducted to develop a manual operated piston pressing briquette machine for small hold farmers in the FMPHT Divisional research workshop. Rice husk and grinded maize stem with suitable binding material will be used as a raw material for briquetting.

Design consideration

- This machine should be suitable for using in the household level.
- This briquette machine should be very simple which would be manually operated.
- This machine should be very handy to operate.
- Existing pressing machines have some environmental hazard but it should be smoke free and environmentally friendly.
- It can be fabricated and repaired by locally available materials.
- It should be easily affordable to small hold farmers to fulfil his daily fuel required for household purpose specially for cooking activities.

Design steps

- According to design, material was collected from local market.
- Firstly, a prototype of basement with cylinder was fabricated as per design

- The cylinder was designed considering the available size of the briquette.
- Pressing piston and pressing unit were designed in a way that sufficient compression strength can develop during pressing.
- Basement with cylinder, pressing piston with scissor jack pressing mechanism and handle were assembled in FMPHT divisional workshop.
- After prototype fabrication, lab test was conducted using charcoal with rice husk, rice husk with soaked flour.

Fabrication

- Materials like mild steel sheet, pipe, plate, box and angle collected from local market and fabricated in FMPHT workshop.
- Pressing unit (scissor jack) was fabricated by using mild steel angle and 2cm diameter round rod, which is set at the top of piston (Plate 9).
- A hand wheel is attached with power screw to make the operational process much easier and handy (plate 10).
- As per design square cylinder constructed and assembled at the bottom of pressing unit (Plate 11).

Plate 9. Fabricated prototype of the manually operated briquette machine.

Plate 10. Pressing piston.

Plate 11. Square cylinder.

Working principle. Scissor jacks are simple mechanisms used to press of lift large loads from short distances**.** A scissor jack uses a simple theory of gears to get its power (Plate 12). As the screw section is turned by handle wheel, two ends of the jack move closer together. Because the gears of the screw are pushing up the arms, the amount of force being applied is multiplied. It takes a very small amount of force to turn the handle wheel, yet that action causes the arms to slide across and together. As this happens the arms extend downward through the cylinder and press the raw material given into the cylinder. Review and literature show that a simple scissor jack can press or lift load approximately 1 to 1.5 ton.

Plate 12. Scissor jack **(**Pressing unit).

Overall dimension of the device is about 138×56×56 (L×W×H). The weight of device found 43.5kg, it might be varied with material used. According to design**,** manually operated briquette machine is fabricated in FMPHT workshop. Functional evaluation of the device will be tested soon. As it has to test the performance using rice husk and maize stem mixer as raw material, the performance of this device will be done in upcoming maize harvesting season.

CLIMATE SMART PRECISION FARMING

Estimating the Standardized Precipitation Evapotranspiration Index Using Data-Driven Techniques: A Regional Study of Bangladesh

Drought is one of the most complicated recurring natural disasters, defined by a deficiency of precipitation, causing prolonged water scarcity. Failure to manage drought risk effectively has the potential to have dire consequences for people, livelihoods, the economy, and ecosystems. The frequency of extreme droughts will nearly double in the coming decades. Thus, drought forecasting, and early warning are critical for agricultural resilience to climate change.

Drought analysis and prediction need reliable rainfall and temperature data recorded for a longer period. However, an uninterrupted climate record for a longer period is not available in most of the meteorological stations of Bangladesh. This limits drought prediction using conventional statistical and numerical models. ML algorithms could be one of the solutions for bridging the climate data gap. Furthermore, to the best of our knowledge, no research has been published in the literature that predicts the SPEI in the study region using ML approaches applied. Hence, this work aimed to assess the performance of standalone models and novel hybrid ML algorithms in SPEI estimation. Additive regression, random subspace, and M5P tree models and their hybridized versions were used to predict SPEI. Agricultural drought is measured in Bangladesh using a 6-month SPEI, while the water scarcities, river flow declines, and hydrological droughts are measured using 9, 12, and 24-month SPEIs. As a result, forecasting models were developed to predict SPEI for those four timescales over 38 years (1980–2018). The models were developed for a single station in northwestern Bangladesh (Rajshahi), which is extremely prone to droughts, and tested at four locations, including Bogura, Rangpur, Mymensingh and Khulna.

Data were collected in the first phase to estimate the SPEI from 1980 to 2018. The best subset regression model for selecting the optimal combination of climatic variables was then used to create seven machine learning models (standalone and hybrid) to predict the multiscale SPEI. The validation stations were used to forecast SPEIs using the best prediction model.

Machine learning algorithms: For the prediction multiscale SPEI, this study considered three tree-based algorithms, random subspace (RSS), additive regression (AR), and M5 pruned (M5P), and their stacking hybrid forms, AR-RSS, AR-M5P, RSS-M5P, and AR-RSS-M5P (Table 18). The basic concept of tree-based algorithms is fitting decision trees to different sub-samples of calibration datasets and then integrating the prediction of each tree to provide the final output. Fitting models to different sub-samples allows data decomposition in detail for better identification of complex input–output relations. The advantages of these non-parametric methods are accurate prediction, little data pre-processing such as normalization or scaling, and no assumptions on space distributions.

Figure 22 shows flowchart illustrating the methodology used. The programme also features a graphical user interface (GUI), which facilitates the programmes operation. There are additional alternatives, such as MATLAB, Python, and R, but preparing and implementing computer codes using those programmes requires considerable time.

A grid search optimization algorithm was used to select optimum ML model parameters. It randomly searches the optimum parameters within a discrete grid space. The value within the range that provides the most accurate prediction is selected.

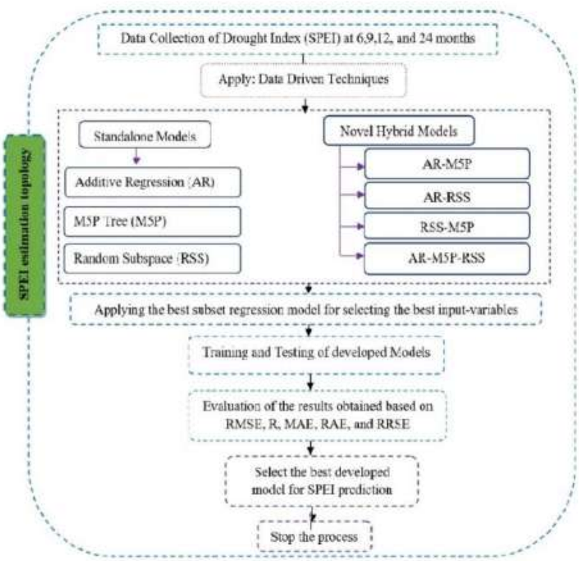


Fig. 22. Flowchart of SPEI estimation methodology in the study area.

Table 18. The parameters of the machine learning algorithm in modeling SPEI-6, -9, -12 and -24.

Model name	Parameter description
Random Subspace (RSS)	Batch size-100, Classifier = REPTree, random seed-1, subspace size = 0.5, numbers of executions slots = 1, number of iterations = 10
Additive Regression (AR)	Batch size-100, Classifier = Bagging, shrinkage = 1, number of iterations = 30
M5 Pruned (M5P)	Batch size-100, Minimum number of instances = 4

Constructing and evaluating models. Choosing suitable input and output variables for non-linear hydrologic systems can be time-consuming. SPEI 6, 9, 12, and 24 were calculated using precipitation and temperature data from BRRI RS, Rajshahi. The most important inputs (at different time lags) for the target variable (output) were selected by using subset regression and sensitivity analyses. When there are many input variables, one of the most critical stages in the soft computing model is feature selection. The current study employed best subset regression to determine the best possible input combinations for the SPI 6, 9-, 12-, and 24-month models. The optimal input combination was determined using six statistical criteria (MSE, determination coefficients (R2), adjusted R2, Akaike's AIC, Mallows' Cp, Akaike's AIC, and Amemiya's PC).

Multiscale SPEI data were predicted using standalone ML models and their stacking hybrid forms at BRRI RS, Rajshahi station. The models were developed using 30-year monthly data (1980–2009), and 9-year data (2010–2018) were used to test the model at BRRI RS, Rajshahi. Evaluation of model outputs was carried out using statistical indices and visual interpretation, including Taylor diagram, scatter, and boxplots. The models with the lowest RMSE, MAE, RAE, RRSE, and greater R during testing were considered superior for drought prediction. An evaluation was performed on the generalizability of the most successful model developed at BRRI RS, Rajshahi station to predict SPEI at other stations (Bogra, Mymensingh, Khulna and Rangpur).

Model Input Selection:

The inputs used to develop the SPEI for various temporal scales at the Rajshahi station are summarized in Table 30.

Table 30. Input variables selected for multiscale SPEI prediction.

Output	Input Variables
SPEI6	SPEI (t-1), SPEI (t-6), SPEI (t-7)
SPEI9	SPEI (t-1), SPEI (t-2), SPEI (t-3), SPEI (t-4), SPEI (t-6), SPEI (t-7), SPEI (t-8)
SPEI12	SPEI (t-1), SPEI (t-3), SPEI (t-4), SPEI (t-5), SPEI (t-6), SPEI (t-7), SPEI (t-8)
SPEI24	SPEI (t-1)

Prediction of droughts using machine learning techniques: According to statistical metrics, the models' performance at Rajshahi station is shown in Table 31. The best results are shown in the table in bold type.

Table 20. Computed statistical index values for the seven machine learning models (individual and hybrid) during training and testing stages.

Model	Training Period (1980–2009)					Testing period (2010–2018)				
	R	*MAE*	*RMSE*	*RAE (%)*	*RRSE (%)*	*R*	*MAE*	*RMSE*	*RAE (%)*	*RRSE (%)*
SPEI6										
AR	0.929	0.268	0.363	34.20	37.70	0.675	0.594	0.770	66.90	71.90
M5P	0.785	0.443	0.596	56.58	61.97	0.757	0.491	0.674	55.26	62.92
RSS	0.809	0.431	0.567	54.99	58.95	0.687	0.571	0.740	64.32	69.12
AR-M5P	0.786	0.453	0.597	57.83	62.06	0.707	0.542	0.715	60.94	66.81
AR-RSS	0.788	0.458	0.593	58.46	61.66	0.642	0.597	0.770	67.20	71.97
RSS-M5P	0.7947	0.444	0.586	56.72	61.02	0.713	0.536	0.708	60.29	66.16
AR-M5P-RSS	0.7697	0.473	0.618	60.37	64.27	0.697	0.547	0.722	61.54	67.43

SPEI9										
AR	0.968	0.168	0.246	21.35	25.25	0.747	0.444	0.600	53.97	57.32
M5P	0.879	0.323	0.465	41.03	47.61	**0.763**	**0.397**	**0.571**	**48.31**	**54.53**
RSS	0.893	0.316	0.444	40.14	45.48	0.762	0.426	0.573	51.77	54.76
AR-M5P	0.858	0.346	0.503	44.01	51.55	0.736	0.447	0.615	54.34	58.75
AR-RSS	0.922	0.284	0.387	36.14	39.65	0.718	0.460	0.619	55.95	59.08
RSS-M5P	0.882	0.320	0.461	40.70	47.23	0.742	0.438	0.612	53.23	58.44
AR-M5P-RSS	0.859	0.345	0.502	43.91	51.42	0.740	0.460	0.619	55.95	59.08
SPEI12										
AR	0.977	0.133	0.210	16.95	21.45	0.833	0.339	0.483	40.62	45.21
M5P	0.925	0.254	0.373	32.33	38.06	**0.869**	**0.281**	**0.424**	**33.56**	**39.70**
RSS	0.909	0.321	0.434	40.74	44.26	0.711	0.472	0.617	56.43	57.82
AR-M5P	0.926	0.249	0.370	31.67	37.80	0.851	0.306	0.44	36.62	41.62
AR-RSS	0.954	0.209	0.298	26.55	30.41	0.802	0.407	0.53	48.64	49.42
RSS-M5P	0.934	0.243	0.350	30.86	35.71	0.849	0.313	0.45	37.44	42.20
AR-M5P-RSS	0.928	0.246	0.365	31.21	37.22	0.847	0.324	0.456	38.74	42.75
SPEI24										
AR	0.975	0.140	0.197	19.28	22.19	0.908	0.227	0.403	18.18	28.92
M5P	0.960	0.168	0.247	23.09	27.90	**0.928**	**0.208**	**0.389**	**16.60**	**27.89**
RSS	0.969	0.156	0.221	21.47	24.91	0.915	0.232	0.401	18.54	28.75
AR-M5P	0.958	0.182	0.254	25.09	28.71	0.884	0.269	0.436	21.49	31.30
AR-RSS	0.959	0.183	0.251	25.13	28.38	0.878	0.280	0.441	22.37	31.62
RSS-M5P	0.963	0.172	0.241	23.70	27.16	0.874	0.283	0.440	22.68	31.58
AR-M5P-RSS	0.962	0.173	0.242	23.84	27.32	0.886	0.270	0.433	21.59	31.09

Numbers in boldface indicate the ideal values.

Based on the testing data, the best-performing model was selected. Table 20 shows that M5P was the best predictor of SPEI on all time scales, with the highest accuracy.

Taylor diagrams (TD) were used to examine the geographic configuration of predicted and calculated (observed) multiscale SPEI values based on various ML models during testing. There was a good correlation between the Taylor diagram (Fig. 23) and the derived performance indicators in Table 31. SPEI has the best M5P prediction–observation agreement (orange triangle) of any timeframe except SPEI9, as shown by the Taylor diagram. The lowest RMSE (0.424) and highest correlations (0.869) were for the M5P model for SPEI9, while the variation in RSS-M5P (0.968) was the most in line with observations.

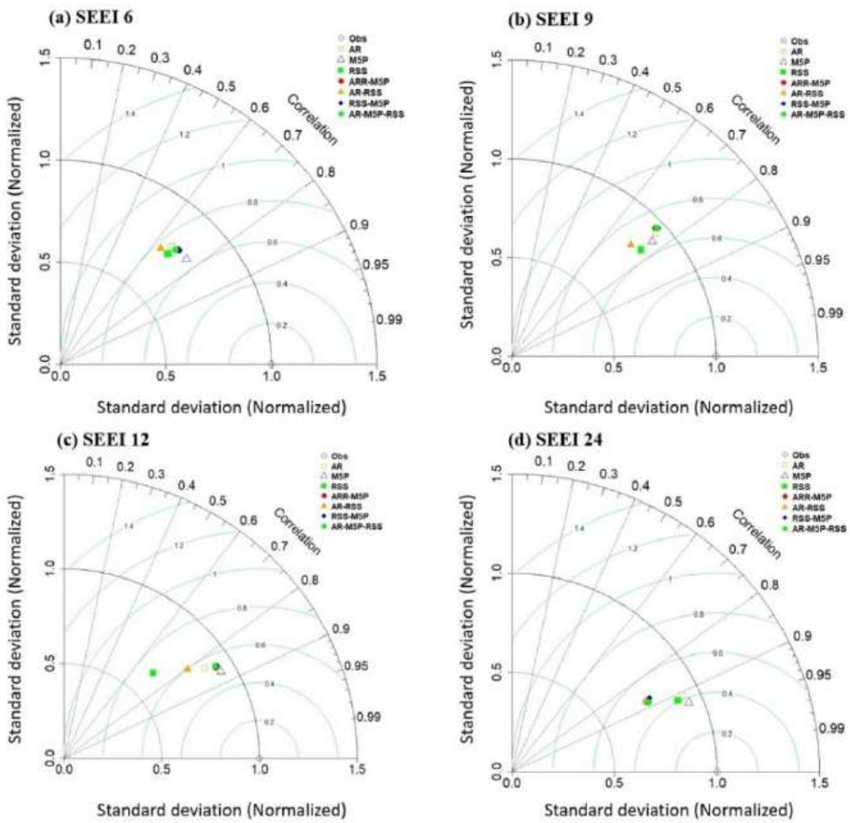


Fig. 23. Taylor diagram representation of model's performance in predicting SPEIs at BRRI RS, Rajshahi station over multiple time scales during the testing period (a)SEEI-6; (b) SEEI-9; (c) SEEI-12; (d) SEEI-24.

Model validation*:* The best predictive model (M5P) was used to predict multi-scaler SPEI values at four different stations located throughout the drought-prone northern part of Bangladesh: Rangpur, Bogura, Mymensingh, and Khulna. Model performance was evaluated at the test locations for the whole study period (1980–2018). According to various statistical indices, the performance evaluation results are summarized in **Table 32**. The model performed satisfactorily in terms of the statistical indices computed. The M5P predicted the SPEI-6, 9, 12, and 24 with R values ranging from 0.787 to 0.802, 0.850 to 0.882, 0.899 to 0.938, and 0.927 to 0.966, respectively. The MAE, RMSE, RAE, and RRSE were all low in terms of prediction on all time scales. In terms of accuracy, SPEI-24 was predicted as the best by the M5P model, followed by SPEI-9 and SPEI-6. According to the findings, drought forecasting in western Bangladesh could benefit from the M5P model developed in this study.

Table 21. Statistical performance of M5P model in predicting SPEIs at the test stations.

Model	Statistical indice				
	R	*MAE*	*RMSE*	*RAE*	*RRSE*
SEPI6-Bogura	0.802	0.44	0.58	54.50	59.47
SEPI6-Khulna	0.793	0.45	0.60	54.14	60.65
SEPI6-Mymensingh	0.787	0.46	0.61	55.37	61.37
SEPI6-Rangpur	0.791	0.46	0.61	56.09	60.85
SEPI9-Bogura	0.882	0.31	0.46	38.03	46.65
SEPI9-Khulna	0.850	0.37	0.52	43.58	52.32

SEPI9-Mymensingh	0.880	0.33	0.47	40.81	46.99
SEPI9-Rangpur	0.861	0.35	0.51	42.79	50.38
SEPI12-Bogura	0.938	0.24	0.34	29.04	34.34
SEPI12-Khulna	0.899	0.30	0.44	36.15	43.37
SEPI12-Mymensingh	0.925	0.26	0.37	31.57	37.43
SEPI12-Rangpur	0.929	0.24	0.37	30.13	36.65
SEPI24-Bogura	0.962	0.17	0.27	20.60	26.45
SEPI24-Khulna	0.927	0.24	0.37	28.25	36.17
SEPI24-Mymensingh	0.961	0.18	0.27	21.94	26.80
SEPI24-Rangpur	0.966	0.16	0.26	19.28	25.17

Newly developed machine learning models for forecasting SPEI in Bangladesh were evaluated in this study. In Rajshahi, Bangladesh's most drought-prone location, the models were developed to predict SPEI for the period from 1980 to 2018. The model was validated at four stations distributed over the country's western region. SPEI was accurately predicted in Rajshahi using the M5P model. *R* values for SPEI-6, 9, 12, and 24 at the validation stations were 0.787–0.802, 0.850–0.882, 0.899–0.938 and 0.927–0.966, respectively. The M5P model can forecast droughts on multiple timescales according to correlation and low errors. As a result of climate change, the model's output could help predict when droughts will occur in the country and help mitigate their growing negative effects. This study considered only three tree-based algorithms for drought prediction. Bangladesh's droughts can be predicted using other ML models to see how well they work. Optimization algorithms can be combined with machine learning models to improve predictability.

Land suitability classification mapping through blending of GIS and machine learning approaches

The modern combine harvester is a versatile machine, which efficiently harvest a variety of grain crops within very short time. Combine harvesters are one of the most economically important labour saving inventions, significantly reducing the fraction of the population engaged in agriculture. However, the excessive moisture content, water logging, wet and muddy conditions of fields make combine harvesters unsuitable for harvesting operations. A suitable land selection is a prerequisite for harvesting crops in short periods using the combine harvester to overcome these issues. Considering the above matters, a GIS based suitable land classification map for combine harvester is urgently needed to reduce the human drudgery, production cost, harvesting losses and increase the cropping intensity, crop productivity. The current study applied the Weighted Overlay analysis technique. Machine learning algorithm like Extra Tree Classifier model was used instead of manual interpretaion of other methos like Analytical Hierarchy Process (AHP) to identify the relative weight of each thematic layers. A suitable land classification map could be a great opportunity to identify the suitable rice regions for smoothly harvesting operation of combine harvester through increasing the total agricultural production.

Study area. Study area is located in the north of sub-district Kaliakoir and west of Gazipur district Bangladesh, covering an area of 9.61 square kilometers (km2). The Kaliakoir is spread into 151 Mouzas and among them Uttor Simulia and Montala were choosen for this study. Figure 24 showing the details of the study area.

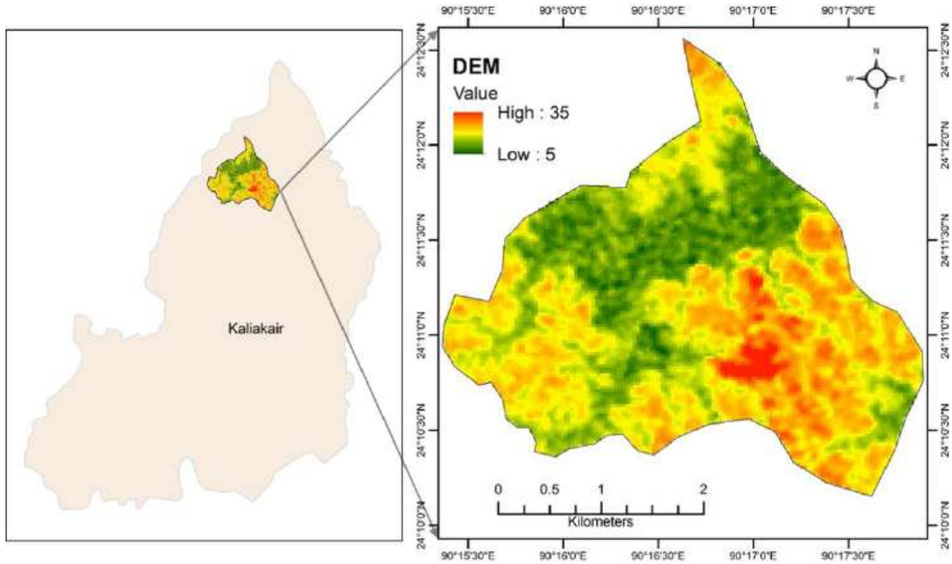


Fig. 24. Study area map covering the Uttor Simulia and Montala Mouza at Kaliakoir, Gazipur.

Methodological framework.

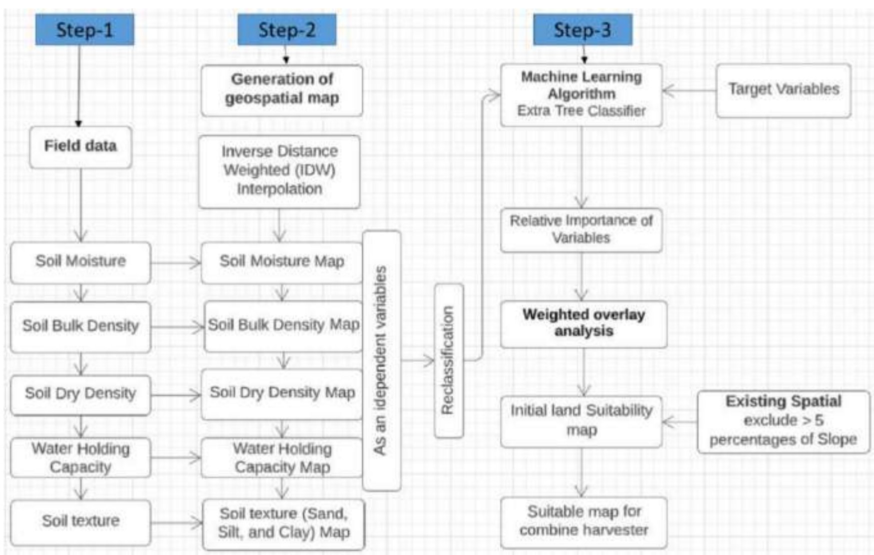


Fig. 25. Flow diagram of the processes used in this study.

Generation of thematic layers. The soil texture (sand, silt, clay), Bulk density, soil moisture, soil dry density, water holding capacity were the selected parameters in this study. Lab basis soil datasets were obtained from the BRAC Soil analytical lab, CERDI Road in Gazipur. The soil datasets were processed in Microsoft Office Excel 2016. The excel file was joined to ArcMap 10.7.1 through the Add Data dialog box. In this study, Inverse distance weighing (IDW) interpolation technique was used to generate each thematic layer. The prossecing extent was used as study area limited to a specific geographical area. A total of seven thematic layers were produced to generate a suitable land classification for combine harvester. Finally, all thematic maps were reclassified in five sub-classes to generate a common scale for all maps. Figure 25 presents the methodological framework.

Relative importance using machine learning approach. Many stratistical approaches like linear and multiple linear regreassion analysis used to analyze the relationship between the thematic factors and target variables. In this study, the target variables were selected as 1 where combine harvester was easily operated and 0 where combine harvester was not properly operated. However, it is very hard to develop the relationship between a lot of thematic factors and target variables due to its complexity of linear regression (Vázquez-Quintero et al., 2020). In this study, Extra Tree (Extremely Randomized Trees) machine learning algorithm was applied to examine the relationship of selected thematic layers and target variables and to identify the relative importance of all the variables. Generally, Extra Tree classifier constructs a set of decision tree and where decision rule is randomly selected. The selected algorithm helps to reduce the variance more strongly comapared to others methods (Geurts et al., 2006). The algorithm works as similar to Random Forest except the randomly selection of split values.

Delineation of suitable areas for combine harvester. Weighted overlay analysis is a multi-criteria decision based technique and used to develop the suitable area map for combine harvester depends on the number of thematic layers. The method provide a common measurement scale of all values to diverse and dissimilar inputs in order to generate an intregated approach. The weighted overlay technique is one of the most applied approach for overlay analysis to solve the multicriteria problems like as site selection and land suitability models. The weighted overlay analysis helps to reclassify the criteria of each thematic layer to the same scale according to the relative importance on land suitability. The values from 1 to 5 were applied to each class. The value of 1 was assigned to areas with the lowest suitabillity and value 5 was assigned to the mostly suitable areas. The thematic layers were multiplied by relative importance weight of each factor. Finally, all thematic layers were added for final weight to generate a suitable area map of the study area using the following formula:

$S = \sum Wi * Xi$...............(1)

Where, Wi = The weight of ith thematic map

Xi = Criterion score of class value for factor i

S = Suitability index map

In this research, the selected thematic layers were intregated in ArcGIS environment in order to generate a map representing suitable areas for the combine harvester operation during the harvesting season. the final intregated layer was derived by the summation of each pixel using the following formula:

$S = (CLf * CLc + SAf * SAc + SIf * SIc + BDf * BDc + SMf * SMc + DDf * DDc + WHf * WHc)$............... (2)

Where, CL = Clay

SA = Sand

SI = Silt

BD = Bulk density

SM = Soil moisture

DD= Soil dry density

WH = Water holding capacity

The subscript letter f indicates the weight of each thematic layer and c represents the weight of each class of the thematic layers. Finally, the natural break classification technique was applied to break the classified values in 1 (Very low), 2 (low), 3(moderate), 4 (high) and 5 (very high).

Spatial assessment of soil physical properties. Figure 26 shows the spatial distribution of soil texture (Sand, Silt, Clay) maps. The sand, silt, clay maps were classified in five sub-classes. Higher and lower percentages of clay were found as 19.98 to 13.02%, silt were 51.31 to 40.25%, sand were 39.23 to 33.38% respectively. Study findings indicate that higher percentages of sand and clay highly affected the combine harvester performance during the harvesting operation. Alternatively, higer percentages of silt play a vital role for smoothly operation of combine harvester at fields where lower percentages of silt indicate the lower harvesting operation.

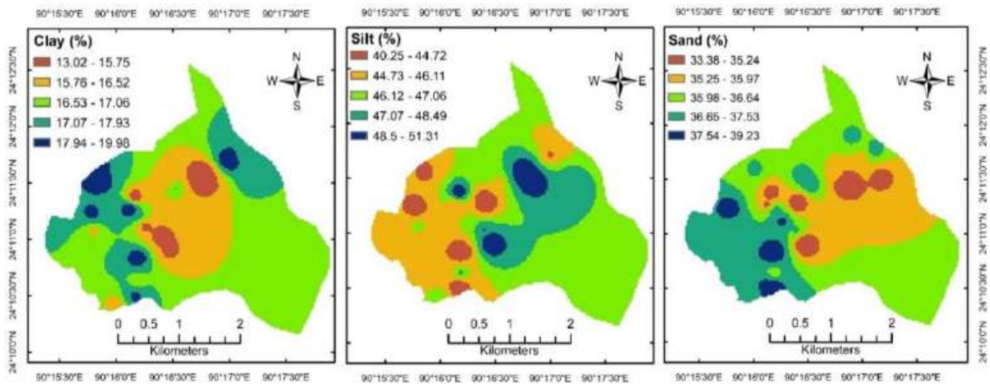


Fig. 26. Percentages of soil texture (clay, silt, and sand) spatial maps over the study regions.

Figure 27 shows the spatial distribution of soil bulk density, soil moisture, soil dry density, water holding capacity maps over the study region. The higher and lower soil bulk density were 1.75 to 1.34 (g/cc); soil moisture were 50.74 to 22.48%; soil dry density were 1.42 to 0.93 (g/cc); water holding capacity were 76.0 to 61.43% respectively. The bulk density, soil dry density, water holding capacity showed highly correlation. Higher values of bulk density, soil dry density, water holding capacity indicated suitable land for combine harvester where lower values showed the opposite results. However, percentages of higher moisture lead to make the land condition unfavourable for combine harvester and indicated as unsuitable land cover patterns.

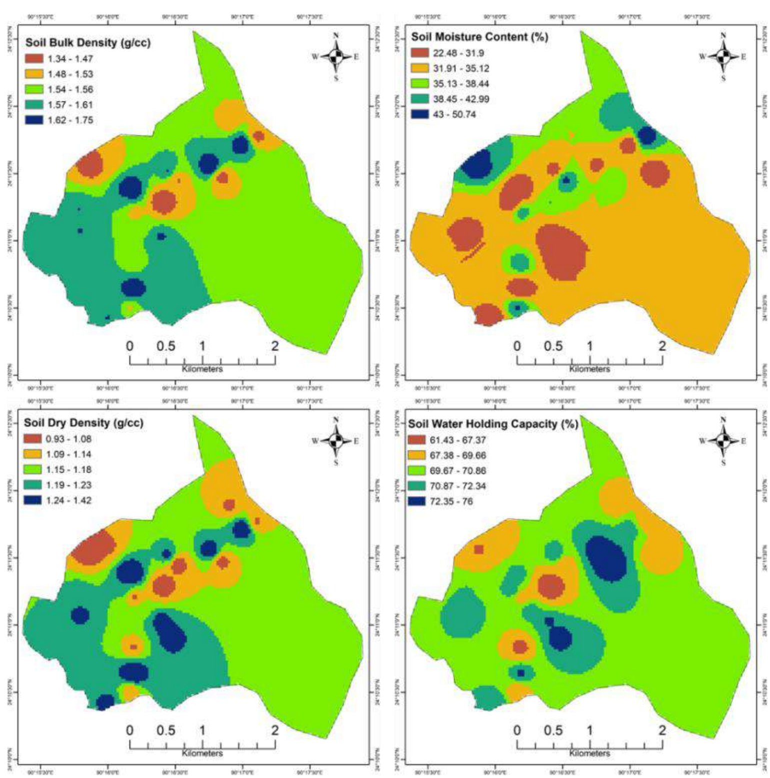


Fig. 27. Spatial distribution of soil bulk density, soil moisture, soil dry density, and water holding capacity maps.

Assessment of land suitability map for combine harvester. Assessment of land suitability for combine harvester is crucial during the time of mechanization in Bangladesh. Figure 28 shows the spatial distribusion of land suitability map for combine harvester in the target regions. The map was reclassifed and project to WGS_1984_UTM_Zone_46N coordinate system and pixel cell size was set as 30*30 m spatial resolution. The majority filter was applied to replace cells in a raster based on the majority of their contiguous neighboring cells (4). The land suitability map was classified in four sub-categories like as very suitable, moderate, low, and very low respectively. Total pixels of each classes were calculated in square kilimeter (sq.km). Study findings indicates that 1.88 sq.km2 areas are very highs suitable, 4.16 sq.km2 areas are moderately suitable, 2.67 sq.km2 areas are low suitable, and 0.86 sq.km2 very low suitable. Suitable land mainly observed at southwest and east side of the area. In opposition, low and very suitable land areas were indentified at the northwest, northeast and central portions of the study regions. The study will help the comercial combine harvester user, policy makers to idendify the suitable land for combine harvester in study region which will helps to enhance mechanization as well as food security in Bangladesh. The methodology also applicable for large areas based on the number of soil sample collection.

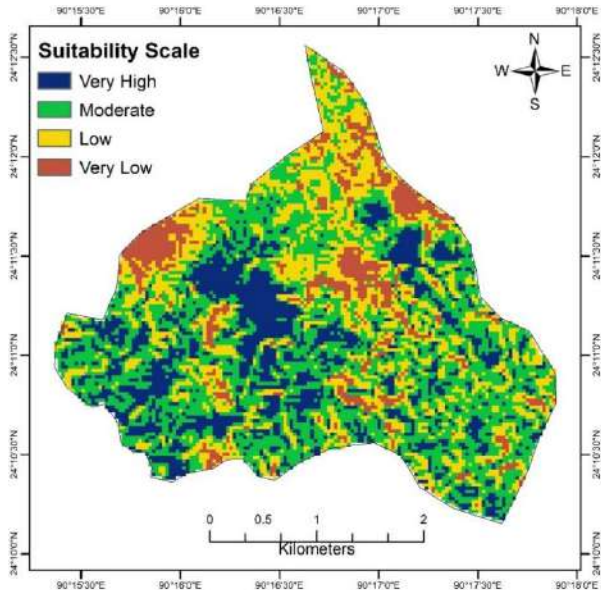


Fig. 28. Spatial distribusion of land suitability map for combine harvester.

MILLING AND PROCESSING TECHNOLOGY

Test, evaluation and modification of rubber roll de-husker and friction type polisher

The rice rubber rollers are constructed of two such rubber holdings, which are of same diameter, however, they operate at different speeds in order to remove the husk from the paddy. Among the two rubber rollers, one of them has a fixed position and the other is adjusted in order to suit the needs of the desired clearance. The adjusted rice rubber roller is operated at slightly less speed and the fixed one is operated at the other speed. Both the rice rubber rollers have an aspirator attached to the base of the machine so as to separate the hulls or the husk from the brown rice. This ensures that after the rice rubber roller operation, the entire husk is collected at one end and the rice is left inside the roller space. FMPHT Division modified rubber roll de-husker thats operates with 4 kW (3-phase 4 wire 1440 rpm) electric motor. Fixed and adjustable rubber roll diameter and length is 230 mm and 154 mm respectively. The RPM of the fixed and adjustable rubber roll are 1,050 and 790 rpm respectively. The blower rpm is 1020 rpm.

To fabricate stairway for facilitate carrying paddy 16 BWG sheet and 50 × 50 mm angle bar was used in the hopper. Bottom end of the de-husker connected with a husk aspirator through a pipe (dia. 200 mm). Aspirator fan is dia.330 mm and operates by 1.5 kW (2840 rpm) motor (Plate 22). A cyclone separator was modified and attached in the de-husker for collecting husk. Previously, husk was directly collected from aspirator discharge outlet with gunny bag, thus created huge amount of dust in the working area. Rubber roll de-husker does not damage the aleuronic layer of paddy. An airstream is blown over the grains and immature grains drop into the separate hopper for discharge. The paddy and husk discharge separately. Bangabandhu dhan100 (un-parboiled) was used in this experiment. The moisture content was 11% (wb.) and each sample size was 20 kg. De-husked paddy was processed in MNMP-15 model friction type polisher to evaluate the commercial value of milling parameter (plate 23).

Plate 22. Modified de-husker.

The average de-husking capacity of the husker was 815 kg/h and husking efficiency was about 90.92% (Table 22). Husking efficiency can be increased by closing the adjustable roller which increases the broken rice (brown rice). The average brown rice percentage was found 78.33% and the rest was husk and embryo. Average fixed and adjustable rubber roll rpm was found 1,050 and 790 respectively.

Table 22. Performance of developed husker for Bangabandhu dhan100.

Capacity (one pass) Kg/h	Husking efficiency (one pass) %	Brown rice, % (based on input paddy)	Adjustable roll speed (rpm)	Fixed roll speed (rpm)	Ratio of fixed and adjustable roller
802	90.50	79.0	788	1048	24.81
820	91.00	78.0	792	1050	24.57
823	91.25	78.0	791	1052	24.85
815	90.92	78.33	790	1050	24.80

Adjustable rubber roll rotates at average rpm of 790 which is 24.80 % less rpm than the fixed rubber roll. The difference in peripheral speed subjects the paddy grain falling between the rolls to a shearing action that strips off the husk. The clearance between the rolls is adjustable and it should be less than the thickness of the grain.

Evaluation of milling parameter of Bangabandhu dhan100 processed in friction type polisher

The average brown rice percentage of Bangabandhu dhan100 was found 78.33% (Table35) and it was polished in friction type polisher (Plate 23). The average capacity of the polisher was 762.3 kg/h and the average milling recovery was 64.5 %. The average head rice recovery (based on input paddy) was 58.3 % and head rice recovery (based on total milled rice) was 90.35 (Table 23).

Table 23. Milling parameter of Bangabandhu dhan100 processed in friction type polisher.

Capacity of bPolisher Kg/h	Milling yield %	Head rice % (Based on input paddy)	Head rice % (Based on total milled rice)	Broken rice % (Based on input paddy)	Broken riceb%b(Based on total milled rice)
760.0	64.0	58.0	90.63	6.0	9.37
762.0	65.0	58.6	90.15	6.4	9.85
765.0	64.5	58.4	90.54	6.1	9.45
762.3	64.5	58.3	90.35	6.17	9.56

The broken rice percentage was 6.17 % (based on input paddy) and 9.56% (based on total milled rice).

Plate 23. MN-15 friction type polisher in operation.

Husking efficiency and milling recovery was found around 90.92% and 64.5 % respectively for Bangabandhu dhan100 polished in friction type polisher followed by de-husking. The average head rice recovery based on input paddy was 58.3 %, which is promising for processing of quality rice. Steel engelberg huller may replace with one rubber roll de-husker and a polisher for better quality rice. De-husker also separate husk and polisher separate bran. Separately collected husk and bran is suitable for briquette and edible oil production.

Effect of aging on milling performance of premium quality rice

Aging is a post-harvest storage process to improve rice quality and functional properties. Aging is important in the post-harvest process because it can extend shelf life and increase the commercial value. During aging of rice, a number of physiochemical properties changes that causes impact on rice cooking and eating quality. Some report showed that aging generally results in a higher head rice yield on milling, higher volume expansion and water absorption upon cooking, and harder, less sticky cooked rice. Considering these points, an experiment was taken to find out aging effect on milling parameters of the premium BRRI variety. The experiment was conducted using BRRI dhan50 as un-parboiled condition and milling was done in semi-auto rice mill at FMPHT division in BRRI HQ Gazipur. Table 24 shows the milling parameter of BRRI dhan50 immediate by after harvesting.

The paddy was stored in three different types of storage structure at 9.3% moisture content (wb). These are hermetic bag, plastic drum and painted motka. Milling quality was assessed at every three month interval up to 15 months from the time of storage. Seven treatments with three replications were taken for every storage structure. The treatments were T_1 = Milling immediate after by harvesting, T_2 = Milling after three months, T_3 = Milling after six months, T_4 = Milling after nine months and T_5= Milling after 12 months T_6= Milling after 15 months T_7= Milling after 18 months.

In one diately after harvesting, the initial moisture content of BRRI dhan50 was 10.52% (wb). The milling yield, head rice recovery (based on milled rice) and whiteness index were 63.25%, 74.80 % and 43.40.

Table 24. Milling parameter of BRRI dhan50 immediate by after harvesting.

Milling parameter	
Moisture content %	10.52
Milling yield %	63.25
Milling degree %	9.32
Head rice % (Based on total milled rice)	74.80
Broken rice % (Based on total milled rice)	25.20
Whiteness Index	43.40

In the hermetic bag from three months to 15th month the moisture content of BRRI dhan50 was ranged from 10.10%(wb) to 11.30%(wb) and milling yield was ranged from 63.25% to 66.05%. The head rice recoveries (based on milled rice) were 75.95% after three months, 76.89% after six months, 77.47% after nine months, 77.90% after 12 months and 78.15% after 15 months of aging period (Table 25).

In the plastic drum from three months to 15 month the moisture content of BRRI dhan50 was ranged from 9.80%(wb) to 10.20%(wb) and milling yield was ranged from 63.10% to 66.25%. The head rice recoveries (based on milled rice) were 75.18% after three month, 76.10% after six month, 77.30% after nine months, 78.10% after twelve month and 79.90% after 18 months of aging period (Table 25).

In the painted motka from three months to 15 months the moisture content of BRRI dhan50 was ranged from 11.20%(wb) to 14.45%(wb) and milling yield was ranged from 52.06% to 62.52%. The head rice recoveries (based on milled rice) were 74.90% after three month, 75.12% after six month, 70.75% after nine months, 68.95% after 12 months and 65.20% after 18 months of aging period. (Table 25).

Table 25. Milling parameter of BRRI dhan50 after different months of ageing.

After three months of ageing			
Milling parameter	Hermetic bag	Plastic drum	Painted motka
Moisture content	10.10	9.80	11.20
Milling yield %	63.25	63.10	62.52
Milling degree %	10.96	10.65	10.56
Head rice % (Based on total milled rice)	75.95	75.18	74.90
Broken rice % (Based on total milled rice)	24.05	24.90	25.10
Whiteness Index	42.60	42.35	42.10
After six months of ageing			
Moisture content	10.60	10.10	11.90
Milling yield %	64.36	63.43	62.24
Milling degree %	10.80	10.58	10.69
Head rice %(Based on total milled rice)	76.89	76.10	75.12
Broken rice % (Based on total milled rice)	23.11	23.90	24.90
Whiteness Index	41.97	40.86	40.10
After nine months of ageing			
Moisture content	10.80	10.30	12.60
Milling yield %	65	64	58.7
Milling degree %	10.25	9.69	10.50
Head rice % (Based on total milled rice)	77.47	77.30	70.75
Broken rice % (Based on total milled rice)	22.53	22.70	29.25
Whiteness Index	41.35	40.30	39.95
After 12 months of ageing			
Moisture content	11.05	10.65	13.58
Milling yield %	65.73	65.82	56.77
Milling degree %	10.25	10.30	10.41
Head rice % (Based on total milled rice)	77.90	78.10	68.95
Broken rice % (Based on total milled rice)	22.10	21.90	31.05
Whiteness Index	41.03	39.85	39.05

After 15 months of ageing			
Moisture content	11.30	10.80	13.5
Milling yield %	66.05	66.25	52.06
Milling degree %	10.15	10.05	10.22
Head rice % (Based on total milled rice)	78.15	79.90	65.20
Broken rice % (Based on total milled rice)	21.85	20.10	34.80
Whiteness Index	40.21	39.60	38.50

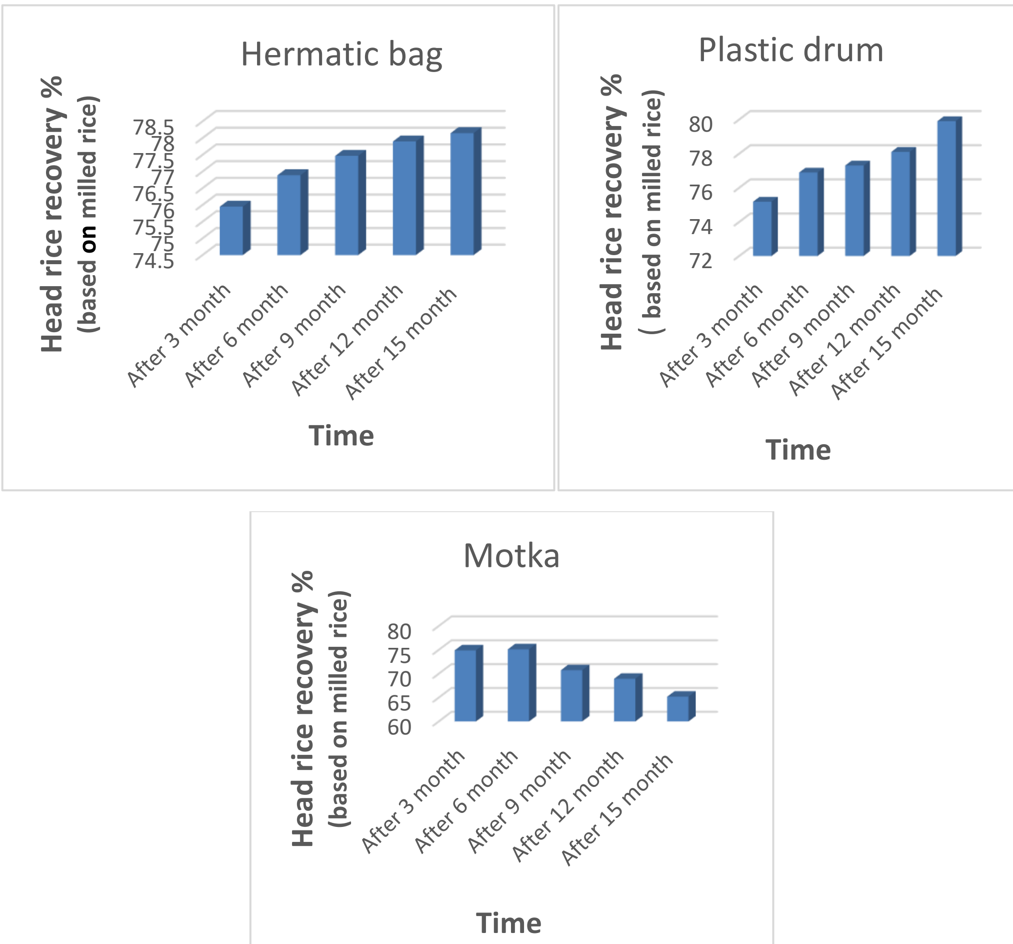


Fig 29. Relationship between head rice recovery and aging period of different storage structure.

Figure 29 shows that the head rice recovery was increased simultaneously with the months of aging period increased for hermatic bag and plastic drum. In the painted motka, the head rice recoveries were increased up to six months of aging period and then decreased up to 15 months of aging period. Due to porous behaviour moisture uptake was observed in motka which reduced the quality of paddy and head rice recovery. Whiteness index was decreased for all storage structure after different months of ageing. From this study, higher head rice recovery was found in plastic drum after 15 months of ageing period which is promising for premium quality rice.

Design and development of a solar dryer

When paddy reaches maturity, it is harvested at high moisture contents of about 24-26 percent (wb). If harvested moisture content is about 24-26 percent, it needs immediate drying to save the paddy. Drying of paddy is usually done in two ways. One is open sun drying and the other is mechanical drying by using different types of dryers. Open sun drying is cheap but now it is labor-intensive and degrades product quality. To protect freshly harvested paddy from deterioration, and reduce the wastage through bacterial action, accelerate the time for drying the products, different types of mechanical dryers are designed and used for different types of crops like maize and rice. Farmers are not applying yet improved drying techniques to dry their paddy seeds. So, with the growing need for better and higher quality seeds as well as for more effective post-harvest operations, rice drying by farmers may currently present a challenge in terms of processing techniques and the prevention of seed quality degradation.

Design considerations

The quality of the finished product after being dried in a dryer is impacted by the drying behavior of the rice, which is characterized by the moisture, temperature, and stress distributions inside the material during drying as well as the quality characteristics of individual kernels. The moisture must be reduced for this dryer to an acceptable level for getting maximum germination rate. Therefore, it is important to control the drying conditions precisely to improve the drying process and product quality.

Description of the dryer

The dryer's design is based on the concept of batch-type dryers. A solar-assisted grain dryer was developed and constructed in the Farm Machinery and Post-harvest technology Division of BRRI, Gazipur by using locally available materials. The solar-assisted dryer consists of the following components: flat plate solar air collector (collector stand, inlet of the collector, outlet of the collector), drying chamber (drying chamber inlet, drying chamber outlet), air distribution model, and a blower, flexible pipe, etc. Figures 31-32 show the schematic diagram of the total system developed for the experimental work.

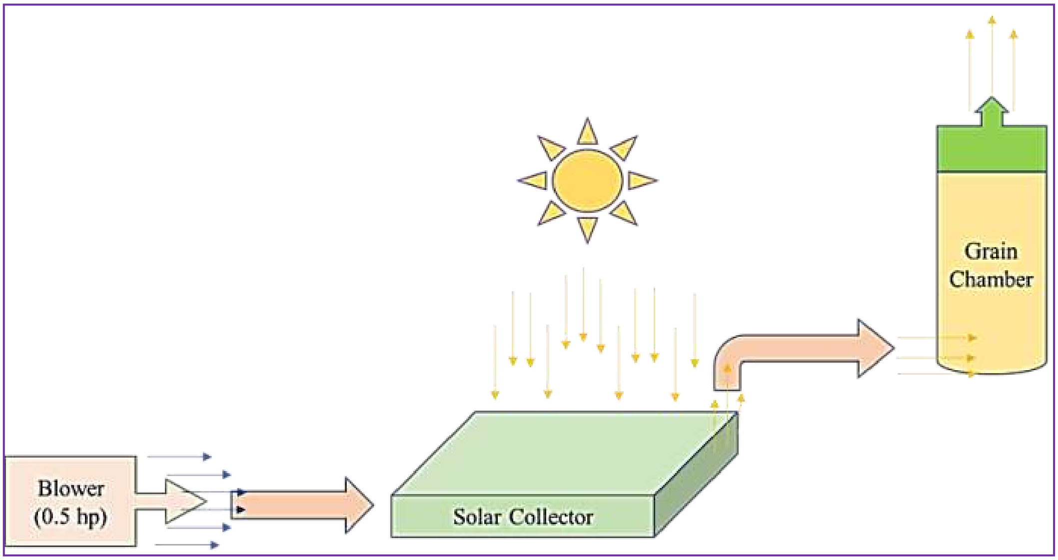


Fig. 30. Schematic diagram drying process of the dryer.

Development and fabrication of dryer. A solar collector with the dimensions of 148 cm × 130 cm × 20 cm was constructed to capture solar heat from the sun. It was painted black for absorbing more solar heat to become hot on the inner side of the collector. A blower was used to force hot air into the grain chamber whose height was 87 cm and the diameter of the chamber was 57 cm. Hot air was passed through a duct to a grain drying tank. Figures 31-32 show the pictorial illustrations of the different components of the dryer shown in fig 33-34. Fig. 35 shows the flow behaviour of drying air within the drying chamber and figure 34 shows the drawing view with actual view of the solar-assisted paddy dryer.

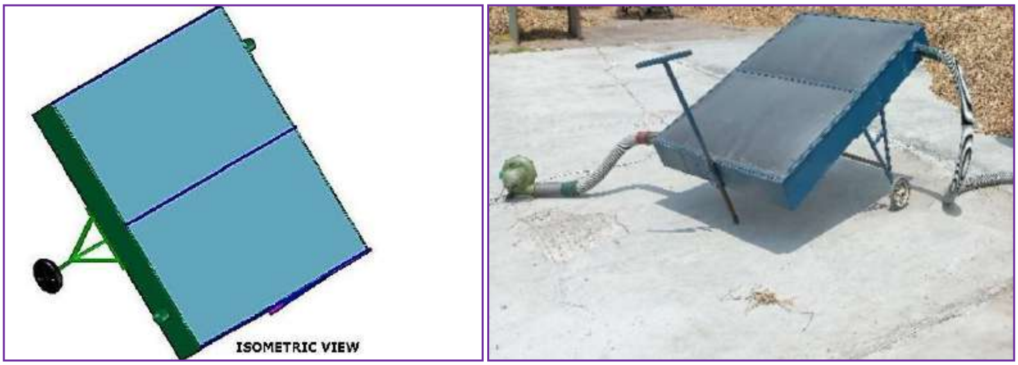


Fig. 31. Photographic views of the flat plate solar collector.

Fig. 32. Photographic views of the perforated cylinder of the drying chamber.

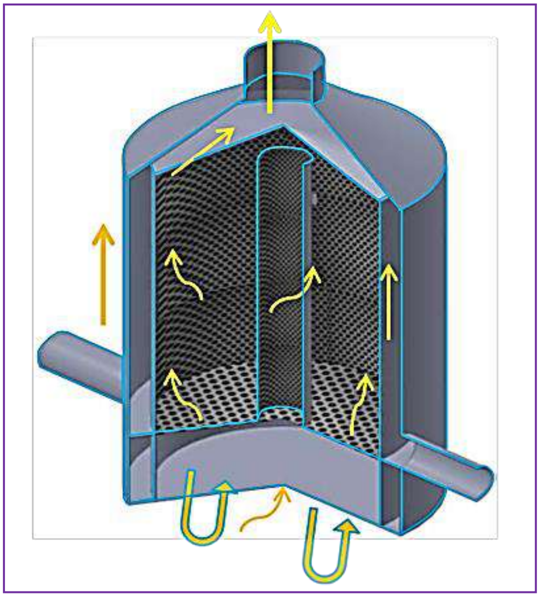


Fig.33. Flow behaviour of drying air within the drying chamber.

Performance test of the machine

The preliminary performance test was done on the machine to identify faults in the dryer's functional elements. A simple comparative study was organized using two different dryers in FMPHT Divisional research workshop.

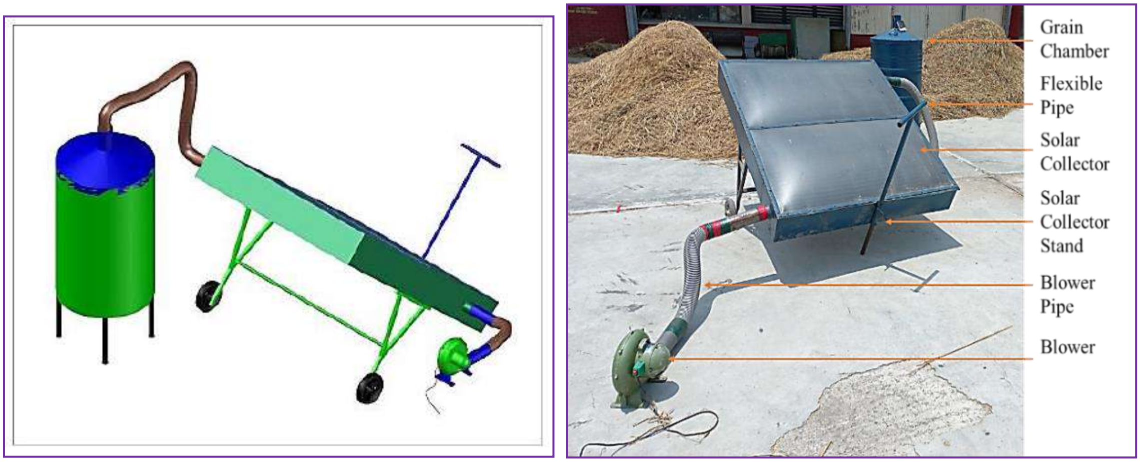


Fig.34. Complete view of the developed dryer.

Any solar system's performance depends on how much solar irradiation it can collect. For collecting the maximum amount of solar radiation, all types of solar collectors must be directed towards the sun so that all the sun's rays fall normally on the optical system, which can increase the efficiency of the system. Energy collection is increased for a given system if it is oriented in such a manner that the surface normal at the center coincides with the solar beam all the time. This will be possible only if the system is rotated continuously according to the position of the sun, i.e. the tracking is done with sun movement. Energy collection will be reduced if no tracking is done.

Fig.35. Performance test of the developed machine.

The test sample was BRRI dhan50. The initial moisture content of the test sample was recorded as more than 28%. About more than 10 hours are required to reduce the moisture content from 28.7% to below 14 % by newly developed solar dryer (Fig. 35). Two divisions of BRRI conducted germination tests for the dried seed of two types of dryers that were batch-type dryer and newly developed solar dryer. Figure 36 shows the moisture content reduced with respect to drying time. For BRRI dhan50 92-98% seed germination was found by using this solar-assisted dryer (Fig 37).

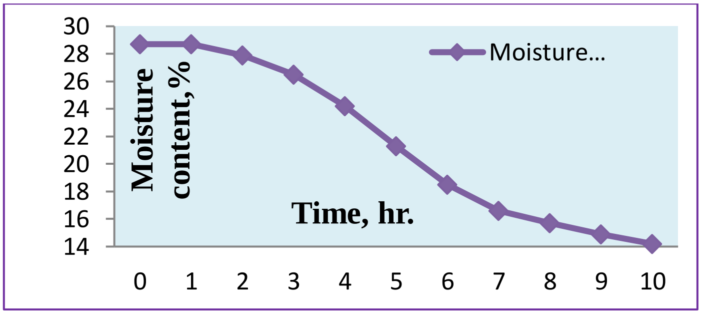


Fig.36. Variation of moisture content with drying time.

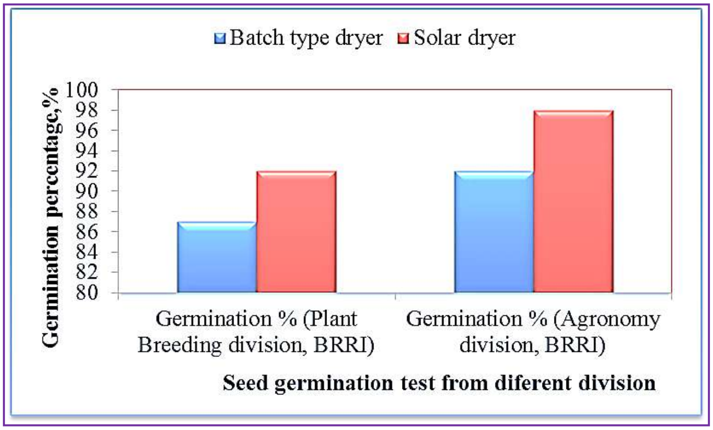


Fig. 37. Germination test of BRRI dhan50 using the different dryers.

Solar-assisted dryer was developed, fabricated, and tested for paddy seed drying. The dryer was able to dry the paddy from an initial moisture content of 28.7% to a moisture content of 14 %. Powered by a 0.5 hp single-phase electric motor. The dryer can be scaled up for commercial drying of paddy seed. It is recommended for use on a small-scale level where there is not enough space for sun drying, has the possibility to mix up dust/inert matter or other seeds, to attack birds or others, and the possibility for microbial contaminations.

POPULARIZATION OF BRRI DEVELOPED FARM MACHINERY AND POSTHARVEST TECHNOLOGY

Training on Operation and Maintenance of Farm Machinery

Training is an effective tool to developed technical and efficient manpower for effective use, repair and maintenance of agricultural machinery in the farm yard. Proper operation and maintenance increase the life time of a machine and as result more income generating activities (IGA) could as accomrtished that also increase the productivity of the machine. In order to build up trained manpower on farm machinery in the rural areas SFMRA project of FMPHT HQ as well as BRRI conducted two-day long residential training programme at BRRI head quarter, Chuadanga, Mithapukur of Rangpur, Jashore and Godagari of Rajshahi district.

Two-day long residential training

Two-day long residential training was conducted under the financial and technical supported of SFMRA project of FMPHT Division in order to introduce BRRI developed and other agricultural machines at farmer's levels; to developed skilled operators on agricultural machinery at farm levels and to build up awareness about the use and benefit of using agricultural machines. The trainings were conducted at BRRI HQ Chuadanga, Mithapukur of Rangpur, Jashore and Godagari of Rajshahi district.

Twenty participants attended in each training program. Participants were selected by direct consultation with BRRI regional stations and respective DAE office by maintaining selection criteria. Priorities were given to select the participants on the basis of having experience on operating agricultural machinery. Lecture and practical session were arranged by BRRI scientists, DAE personnels (AD, DD, UAO and Aril. Engg.) and Academicians (University professors). Knowledge was shared to the participants on the operation and maintenance of BRRI developed machinery as well as technologies othe agricultural machinery. During practical session machinery were operated by the participants for gathering experience on agricultural machinery operations in no load condition in the drying yard/road. After successful operation in the drying yard/ road participants were taken to the main field for practical operation of agricultural machinery.

Major activities done by the participants of the training programme

The following BRRI developed machinery; technologies and other agricultural machinery were introduced and practically operated to the trainees during training programme:

- Demonstration on seedling raising technique for mechanical rice transplanter
- Operation and maintenance of mechanical rice transplanter
- Operation and maintenance of BRRI prilled urea applicator
- Operation and maintenance of BRRI manual and power weeder
- Operation and maintenance of whole feed combine harvester
- Operation and maintenance of self-propelled rice/wheat reaper
- Operation and maintenance of BRRI open drum thresher
- Operation and maintenance of BRRI closed drum thresher
- Operation and maintenance of BRRI winnower
- Hands on repair and maintenance of diesel engine
- Practical field operation of agricultural machinery in the farm level

A total of 56 batches of residential training programme was conducted and in total 1,154 of participants were trained in the programme. Among them 1,085 were male and 69 were female. Participants of the training programme were attended from BRRI RS adjacent areas and from its jurisdiction districts. An inaugural session was held at the 1st day of the training programme and after that a pre-evaluation of the trainees was done. Lecture and mostly practical session were arranged in all the locations. Step by step procedure to raise seedling in tray was shows practically to the participants. After this machines like mechanical rice transplanter, combine harvester, self-propelled reaper, BRRI open drum thresher, BRRI closed drum thresher, BRRI prilled urea applicator, BRRI power and manual weeder, BRRI winnower and power tiller were operated at figst in no load condition in threshing floor/road and after that these machines were operated by the trainees in the field one after another (Plats 24). At the end of the training, a post-evaluation and trainee's reactions regarding the training were collected. Certificates, leaflets and a set of tools were distributed among the participants.

a) Inauguration of training programme

b) Operation of manual seed sower machine

c) Introduction of rice transplanter

d) Introduction of reaper and reaper binder

Plate 24. Pictorial view of hands-on training.

Formal trainings were very effective as the participants were isolated from their home and were able to concentrate fully in the class room. The trainees wanted to have one week instead of two days training to improve their skills in farm machinery. Trainees opined that they are now more confident about the use of the machinery and the hand tools will be useful for their work.

Adaptive Research Division

SUMMARY

During the reporting period, 13 different categories of advanced lines adaptive research trials (ALART) were conducted at 133 farmers' field throughout the country. Advanced breeding lines were supplied from Plant Breeding Division, Plant Pathology Division and BRRI RS, Barishal. Considering on some important characteristics and farmers' opinion, three advanced breeding lines for different characteristics were recommended for proposed variety trial (PVT). During Aman 2021, the entry IR16F1148 was found suitable for submergence tolerance ecosystem (Short duration) and recommended for PVT. While two genotypes BRHII-9-11-4-5B and BRH13-2-4-6-4B were found suitable for favourable environment in Boro season.

Seed Production and Dissemination Programmes (SPDP) were conducted by using different BRRI and TRB projects. About 1971 demonstrations were conducted in 200 upazilas of the country, from which about 616.5 tons of paddy were produced and 64 tons were retained as seeds by the farmers. About 41 thousand farmers gained awareness and knowledge about BRRI varieties through demonstrations, knowledge sharing, field days, field visit and interactions with farmers and extension personnel. Among them, about 15 thousand farmers were motivated to adopt BRRI varieties. A new model demonstration was conducted in three different locations of two different districts by using 4-stakeholders for rapid dissemination of rice technology.

A total of 400 Head to Head Adaptive Trial (HHAT) were conducted through Public Private Partnership (PPP) during the reporting period (200 HHAT in Aman 2021 and 200 in Boro 2022) under TRB project. In Amanseason, BRRI dhan87 was found as the highest yielder (5.84t ha^{-1}) having growth duration 130 days in HHAT (Long duration).

ARD conducted 113 batches of farmers' training at different locations of the country, in which 3,390 trainees participated on modern rice production technologies. A total of 71 field days were conducted at different locations of the country. At BRRI farm, 7,780 kg quality seeds of recently released BRRI varieties were produced during T. Aman 2021 and Boro 2022 seasons.

TECHNOLOGY VALIDATION

Advanced Line Adaptive Research Trial (ALART)

Early T. Aman 2021, ALART Stagnant Water (SW). Two advanced lines bred for stagnant water condition (50-100 cm water depth) i.e., BR10230-7-19-B, BR9390-6-2-1B along with BR23 and BRRI dhan91 as checks were tested in ten different locations. The plots were selected in representative stagnant water rice area where flood water depth was expected to be around 50 to 100 centimeter. All the advanced lines and check varieties were damaged and not suitable for data collection in four locations i.e., Gazipur (sadar), Cumilla (Langolkot), Jashore (Keshobpur) and Gopalganj (sadar). The result obtained from six locations i.e., Barishal (sadar), Satkhira (sadar), Chandpur (Kachua), Rangpur (Kaunia), Kurigram (Rajarhat), Gazipur (Sreepur) were used for analysis (Table1). Considering the phenotypic and overall performances, ALART monitoring committee did not like any of the materials. Farmers also didn't show interest about the advanced lines due to their lower yield, higher lodging tendency and most importantly rat infestation. All the tested BRRI lines were severely attacked by rat whereas the local varieties were rat free. So, none of the advanced lines was recommended for PVT.

Table 1. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART (SW) during T. Aman 2021.

Genotype	Location							G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})									
	L1	L2	L3	L4	L5	L6	Mean			
BR10230-7-19-B	4.41	3.39	0.92	1.27	1.37	1.78	2.19	194	25.60	160
BR9390-6-2-1B	4.24	2.46	1.38	2.35	4.47	3.83	3.12	194	26.15	141
BR23 (ck)	5.03	3.00	1.01	2.48	4.83	2.73	3.18	205	26.06	129
BRRI dhan91 (ck)	3.00	3.73	0.16	0.50	0.72	1.61	1.62	193	23.36	158
$LSD_{0.05}$	**0.72**						**0.29**	**1.0**	**0.43**	**3.0**

L1-Barishal, L2-Satkhira, L3-Chandpur, L4-Rangpur, L5-Kurigram, L6-Gazipur

T. Aman 2021, ALART, Insect Resistant Rice-Brown Plant Hopper (IRR-BPH). Two advanced lines BR9880-40-1-3-34 and BR9880-27-4-1-18, along with the check varieties BRRI dhan87 and BRRI dhan93 were tested at farmers' field in ten locations such as Satkhira (Sadar), Sirajganj (Raiganj), Kurigram(Rajarhat), Kurigram (Sadar), Gaibandha (Polashbari), Rangpur (Mithapukur), Lalmanirhat(Sadar), Lalmonirhat (Kaliganj), Khulna (Koyra), Gazipur (West Byde). The trial site at Koyra, Khulna was damaged due to heavy rainfall and inundation immediately after transplanting. Among all the entries, check variety BRRI dhan93 produced significantly the highest grain yield (4.69 t ha^{-1}) followed by the advanced line BR9880-40-1-3-34 (4.38 t ha^{-1}) and BR9880-27-4-1-18 (3.83 t ha^{-1}) (Table 2). Farmers didn't prefer the advanced line BR9880-40-1-3-34 andBR9880-27-4-1-18 compared to BRRI dhan93 (ck). Considering Grain yield, and other characteristics, none of the tested line was recommended for PVT.

Table 2. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART(IRR-BPH) during T. Aman 2021.

Genotype	Location										G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})												
	L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean			
BR9880-40-1-3-34	5.03	3.92	4.25	3.82	2.55	3.30	4.35	5.69	6.50	4.38	130	20.44	118
BR9880-27-4-1-18	5.52	3.78	1.94	3.32	2.47	3.23	4.26	4.39	5.56	3.83	128	21.74	121
BRRI dhan87 (Ck)	6.02	2.57	2.55	3.12	2.63	2.93	2.89	5.34	5.41	3.72	127	22.88	126
BRRI dhan93 (Ck)	5.57	4.20	4.30	4.12	3.16	3.47	5.04	5.48	6.86	4.69	133	19.93	125
$LSD_{0.05}$	**0.62**									**0.21**	**0.25**	**0.24**	**1.87**

L1- Sadar, Satkhira, L2- Rajarhat, Kurigram, L3- Mithapukur, Rangpur, L4- Palashbari, Gaibanda, L5- Sadar, Lalmonirhat, L6-Kaliganj, Lalmonirhat, L7-Sadar, Kurigram, L8- BRRI, Gazipur L9- Raiganj, Sirajganj.

T. Aman 2021, ALART, salt tolerant rice (STR). Three salt tolerant advanced lines: IR108158-B-2-AJY1-1, IR15T1464 and TP30649 along with BRRI dhan73 (Tol. ck) and BRRI dhan87 (Sus. ck) were evaluated in ten locations such as BRRI research farm (Gazipur), Satkhira (Sadar and Kaliganj), Khulna (Dumuria and Batiaghata), Patuakhali (Kalapara), Feni (Sonagazi), Noakhali (Companiganj) and Bagerhat (Sadar and Rampal). Across the locations, water salinity records were taken in different dates. But no significant salinity was observed in the selected locations during Aman season. Among the genotypes, the highest mean grain yield (5.49 t ha^{-1}) was obtained in BRRI dhan87 (Sus. ck) followed by TP30649 (5.33 t ha^{-1}), IR15T1464 (5.23 t ha^{-1}), IR108158-B-2-AJY1-1 (5.15 t ha^{-1}) and BRRI dhan73 (Tol. ck) (5.01 t ha^{-1}). The mean growth duration of tolerance check variety BRRI dhan73 was almost similar to the tested genotypes ranged from 120 to 125 days (Table 3). So, none of the lines was found suitable for proposed variety trial (PVT).

Table 3. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART(STR) during T. Aman 2021.

Genotype	Location											G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})													
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean			
IR108158-B-2-AJY1-1	4.98	4.77	4.82	5.08	5.04	5.14	4.88	5.43	6.10	5.27	5.15	125	21.4	119
IR15T1464	4.94	5.01	4.94	5.06	5.35	5.42	5.05	5.51	5.43	5.59	5.23	123	23.9	119
TP30649	5.23	5.47	5.27	5.58	5.70	4.86	4.68	5.62	5.49	5.37	5.33	120	20.2	118
BRRI dhan73 (Tol. Ck)	5.23	5.29	4.98	5.36	4.39	5.25	5.10	4.91	5.32	4.33	5.01	123	22.1	123
BRRI dhan87(Sus. Ck)	5.83	5.67	5.94	6.24	5.60	4.91	4.79	5.52	5.76	4.62	5.49	127	22.4	123
$LSD_{0.05}$	**0.43**										**0.14**	**0.31**	**0.48**	**1.22**

L1-Sadar, Satkhira, L2- Kaliganj, Satkhira, L3- Dumuria, Khulna, L4- Batiaghata, Khulna, L5- Kolapara, Patuakhali, L6-Sonagazi, Feni, L7-Companyganj, Noakhali, L8-Sadar, Bagerhat, L9- Rampal, Bagerhat, L10- BRRI, Gazipur

T. Aman 2021, ALART for submergence tolerant rice; Short duration (SubTR-SD). One advanced line: IR16F1148 with BRRI dhan71 (Sus.ck) and Binadhan-11 (Tol. ck) as checks were tested at farmers' field in 10 locations such as Chattogram (Mirsharai) Lalmonirhat (Sadar), Lalmonirhat (Aditmari), Kurigram(Sadar), Gaibandha (Palashbari), Rangpur (Kaunia), Rangpur regional station research field (RSRF), Rangpur (water tank), Gazipur (West byde) and Gazipur (water tank). Across the locations, water level records were taken in different dates except Rangpur (RS RF) and Gazipur (WB) because those locations were not located in submergence prone areas. In Rangpur (Kaunia) the plot was completely damaged due to longer submerged condition for 25 days. Irrespective of genotypes and locations, the advanced line (IR16F1148) produced higher mean yields (4.98 t ha^{-1}) than the two check varieties BRRI dhan71 (4.02 t ha^{-1}) and Binadhan-11 (4.06 t ha^{-1}) (Table 4). Farmers also preferred advanced line (IR16F1148) compared to both of the check varieties. So, considering everything advanced line (IR16F1148) was recommended for PVT.

Table 4. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART (SubTR-SD) during T. Aman 2021.

Genotype	Location									G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean			
IR16F1148	5.31	5.44	5.64	4.95	5.05	4.04	3.84	5.57	4.98	129	22.48	121
BRRI dhan71 (Sus.ck)	4.37	5.20	5.18	4.15	4.72	3.65	1.43	3.43	4.02	126	24.00	118
Binadhan-11 (Tol. ck)	3.99	4.70	5.15	4.45	4.26	3.91	3.02	3.00	4.06	125	26.47	111
$LSD_{0.05}$				**0.68**					**0.24**	**0.42**	**0.41**	**1.87**

L1- Rangpur (Water tank), L2- Rangpur (RS,RF), L3- Sadar, Lalmonirhat, L4- Aditmari, Lalmonirhat, L5- Polashbari, Gaibandha, L6-Sadar, Kurigram, L7-Mirsari, Chattogram, , L8- BRRI, Gazipur

T. Aman 2021, ALART for submergence tolerance rice. Long duration (SubTR-LD): Two advanced lines: BR9158-19-9-6-50-2-HR1 and IR13F441along with BRRI dhan44 (Sus. ck) and BRRI dhan52 (Tol. ck) as checks were tested at farmers' field in 10 locations such as Chattogram (Mirsharai), Lalmonirhat (Sadar), Lalmonirhat (Aditmari), Kurigram (Sadar), Gaibandha (Palashbari), Rangpur (Kaunia), BRRI RS, Rangpur research field, Rangpur (water tank), BRRI HQ, Gazipur (West byde) and Gazipur (water tank). Across the locations, water level records were taken in different dates except BRRI RS, research field (RSRF) BRRI HQ and Gazipur (WB) because those locations were not located in submergence prone areas. Irrespective of genotypes and locations, both the advanced lines (BR9158-19-9-6-50-2-HR1 and IR13F441) produced similar higher yields (5.00 t ha^{-1}) than the two check varieties BRRI dhan44 (4.16 t ha^{-1}) and BRRI dhan52 (4.72 t ha^{-1}) (Table 5). Farmers did not prefer both of the tested entries compared to the check varieties. None of the advanced lines was recommended for PVT. But based on yield performance and other characteristics, the above lines may be reevaluated in those areas where BRRI dha52 is popular, especially in Barishal region.

Table 5. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART(SubTR-LD) in T. Aman, 2022.

Genotype	Location										G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})												
	L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean			
BR9158-19-9-6-50-2-HR1	6.32	4.10	5.42	4.39	5.59	5.54	5.55	2.54	5.58	5.00	150	30.87	136
IR13F441	5.95	4.40	5.29	5.06	5.25	5.26	5.81	2.94	5.04	5.00	148	21.04	133
BRRI dhan44 (Sus. ck)	6.06	3.82	4.28	4.01	4.87	5.22	3.89	1.10	4.16	4.16	147	28.74	128
BRRI dhan52 (Tol. ck)	5.72	4.54	5.14	4.10	5.30	4.85	5.76	1.97	5.14	4.72	145	27.04	128
$LSD_{0.05}$					**0.62**					**0.21**	**0.24**	**0.27**	**1.53**

L1- BRRI, Gazipur, L2- Rangpur (Water tank), L3- Rangpur, Sadar, L4- Sadar, Lalmonirhat, L5- Aditmari, Lalmonirhat, L6-Polashbari, Gaibandha, L7-Sadar,Kurigram, L8- Kaunia,Rangpur, L9-Mirsari, Chattogram

T. Aman 2021, ALART, zinc enriched rice (ZER): One zinc enriched advanced rice genotype BR9674-1-1-5-2-P4 along with BRRI dhan49, BRRI dhan72 and BRRI dhan87 as checks were tested at farmers' field in ten locations such as Kushtia (Sadar), Habiganj (Bahubol), Rajshahi (Paba), Cumilla (Debidwar), Jhalkathi (Nalchiti), Faridpur (Nagarkanda), Rangpur (Mithapukur), Feni (Sonagazi), Satkhira (Sadar) and BRRI HQ Gazipur (West Byde). Among all the entries including checks, the only advanced line produced the lowest yield (5.02 t ha^{-1}). In this trial, the check variety BRRI dhan49 produced higher grain yield than the genotype (BR9674-1-1-5-2-P4) and other the check variety BRRI dhan72 and BRRI dhan87. Farmers didn't prefer BR9674-1-1-5-2-P4 entry compared to the check varieties. Based on results, evaluation committee report and farmers perspective, BR9674-1-1-5-2-P4 entry was not recommended for PVT.

Table 6. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART(ZER) during T. Aman, 2021.

Genotype	Location										G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})												
	L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean			
BR9674-1-1-5-2-P4	4.45	5.47	5.37	5.15	4.52	4.34	5.57	5.67	4.66	5.02	119	22.1	121
BRRI dhan49 (ck)	5.76	6.01	5.85	5.20	5.80	5.15	6.03	5.03	5.34	5.57	130	20.0	108
BRRI dhan72 (ck)	5.63	6.14	4.41	5.46	5.17	4.87	5.88	5.52	3.67	5.19	126	27.4	119
BRRI dhan87 (ck)	5.90	6.60	4.59	5.39	5.93	4.73	6.20	5.72	4.54	5.51	125	23.5	124
$LSD_{0.05}$	**0.68**									**0.22**	**0.31**	**0.31**	**1.24**

L1-Kushtia, L2- Habiganj, L3- Rajshahi, L4- Cumilla, L5- Jhalakathi, L6- Faridpur, L7-Sonagazi, L8- Satkhira, L9-BRRI HQ, Gazipur.

Boro 2022, ALART, premium quality rice (PQR): Two premium quality advanced lines: BR9930-2-3-2-2 and BR9930-2-3-3-1 along with three check varieties BRRI dhan50, BRRI dhan63 and BRRI dhan81 were evaluated in ten locations such as BRRI HQ research farm (Gazipur), Rangpur (Sadar), Rangpur (Mithapukur), Rajshahi (Paba), Rajshahi (Godagari), Sirajganj (Sadar), Cumilla (Debiddar), Feni (Sadar), Kushtia (Sadar) and Habiganj (Sadar). Both the advanced lines and the check variety BRRI dhan63 produced almost similar mean yield (Table 7). Farmers did not prefer the advanced lines compared to the check varieties. Considering all the necessary attributes, none of the lines was recommended for PVT.

Table 7. Grain yield, growth duration and plant height of the rice genotypes under ALART(PQR) during Boro 2022.

Genotype	Location											G. duration (day)	Plant height (cm)
	Grain yield (tha^{-1})												
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean		
BR9930-2-3-2-2	7.24	7.09	5.91	6.21	8.03	6.13	5.36	5.88	6.12	5.89	6.39	152	115
BR9930-2-3-3-1	7.05	7.16	5.98	6.48	8.37	6.00	5.25	6.39	5.96	5.71	6.44	153	117
BRRI dhan50 (ck)	6.34	6.35	5.82	6.22	7.38	5.43	5.84	6.52	4.73	4.71	5.93	157	90
BRRI dhan63(ck)	6.91	6.51	5.67	6.05	8.12	5.63	6.18	6.83	4.99	6.26	6.31	151	89
BRRI dhan81(ck)	6.23	5.50	5.02	5.44	5.86	4.97	6.01	5.78	4.99	5.40	5.52	148	99
$LSD_{0.05}$	**0.65**										**0.21**	**0.31**	**1.57**

L1-Sadar, Rangpur, L2- Mithapukur, Rangpur, L3- Paba, Rajshahi, L4- Godagari, Rajshahi, L5- Sadar, Sirajganj, L6-Debiddar, Cumilla, L7-Sadar, Feni, L8-Sadar, Kustia, L9- Sadar, Habiganj, L10- BRRI HQ, Gazipur

Boro 2022, ALART, salt tolerant rice (STR-1): Three salt tolerant advanced lines: BR11715-4R-186, BR11723-4R-27 and BR11723-4R-12 along with BRRI dhan67 (Tol. ck) and BRRI dhan92 (Sus. ck) were evaluated in ten locations such as BRRI research farm (Gazipur), Satkhira (Assasuni, Kaliganj and Debahata), Patuakhali (Kalapara), Barguna (Amtali), Feni (Sonagazi), Noakhali (Companiganj) and Bagerhat (Rampal) and Gopalganj (Tongipara). Experiments of STR-1 in Rampal, Bagerhat was damaged due to high salinity at seedling stage. In Barguna (Amtali), experimental plot was not maintained properly due to lack of irrigation water after transplanting. Even two lines of STR-1 was damaged seriously by bird attack in Kalapara, Patuakhali and data were not available from this site. So, statistical analysis was done using data from seven locations. No yield advantage of the advanced lines were observed compared to the check variety BRRI dhan92. Growth duration of lines was 5-7 days higher than BRRI dhan92 (Table 8). Regarding other phenotypic and yield components parameter, there were no significant advantage observed in lines compared to the check varieties. So, none of the lines was found suitable for proposed variety trial (PVT).

Table 8. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART(STR-1) during Boro 2022.

Genotype	Location									G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean			
BR11715-4R-186	7.13	7.67	4.78	4.81	5.32	6.83	5.65	8.48	6.33	157	20.5	110
BR11723-4R-27	7.22	7.48	4.61	4.66	5.10	7.03	0.00	8.32	6.35	157	20.4	108
BR11723-4R-12	6.77	7.14	4.74	4.81	5.02	6.77	0.00	7.56	6.12	157	20.7	109
BRRI dhan67 (CK)	6.18	6.54	5.81	5.76	5.99	5.80	5.80	5.93	5.98	141	19.6	105
BRRI dhan92 (CK)	7.54	8.05	5.69	5.56	5.83	6.65	4.56	7.86	6.47	152	22.7	111
$LSD_{0.05}$	**0.42**								**0.16**	**0.42**	**0.18**	**1.02**

L1-Sonagazi, Feni, L2- Companiganj, Noakhali L3- Assasuni, Satkhira L4-Kaliganj, Satkhira L5- Debhata, Satkhira, L6-Tongipara, Gopalganj L7- Kalapara, Patuakhali L8-BRRI, Gazipur

Boro 2022, ALART, salt tolerant rice (STR-2). Three salt tolerant advanced lines: BR11712-4R-227, BR11716-4R-105 and BR11716-4R-102 along with BRRI dhan67 (Tol. ck) and BRRI dhan92 (Sus. ck) were evaluated in ten locations such as BRRI HQ research farm (Gazipur), Satkhira (Assasuni, Kaliganj and Sadar), Patuakhali (Kalapara), Barguna (Amtali), Feni (Sonagazi), Noakhali (Companiganj) and Bagerhat (Rampal) and Gopalganj (Tongipara). Experiments of STR-2 in Rampal, Bagerhat was damaged by high salinity during seedling stage. Among the genotypes the highest mean grain yield was obtained in BRRI dhan92 (Sus. ck) followed by BRRI dhan67 (Tol.

ck), BR11712-4R-227(5.91 t ha^{-1}), BR11716-4R-105 (5.65 t ha^{-1}) and BR11716-4R-102 (5.58 t ha^{-1}). Compared to the standard checks, the mean growth duration of lines was higher (6-9 days) and it ranged from 161-164 days (Table 9). Regarding other phenotypic and yield component parameters, there were no significant advantage observed in lines compared to check varieties. So, none of the tested lines wasfound suitable for PVT.

Table 9. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART (STR-2) during Boro 2022.

Genotype	Location										G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})												
	L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean			
BR11712-4R-227	4.74	5.54	7.36	5.03	6.91	4.70	5.51	6.11	7.33	5.91	161	22.0	105
BR11716-4R-105	4.85	4.60	7.15	5.14	6.97	4.64	4.77	5.08	7.63	5.65	162	24.7	104
BR11716-4R-102	4.73	4.49	7.02	5.45	6.74	4.84	4.56	4.99	7.44	5.58	164	23.8	105
BRRI dhan67 (TolCk)	5.99	5.53	6.44	6.05	5.51	5.83	5.70	5.97	7.33	6.04	140	21.1	104
BRRI dhan92 (SenCk)	6.05	5.29	8.22	7.38	6.61	4.52	5.51	5.71	7.44	6.30	155	22.7	107
$LSD_{0.05}$					**0.34**					**0.13**	**0.40**	**0.31**	**1.25**

L1- Amtoli, Borguna, L2- Asasuni, Satkhira, L3- Companiganj, Noakhali L4-Sadar, Gazipur L5-Sadar, Gopalgonj L6-Kolapara, Patuakhali L7- Kaliganj, Satkhira L8- Sadar, Satkhira L9-Sonagazi, Feni.

Boro 2022, ALART, cold tolerant rice (CTR): Three cold tolerant advanced lines IR100722-B-B-B-B-11, IR100723-B-B-B-B-61, TP16199 along with BRRI dhan28 and BRRI dhan67 as checks were evaluated in ten locations such as BRRI HQ research farm (Gazipur West byde); Kishoreganj (Karimganj, Mithamoin, Itna, Nikli); Netrakona (Mohonganj, Modon); Habiganj (Baniachang, Ajmeriganj) and Sunamganj (Taherpur). In this trial, the genotype (IR100722-B-B-B-B-11) produced slightly higher grain yield than the other genotypes (IR100723-B-B-B-B-61, TP16199) and the check variety BRRI dhan67. But the mean growth duration of the advanced lines was 7-10 days (Table 10) higher than the check varieties which may not be suitable for Haor areas. The tested genotypes were not attractive to the farmers due to its poor phenotypic acceptance, higher pest and disease infestation and highly lodging susceptibility. Based on results, ALART monitoring team report and farmer's perspective, none of the entries was recommended for PVT.

Table 10. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART(CTR) during Boro 2022.

Genotype	Location											G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})													
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean			
IR100722-B-B-B-B-11	5.26	4.70	3.97	4.15	5.43	4.84	5.84	5.59	3.24	6.60	**4.96**	**151**	**21.9**	**115**
IR100723-B-B-B-B-61	4.18	4.95	3.70	3.72	6.24	4.24	5.21	5.67	3.76	5.82	**4.75**	**150**	**21.3**	**113**
TP16199	4.43	5.50	3.83	3.71	5.21	5.10	5.93	5.72	2.13	6.11	**4.77**	**155**	**21.7**	**118**
BRRI dhan28(Ck)	3.69	4.74	2.84	2.75	4.09	3.46	5.01	5.44	2.93	5.94	**4.09**	**145**	**21.8**	**107**
BRRI dhan67(Ck)	5.08	5.02	3.69	4.04	4.90	3.53	5.96	5.49	3.09	6.05	**4.68**	**147**	**21.6**	**117**
$LSD_{0.05}$						**0.67**					**0.21**	**NS**	**0.77**	**1.67**

L1-Ajmeriganj, L2- Baniachang, L3- Itna, L4- Nikli, L5- Mithamoin, L6-Mohonganj, L7-Modon, L8-Karimganj, L9-Taherpur, L10-BRRI HQ, Gazipur.

Boro 2022, Favourable Boro Rice-Barishal (FBR-Barishal). Four advanced lines developed by BRRI RS, Barishal: BRBa 1-4-9, BRBa 2-5-3, BRBa 3-1-7and BRBa 3-2-4 were evaluated against two check varieties BRRI dhan58 and BRRI dhan89 in twelve different locations of the country. The entries were evaluated in twelve locations such as Gopalganj (Kotalipara), Faridpur (Sadar), Barishal (Aghailjihara), Natore (Naldanga), Sirajganj (Tarash), Brahmonbaria (Kasba), Feni (Fulgazi), Kushtia (Sadar), Habiganj (Baniachang), Mymensingh (Sadar) and BRRI research farm

Gazipur. Farmers were not so much impressed about the tested entries compared to check varieties BRRI dhan58 and BRRI dhan89 (Table 11). Considering yield, growth duration and insect disease reactions, none of the tested lines was found suitable for PVT.

Table 11. Grain yield, growth durationand plant height of the rice genotypes under ALART(FBR-Barishal) during Boro 2022.

Genotype	Location Grain yield (tha^{-1})													G. duration (day)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Mean		
BRBa 1-4-9	6.22	7.22	5.59	7.89	7.7	6.54	7.75	5.84	7.57	7.76	9.00	7.42	7.21	158	120
BRBa 2-5-3	5.19	6.94	5.77	7.6	7.53	7.31	7.49	6.03	7.92	7.77	8.61	7.67	7.15	155	99
BRBa 3-1-7	6.26	6.59	6.74	7.94	7.12	7.24	7.83	5.74	7.81	7.7	8.85	7.52	7.28	155	100
BRBa 3-2-4	5.43	7.11	6.69	7.82	6.88	6.81	7.98	5.04	6.87	6.85	8.25	7.64	6.95	154	105
BRRIdhan58	5.4	6.72	5.32	6.59	6.84	5.84	7.15	5.22	7.05	6.75	6.88	7.04	6.40	152	103
BRRIdhan89	7.07	7.08	5.67	7.48	7.07	6.23	7.94	6.33	7.77	6.99	7.46	8.17	7.11	157	111
$LSD_{0.05}$							**0.75**						**0.21**	**0.29**	**1.17**

L1- BRRI HQ Gazipur, L2- Mymensingh, L3- Baniachang, Habiganj, L4- Kotalipara, Gopalganj, L5- Noldanga, Natore, L6-Kasba, Brahmonbaria, L7-Aghaliljigara, Barishal, L8-Sadar, Faridpur, L9-Mithapukur, Rangpur, L10- Sadar, Kushtia, L11- Tarash, Sirajganj, L12-Fulgazi, Feni

Boro 2022, ALART, Blast resistant rice (BRR). Four advanced lines, BR(Path)12452-BC3-42-22-11-4, BR (Path)12452-BC6-53-21-11, BR (Path) 13784-BC3-61-1-6-HR3 and BR (Path) 13784-BC3-63-6-4-HR6 were tested along with the check varieties BRRI dhan28 and BRRI dhan88 in 11 different locations such as Faridpur, Barishal, Rajshahi, Rangpur, Dinajpur, Sirajganj, Cumilla, Kushtia, Habiganj, Satkhira and Gazipur. Overall, none of the advanced line was preferred by farmers and extension personnel due to poor yield over the check variety BRRI dhan88 (Table12). All the tested materials showed some degrees of lodging tendencies and blast disease was also reported in some locations by ALART monitoring team. Since these ALART materials were tested to see the resistance against blast disease, farmers were not convinced with them and none of the line was recommended for PVT.

Table 12. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART(BRR) during Boro 2022.

Genotype	Location Grain yield ($t\ ha^{-1}$)												G. duration (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	Mean			
BR(Path)12452-BC3-42-22-11-4	6.81	5.66	6.49	6.03	5.37	9.40	4.74	4.39	5.72	5.62	5.70	5.99	145	22.32	113
BR(Path)12452-BC6-53-21-11	6.81	6.49	6.94	6.36	5.34	7.28	6.01	5.75	5.67	5.25	5.18	6.10	146	22.33	117
BR(Path)13784-BC3-61-1-6-HR3	8.02	5.84	6.64	6.00	6.44	8.93	5.91	5.79	4.97	5.41	5.79	6.34	145	24.43	106
BR(Path)13784-BC3-63-6-4-HR6	8.04	5.87	6.68	6.73	7.23	9.87	5.42	5.81	5.19	5.23	4.99	6.46	145	24.32	103
BRRI dhan28 (ck)	7.33	4.43	7.39	6.30	6.93	8.45	5.75	5.56	4.85	5.10	6.39	6.22	144	22.96	110
BRRI dhan88 (ck)	8.17	6.95	7.13	7.02	7.16	8.88	6.09	6.04	5.29	5.04	5.83	6.69	145	21.37	100
$LSD_{0.05}$						**0.73**						**0.22**	**0.2**	**0.32**	**1**

L1-Faridpur, L2- Barishal, L3- Rajshahi, L4- Rangpur, L5- Dinajpur, L6-Sirajganj, L7-Cumilla, L8-Kushtia, L9-Habiganj, L10-Satkhira, L11- Gazipur

Boro 2022, ALART superior high yielding rice (SHR): Three superior high yielding rice (SHR) advanced lines i.e., BRHII-9-11-4-5B, BRH13-2-4-6-4B, BRH13-7-9-3-2B, developed by BRRI Plant Breeding Division were evaluated against the check varieties BRRI dhan63 and Zirashail in 12 different locations of the country. The entries were evaluated in twelve locations such as Gopalganj (Sadar), Sirajganj (Kamarkhanda), BRRI HQ Gazipur (WB), Rajshahi (Paba), Habiganj (Baneachong), Satkhira (Sadar), Kushtia (Sadar), Rangpur (Mithapukur), Cumilla

(Debidwar), Barishal (Sadar), Bhanga (Nagarkanda) and Feni (Sonagazi). Farmers and extension personnel showed their interest for entry no. 1 and 2 for their good morphological appearance, higher yield, fine grain shape and also medium growth duration compared to check varieties BRRI dhan63 and Zirashail (Table 13). Considering all the necessary attributes, any one of the advanced lines BRHII-9-11-4-5B (entry no. 1) or BRH13-2-4-6-4B (entry no. 2) may be recommended for PVT.

Table 13. Grain yield, growth durationand plant height of the rice genotypes under ALART(SHR) during Boro 2022.

Genotype	Location													G. duration (day)	Plant height (cm)
	Grain yield (t ha^{-1})														
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Mean		
BRHII-9-11-4-5B	7.31	7.62	7.66	7.08	5.56	5.6	6.62	7.68	6.20	6.94	7.51	6.24	6.84	154	101
BRH13-2-4-6-4B	7.58	7.85	8.56	6.97	5.16	5.81	5.9	7.79	6.00	6.94	7.26	6.11	6.83	154	101
BRH13-7-9-3-2B	6.76	6.43	7.15	6.45	5.04	5.74	7.06	7.38	5.70	6.59	6.3	6.46	6.42	155	116
BRRI dhan63 (ck)	6.11	6.83	7.18	6.78	4.99	5.54	6.48	7.31	5.60	6.17	7.27	6.31	6.38	148	91
Zirashail (ck)	5.27	4.82	6.53	5.16	4.45	5.53	5.74	5.88	5.00	5.56	5.22	5.77	5.41	146	105
$LSD_{0.05}$						**0.96**							**0.21**	**0.29**	**1.76**

L1-Sadar, Gopalganj, L2- Paba, Rajshahi L3- Kamarkhanda, Sirajganj, L4- BRRI HQ, Gazipur, L5- Baneachang, Habiganj, L6-Sadar, Satkhira, L7-Sadar, Kushtia, L8-Mithapukur, Rangpur, L9- Debidar, Cumilla, L10-Sadae, Barishal, L11-Nagarkanda, Bhanga, L12-Sonagazi, Feni

TECHNOLOGY DISSEMINATION

Seed production and dissemination programme (SPDP)

Scientists of ARD conducted different demonstration trials and involved in different promotional activities for rapid dissemination of BRRI developed technologies. Among them, SPDP was very important activity where BRRI developed different promising rice varieties were demonstrated at farmers' field in different seasons for rapid dissemination. SPDPs were conducted in collaboration with DAE using different sources of funds such as GoB and TRB.

SPDP during B. Aus 2021 under GoB. Twelve demonstrations were conducted on SPDP during B. Aus 2021 at six upazilas of Bhola districts under GoB. Two modern rice varieties (BRRI dhan43 and BRRI dhan83) were used as cultivar. Among the demonstrated varieties, BRRI dhan83 produced the highest mean grain yield 4.14 t ha^{-1} followed by BRRI dhan43 (3.41 t ha^{-1}). A total of 5052 kg grains were produced from all demonstrated plots and 800 kg quality seeds were retained by the farmers for the next year use. About 620 farmers acquired awareness and knowledge about the varieties through field visits, discussion, knowledge sharing and field day. A total of 235 farmers were motivated and showed their interest to cultivate these varieties in the next year.

SPDP during T. Aus 2021 under GoB. Eighty-seven SPDPs were conducted in different agro-ecological regions of the country covering 25 upazilas of 12 districts in T. Aus 2021 under GoB. Three modern rice varieties (BRRI dhan48, BRRI dhan82 and BRRI dhan98) were used in this programme. Among the varieties, BRRI dhan98 produced the highest mean grain yield 5.55 t ha^{-1}. The mean grain yield of BRRI dhan48 and BRRI dhan82 was almost similar and it was 4.63 t ha^{-1}and 4.64 t ha^{-1}, respectively. The highest average growth duration was found in BRRI dhan98 (111 days) followed by BRRI dhan48 (110 days). However, the lowest average growth duration was found in BRRI dhan82 (105 days). A total of 31,768 kg grains were produced from all demonstrated plots from which 7,013 kg quality seeds were retained by the farmers for the next year use. About 3,320 farmers acquired awareness and knowledge about the varieties through field visits, discussion and knowledge sharing. A total of 1,411farmers were motivated and showed their interest to cultivate these varieties in the next year. BRRI dhan48, BRRI dhan82 and BRRI dhan98 were highly preferred by the farmers for its higher grain yield and shorter life cycle in Aus season

Dissemination of BRRI hybrid dhan7 during T. Aus 2021 under GoB:. Demonstrations were conducted during T. Aus 2021 at 14 upazilas of five districts (Chuadanga, Bhola, Borguna, Manikganj, Gaibandha) under GoB. BRRI hybrid dhan7 was used as cultivar. Average grain yield of BRRI hybrid dhan7 was 5.83 t ha^{-1}in the above demonstration sites. However, the highest grain yield produced by BRRI hybrid dhan7 was 7.19 t ha^{-1} at Daulatkhan, Bhola. And the lowest grain yield produced by BRRI hybrid dhan7 was 4.56 t ha^{-1}atTajumuddin upzilla of Bhola district. The mean growth duration of BRRI hybrid dhan7 was 111 days. However, it ranged from 101 to 125 days. A total of 21,854 kg grains were produced from all demonstrated plots. About 1,075 farmers acquired awareness and gained knowledge about the varieties through field visits, discussion and knowledge sharing. A total of 410 farmers were motivated and showed their interest to cultivate BRRI hybrid dhan7 in the next year.

Performance of BRRI dhan98 during T. Aus 2021. Three special-SPDPs were conducted in Sylhet (S. Surma), Manikganj (Harirampur) and Gaibandha (Palashbari) districts during T. Aus season in 2021using BRRI dhan98. Its objective was to observe the performance and adaptability of latest BRRI released T. Aus variety. The growth duration varies from 107 to 115 days and average yield was 5.04 t ha^{-1}. A total of about 5,870 kg grains were produced from three demonstration plots and 1,030 kg quality seeds were retained by the farmers for the next year cultivation. About 460 farmers acquired awareness and knowledge about the varieties through field visits, discussions and knowledge sharing. A total of 125 farmers were motivated to grow BRRI dhan98 in the next season.

SPDP in Jhum cultivation during Aus 2021. These SPDPs were conducted in Jhum cultivation in three upazilas of three hill tract districts during T. Aus 2021. BRRI dhan48, BRRI dhan82 and BRRI hybrid dhan7 were used in those SPDPs. Among the varieties, BRRI hybrid dhan7 yielded the highest (3.60 t ha^{-1}). BRRI dhan48 yielded 3.56 t ha^{-1} followed by BRRI dhan82 (3.03t ha^{-1}). The mean growth duration of BRRI hybrid dhan7, BRRI dhan48 and BRRI dhan82 was 113 days, 109 days and 105 days respectively. The total production of three varieties was 4,129 kg and 220 kg seeds of two inbred varieties were retained by the farmers for next Jhum cultivation. A total of 385 farmers gained knowledge from these SPDPs and 70 farmers were motivated to grow BRRI varieties next year.

SPDP in valley of hills during T. Aus 2021. These SPDPs were conducted in valley cultivation in three upazilas of three hill tract districts during T. Aus 2021. Each SPDP was consist of three variety cultivated in three bighas of land (one variety in one bigha land). Quality seeds were supplied to farmers with standard SPDP procedure so that the seeds could be usable in the next year except BRRI hybrid dhan7. BRRI dhan48, BRRI dhan82 and BRRI hybrid dhan7 were selected for SPDPs. Among the varieties, BRRI hybrid dhan7 yielded the highest (6.26 t ha^{-1}) followed by BRRI dhan48 (4.71 t ha^{-1}) and BRRI dhan82 (4.46 t ha^{-1}). A total of 290 kg seeds of two inbred varieties were retained by the farmers for next cultivation. In total 480 farmers gained knowledge from these SPDPs and 125 farmers were motivated to grow BRRI varieties next year.

SPDP T. Aman 2021 under GoB: SPDPs of modern rice varieties in T. Aman 2021 under GoB were conducted in different agro-ecological regions of the country covering 68 upazilas of 26 districts . Plot size of each variety was 1 bigha and three varieties were demonstrated in 3 bighas area in a cluster in each upazila. Among the varieties, BRRI dhan87 produced the highest mean grain yield 5.35 t ha^{-1} followed by BRRI dhan95 (5.3 t ha^{-1}) and BRRI dhan93 (5.14 t ha^{-1}). The lowest mean grain yield (4.48 t ha^{-1}) was found in BRRI dhan78 followed by BRRI dhan94 (4.57 t ha^{-1}). The highest average growth duration was found in BRRI dhan76 (162 days) followed by BRRI dhan79 (140 days). The lowest average growth duration was found in BRRI dhan75 (115 days) followed by BRRI dhan71 (118 days). The highest grain yielder BRRI dhan87 had growth duration of 127 days. However, the lowest grain yielder BRRI dhan78 had growth duration of 137 days. A total of 13,6780 kg grain were produced from all demonstrated plots from which 19,720 kg quality seeds were retained by the farmers for the next year use. About 11,229 farmers acquired awareness and knowledge about the varieties through field visits, discussion and knowledge sharing. A total of 3,793 farmers were motivated and showed their interest to cultivate these varieties next year. BRRI dhan87, BRRI dhan95, BRRI dhan71 and BRRI dhan75 were highly preferred by the farmers for its good taste, quality grain and shorter life cycle that create opportunity to timely establishment of Rabi crops. Besides newly released BRRI dhan87 also preferred by the farmers for its higher grain yield and good grain size.

Performance of BRRI dhan71 and BRRI dhan75 in T. Aman-Potato-Boro cropping pattern during T. Aman 2021. SPDPs were conducted in Potato growing areas of northern part of Bangladesh to introduce short duration T. Aman rice varieties during T. Aman 2021. Two modern rice varieties, BRRI dhan71 and BRRI dhan75 having the growth duration less than 120 days, were cultivated in eight upazilas of four districts (Nilphamari, Thakurgaon, Joypurhat and Bagura) under GoB. The average yield of BRRI dhan71 and BRRI dhan75 was 5.15 t ha^{-1} and 4.99 t ha^{-1} respectively. A total of about 10.86 tons of seeds were produced from all demonstration plots and 1,430 kg quality seeds were retained by the farmers for the next year cultivation. A total of 372 farmers acquired awareness and knowledge about the varieties through field visits, discussion and knowledge sharing. A total of 94 and 112 farmers were motivated to grow BRRI dhan71 and BRRI dhan75 respectively during the next season.

Performance of BRRI hybrid dhan4 and BRRI hybrid dhan6 in different locations during T. Aman 2021. Demonstrations were conducted during T. Aman 2021 at 17 upazilas of nine districts using two hybrid rice varieties (BRRI hybrid dhan4 and BRRI hybrid dhan6). BRRI hybrid dhan4 produced the highest mean grain yield (5.95 t ha^{-1}) than BRRI hybrid dhan6 (5.91 t ha^{-1}). A total of 28,584 kg grains were produced from all the demonstration plots. About 2,463 farmers acquired awareness and gained knowledge about the varieties through field visits, discussion and knowledge sharing. A total of 687 farmers were motivated and showed their interest to cultivate these varieties next year.

Performance of BRRI dhan80 and BRRI dhan87 in hill tracts during T. Aman 2021: Demonstrations were conducted during T. Aman 2021 at six upazilas of three districts in hill tracts (Khagrachari, Rangamati and Bandarban) under GoB. Two rice varieties (BRRI dhan80 and BRRI dhan87) were used as cultivar. Between the demonstrated varieties, BRRI dhan87 produced the highest mean grain yield (5.65 t ha^{-1}) than BRRI dhan80 (4.63 t ha^{-1}) (Table 12). A total of 8,253 kg grains were produced from all the demonstration plots from which 912 kg was retained as seed for next year cultivation. About 784 farmers acquired awareness and gained knowledge about the varieties through field visits, discussion and knowledge sharing. A total of 211 farmers were motivated and showed their interest to cultivate these varieties next year.

Special SPDP (Muzibborsho) in T. Aman, 2021. Materials and locations: 84 Special SPDPs were conducted in 14 upazials of 11 districts of Bangladesh for rapid dissemination of BRRI varieties during T. Aman 2021. Eight modern rice varieties, BRRI dhan75, BRRI dhan76, BRRI dhan79, BRRI dhan87, BRRI dhan90, BRRI dhan93 and BRRI dhan95 were cultivated in this programme under GoB. Plot size of each variety was 3 bigha and two varieties were demonstrated in each location in acluster. The average yield of BRRI dhan75, BRRI dhan76, BRRI dhan87, BRRI dhan90, BRRI dhan93 and BRRI dhan94 was 4.94 t ha^{-1}, 5.59t ha^{-1}, 4.2 t ha^{-1}, 5.625 t ha^{-1}, 5.1 t $ha^{-1}$and 5.76 t ha^{-1} respectively. About 35.452 ton seeds were produced from all demonstration plots and 1680 kg quality seeds were retained by the farmers for the next year cultivation. About 1,876 farmers acquired awareness and knowledge about the varieties through field visits, discussion and knowledge sharing. In total 464 farmers were motivated to grow BRRI varieties in the future.

Performance of BRRI dhan91 in different locations during early T. Aman 2021. Thirty-nine SPDPs were conducted in low land areas of Manikganj, Narayanganj, Munsiganj, Pabna and B. Baria districts during B Aman 2021 using BRRI dhan91. Plot size of each variety was 3 bigha in cluster/upazila. The growth duration varies from 150 to 195 days and average yield was 2.36 t ha^{-1}. Crops were damaged in four locations due to higher water depth. A total of about 8.525 kg paddy rice were produced from all the demonstration plots and 1,070 kg quality seeds were retained by the farmers for the next year cultivation. A total of 590 farmers acquired awareness and knowledge about the varieties through field visits, discussion and knowledge sharing. Among them 150 were motivated to grow BRRI dhan91 in the next season.

SPDP during T. Aman 2021 under TRB. A total of 60 SPDPs were conducted in 16 upazilas of 13 districts under TRB project during Aman 2021. BRRI dhan71, BRRI dhan73, BRRI dhan75, BRRI dhan80 and BRRI dhan87 were demonstrated in the SPDPs. Area of each SPDP was 3 bigha and total area of SPDP was 60 bigha. Irrespective of variety and location, BRRI dhan87 produced the highest mean grain yield (6.02 t ha^{-1}) followed by BRRI dhan73 (5.63 t ha^{-1}) and the lowest mean grain yield was found in BRRI dhan80 (4.81 t ha^{-1}). Across the locations, BRRI dhan87 produced the highest grain yield (6.66 t ha^{-1}) at Sadar, Netrakona while the lowest yield (4.00 t ha^{-1}) obtained in BRRI dhan80 at Lama, Bandarban. Total production of all the varieties was 44,244 kg from which 5,465 kg was retained as seeds (12% of total production) by the farmers for next season cultivation. A total of 3,330 farmers gained awareness and knowledge about the varieties and 576 farmers (16% of total farmers) were motivated to cultivate the varieties. Mean growth duration BRRI dhan71, BRRI dhan73, BRRI dhan75, BRRI dhan80 and BRRI dhan87 was 113, 129, 111, 130 and 128 days respectively.

Head to Head Adaptive Trial (HHAT) during T. Aman 2021under TRB. A total of 200 Head to Head Adaptive Trials (HHAT) were conducted in Aman (wet season) 2021 throughout the country under TRB project. BRRI released varieties BRRI dhan51, BRRI dhan52, BRRI dhan71, BRRI dhan73, BRRI dhan75, BRRI dhan79, BRRI dhan80 and BRRI dhan87 as well as BINA released varieties like Binadhan-17, Binadhan-21 and Binadhan-23 were used in the HHATs. In HHAT (LD), BRRI dhan87 was found as the highest yielder (5.84 t ha^{-1}) having growth duration 130 days. Whereas, BRRI dhan80 produced the lowest yield (4.95 t ha^{-1}). BRRI dhan93, BRRI dhan94 and BRRI dhan95 produced the statistically similar yield and the growth duration was 135 days and 129 days respectively. In the category HHAT (SD), BRRI dhan75 produced the highest grain yield (5.24 t ha^{-1}) having the lowest growth duration 113 days followed by BRRI dhan71 which produced 5.23 t ha^{-1}. Binadhan-17 produced the lowest yield (5.17 t ha^{-1}) which was statistically similar to Binadhan-22. The growth duration was 119 days and 118 days respectively. In Coastal Ecosystem (CE) areas, the average highest yield was Binadhan-23 was recorded 5.10 t ha^{-1}followed by BRRI dhan78 producing grain yield 5.06 t ha^{-1}with 125 days growth duration. BRRI dhan73 also performed well in coastal ecosystem, which produced 4.87 t/ha grain yield having only 125 days growth duration. Among the Flash flood submergence tolerant varities BRRI dhan52 produced the highest mean yield (5.00 t ha^{-1}) having the GD 141 days followed by BRRI dhan51 producing grain yield of 4.99 t ha^{-1} with 142 days growth duration and other tested varieties and line IR13F441 produced statistically similar yield.

SPDPs in Boro 2022. A total of 703 demonstrations were established in 27 upazilas of 13 districts (Tangail, Gazipur, Narshingdhi, Manikganj, Kishoreganj, Mymensingh, Netrakona, Sherpur, Bagerhat, Gaibandha, Khagrachari, Bandarban, Rangamati) under GOB core programme of Bangladesh in Boro 2021-22. Eleven modern rice varieties (BRRI dhan50, BRRI dhan67, BRRI dhan74, BRRI dhan84, BRRI dhan88, BRRI dhan89, BRRI dhan92, BRRI dhan96, BRRI dhan99 and BRRI dhan100) were used in the programme. Among the varieties, BRRI dhan92 produced the highest mean grain yield 7.67t ha-1 followed by BRRI dhan89 (7.42 t ha^{-1}) and BRRI dhan96 (6.57 t ha^{-1}). The lowest mean rice grain yield was 5.47 t ha-1 in BRRI dhan99 followed by 5.48 and 5.53 t ha^{-1} in BRRI dhan97 and BRRI dhan67 respectively (Table 2). However mean rice grain yield of BRRI dhan100 was 6.14 t ha^{-1}which was intermediate among the vasrieties.

SPDP in Boro 2022 under TRB. A total of 66 SPDPs were conducted in 16 upazilas of the demonstrated rice varieties. Yield of the highest grain BRRI dhan92 varied from 5.08-9.28 t ha^{-1} in different locations depending on soil fertility, salinity, cropping pattern and management practices. A total of 2,16,774 kg grains were produced from all demonstrated plots and 21,336 kg quality seeds were retained by the farmers as seed for the next year cultivation. A total of 11,053 farmers acquired awareness and knowledge about the varieties through field visits, discussions and knowledge sharing. A total of 6,010 farmers were motivated and showed their interest to cultivate these varieties next year. BRRI dhan92 and BRRI dhan89 were highly preferred by the farmers for their higher yield. BRRI dhan99 was also preferred by the farmers for its higher paddy production, good taste, quality grain and shorter life cycle that create opportunity to timely establishment of Rabi crops. Therefore, they were motivated to cultivate this variety in 10districts (Gazipur, Netrakona, Mymensingh, Khulna, Chuadanga, Norsingdhi, Kishoreganj, Baguraand Bandaarban) under TRB project during Boro 2021-22. BRRI dhan74, BRRI dhan67,BRRI dhan81, BRRI dhan88,BRRI dhan89 and BRRI dhan92 were used in the SPDPs. Irrespective of variety and location, BRRI dhan92 the highest yield (8.50 t ha^{-1}) in Monohordi, Norsingdhi while the lowest yield (5.00 t ha^{-1}) obtained in BRRI dhan88 at Shibganj, Bagura. Total production of all the varieties was 49,914 kg from which 3,700 kg was retained as seeds (8% of total production) by the farmers for next season cultivation. A total of 3,096 farmers gained awareness and knowledge about the varieties and 731 farmers (22% of total farmers) were motivated to cultivate the varieties. Mean growth duration of BRRI dhan74, BRRI dhan67, BRRI dhan81, BRRI dhan88, BRRI dhan89, and BRRI dhan92 was 146, 144, 141, 139, 157 and 158 days while mean grain yield was 5.17, 6.30, 6.06, 5.88,6.50 and 6.39t ha^{-1}, respectively.

PROMOTIONAL ACTIVITIES

Farmers' training. During the reporting period ARD conducted 113 farmer's training under GoB and one projects (TRB) at different locations of the country in which 3,390 trainees (3051 farmers and 339 SAAOs of DAE) participated during the reporting period of 2021-2022.

Field day. ARD conducted 71 field days at different locations in different seasons of the country under GoB and one project (TRB) during 2021-2022. Around 4,741 participants including farmers, local leaders and DAE personnel participated in the field days.

SEED production at BRRI farm. A total of 5,230 kg and 2,550 kg quality seeds of different BRRI varieties were produced at BRRI farms during T. Aman 2021 and Boro 2022 respectively.

Farmers' Seed Centre. Four farmers' seed centers were established during the reporting period. TRB-BRRI provided six plastic drums in each center. Eighty kg seed can be stored in each drum.

Seed support to farmers and stakeholders under TRB project. Adaptive Research Division distributed 1.50 tons seeds among the farmers and stakeholders. Around 110 farmers will be benefitted through getting seed and technologies directly and indirectly.

Training Division

SUMMARY

Training Division has conducted 57 training programmes in the reporting year with course duration from one day to two months. A total of 1,555 participants from different government and non-government organizations were trained through these courses. Need based course curriculum was developed for these courses. The highest number of participants was from the Department of Agricultural Extension (DAE). The average improvement of BRRI scientists in 2-month Rice Production and Communication Training (RPT) course was 411% in theory and 207% in practical evaluation. Again the overall improvement of knowledge for extension personnel in 1-week Rice Production Training (RPT) varied widely and ranged from 164 to 205%. The results indicate the significance of rice production training for scientists and extension personnel. Effectiveness of imparted trainings was determined on the basis of feedback remarks on different aspect. Most of the trainees expressed positive views about the course content and method of trainings. However, participants of all courses, specially the 1-week course, suggested for increasing duration of the course from 1-week to at least 2-3 weeks. Most of the BRRI's speakers' performance was very good to excellent.

TRAINING NEED ASSESSMENT

A need assessment session was conducted at the beginning of each batch of training to know the expectation of the trainees. A total of 1,297 responses on different issues were received from the trainees of which 724 from GOB, 472 from hybrid rice funded training course and 101 from BRRI scientists (Table 1). Though the participants were different categories and from different regions and environments of the country, their expectations were very much similar. SAAOs showed high expectation about insect and disease management followed by variety related issues. High expectation of participants, in case of 2- month RPT course for BRRI scientists was on scientific report writing followed by variety and statistical analysis related issues.

CAPACITY BUILDING AND TECHNOLOGY TRANSFER

Two-month long rice production training for BRRI scientists

The main objectives of the course were to train the new scientists so that they can:

- Plan and execute research programme on rice and rice based farming system
- Analyze, write and interpret the research findings
- Recognize and apply the major concepts, principles and techniques of modern rice production activities
- Identify and solve rice related field problems and
- Conduct rice production training programme.

The course curriculum was designed as per requirement and objectives of the course. One batch was conducted during the reporting period and 34 scientists were trained. Among the participants, 21 were male and 13 were female. Table 2 presents the particulars of the participants.

Improvement of knowledge was measured on the basis of marks obtained in the benchmark and final evaluation of individual participant. Knowledge improvement through this training was very attractive. On average, it was 411% for theory and 207% for skill (Table 3). Table 4 presents the performance status of 2-month long rice production training.

One-week rice production training

The main objective of the course was to train the field level Sub Assistant Agriculture Officers (SAAO) of DAE so that they can be able to identify and solve the rice related problem in the field. The course curriculum was designed based on the priority of field problems related to rice production and rice based technologies. Lecture, field visit and hands on activities were the leading methodology of this training course. A total of 360 SAAOs were trained during the reporting period using the GOB fund. Among the participants 301 and 59 were male and female respectively (Table 5).

Benchmark and final evaluation tools were applied to assess the knowledge improvement of individual participants. Average knowledge improvement of the participants were 205 (Table 6). Table 7 presents the performance status of 1-week long rice production training.

Training on advanced research data management using R studio

Five 6-day long training programmes on advanced research data management using R studio were conducted in 2021-22. A total of 79 participants were trained through this course. Of which 53 and 26 were male and female respectively. The participants of these courses were scientific officer and senior scientific officer of Bangladesh Rice Research Institute. Table 8 presents the details of the training courses.

Training on modern rice production and rice based farming system

Six batches of training course on modern rice production and rice based farming system ware conducted during 2021-22 using the fund of 'Increase the productivity of hill tract region of Bangladesh through rice based farming system development programme'. The objective of the course was to train the SAAOs of the project areas so that they can recognize the program activities and do work accordingly. Table 9 presents the particulars of the course.

Benchmark and final evaluation tools were applied to assess the knowledge improvement of individual participants. Average knowledge improvement of the participants was 256% (Table 10). Table 11 presents the performance status of modern rice production and rice based farming system training.

Training on hybrid rice and seed production technologies

Eleven batches training course on hybrid rice and seed production technologies were conducted during 2021-22 using the fund of 'development of high yielding hybrid rice varieties, research and modernization project'. The objective of these training course was to increase the knowledge and skill of the SAAOs of the project areas so that they can help the project to disseminate BRRI developed hybrid rice varieties and component technologies into the field level. In this regard, 306 participants were trained and among the participants 273 were male and 33 were female respectively. Table 12 presents the particulars of the course.

Benchmark and final evaluation tools were applied to assess the knowledge improvement of individual participants. Average knowledge improvement of the participants was 253% (Table 13). Table 14 presents the performance status of modern rice production and rice based farming system training.

Under this project another two batches of the training program also conducted for the scientists of BRRI and the personnel of different seed companies, Bangladesh Agriculture Development Corporation (BADC) DAE and different NGOs. Table 15 presents the particulars of the course.

Training on operating of BRRI central laboratory (BCL)

In the history of Bangladesh Rice Research Institute (BRRI), for the first time it has established a world class central laboratory at BRRI. The main objective of the laboratory doing is research at per world standard. Therefore, Ministry of Agriculture (MoA) support with a programme namely strengthening the BRRI central laboratory. Through these programme five training courses namely Hands on training on Molecular biology techniques and basics Bioinformatics, Hands on training in analytical instruments and sampling procedures, Hands on training in HPLC, LCMS and ICPOES and Hands on training in Advanced molecular biology and Bioinformatics for the BRRI scientists were conducted during the reporting period. The beauty of these courses was that the same participants repeatedly trained so that they can finally be able to work in the laboratory efficiently with propely handling the equipments. Table 16 presents the particulars of the course.

Farmers training

BRRI Training Division also conducted some farmers training. During the reporting period 12 day-long modern rice production training for the farmers were conducted in collaboration with DAE using GOB fund. In total 540 farmers were trained through this programmes. Table 17 presents the details about the farmers training.

Training Information of BRRI

During the reporting period, 57 training programmes have been conducted by the Training

Division and a total of 1,555 participants were trained through these training. Among the total participants 1,301 and 254 were male and female respectively (Table 18).

Table1. Expectations of the trainees on different subjects in need during 2015-16.

Subject/issue	Expectation (%)						Subject/issue	Expectation (%)	
	SAAO				SA				
	GOB	Hybrid Proj	All	Rank	GOB	Rank		Scientist	Rank
Disease	18	13	16	2	11	4	Report writing	14	1
Insect	18	17	18	1	13	3	Variety	13	2
Variety	10	13	12	3	18	1	Statistics	13	2
Fertilizer	7	4	6	6	14	2	Disease	10	3
Soil	3	2	3	7	6	6	Molecular science	9	4
Crop mangt.	7	11	9	5	18	1	Physiology	8	5
IWM	10	14	12	3	2	7	Soil science	8	5
Seed	12	10	11	4	9	5	Post harvest technology	5	6
Farm machinery	5	6	6	6	2	7	Irrigation	3	7
Weed	-	-	-	-	2	7	Grain quality	3	7
Others	8	9	8	-	3	-	Others	8	-
Total	100	100	100		100			100	
Response no.	724	472			35			101	

Table 2. Particulars of the 2-month long rice production training in 2021-22.

Batch	Duration	No. of participants			Designation	Organization
		Total	Male	Female		
1	2-month	34	21	13	SO,SSO	BRRI

Table 3. Knowledge improvement through 2-month long rice production training.

Category of valuation	Benchmark evaluation	Final evaluation	Improvement(%)
Theory	17	87	411
Skill	14	43	207

Table 4. Performance status of 2-month long rice production training.

Category /certificate	Participant number	Percentage
Distinction (80-100% marks)	34	100
Satisfactory (60-79% marks)	-	-
Participatory (Less than 60% marks)	-	-

Table 5. Particulars of one week long rice production training conducted by BRRI in 2021-22.

Project	Batch (No.)	No. of participants			Designation	Organization
		Total	Male	Female		
GOB	15	360	301	59	SAAO	DAE

Table 6. Knowledge gain and improvement through 1-week rice production training.

Project	Evaluation (average mark %)		Improvement (%)
	Benchmark	Final evaluation	
GOB	25	73	205

Table 7. Performance status of 1-week long rice production training.

Project	Category of results/ certificates		
	Distinction	Satisfactory	Participatory
GOB	114	149	15

Table 8. Particulars of advanced research data management training using R studio in 2021-22.

Project	Batch (no.)	Participants (no.)			Designation	Organization
		Total	Male	Female		
GOB	5	79	53	26	SO, SSO	BRRI

Table 9. Particulars of one-week modern rice production technique and rice based farming system in 2021-22.

Project	Batch (no.)	Participants (no.)			Designation	Organization
		Total	Male	Female		
	6	125	105	20	SAAO, SAPPO	DAE

Table 10. Knowledge gain and improvement through one-week long modern rice production technique and rice based farming system in 2021-22.

Project	Evaluation (average mark %)		Improvement (%)
	Benchmark	Final evaluation	
	22	71	256

Table 11. Performance status of one-week long modern rice production technique and rice based farming systemin 2021-22.

Project	Category of results/ certificates		
	Distinction	Satisfactory	Participatory
	45	65	20

Table 12. Particulars of five days long hybrid rice and seed production technologies training in 2021-22.

Project	Batch (no.)	Participants (no.)			Designation	Organization
		Total	Male	Female		
Hybrid	11	306	273	33	SAAO	DAE

Table 13. Knowledge gain and improvement through five days long hybrid rice and seed production technologies training in 2021-22.

Project	Evaluation (average mark %)		Improvement (%)
	Benchmark	Final evaluation	
Hybrid	21	73	253

Table 14. Performance status of five days long hybrid rice and seed production technologies training in 2021-22.

Project	Category of results/ certificates		
	Distinction	Satisfactory	Participatory
Hybrid	91	171	44

Table 15. Particulars of hybrid rice and seed production technologies training for BRRI scientists and seed company personnel in 2021-22.

Project	Batch (no.)	Participants (no.)			Designation	Organization
		Total	Male	Female		
Hybrid	2	44	53	26	SO, SSO,	BRRI, Seed Company

Table 16. Particulars of BRRI central laboratory accreditation training 2021-22.

Batch No.	Title	No. of participants		
		Total	Male	Female
1.	Hands on training on Molecular biology techniques and basics Bioinformatics	14	8	6
2.	Hands on training in analytical instruments and sampling procedures	14	5	9
3.	Hands on training in HPLC,LCMS and ICPOES	14	4	10
4.	Hands on training in Advance molecular biology and Bioinformatics	14	11	3
	Total	56	28	28

Table 17. Rice production training courses for farmers in 2021-22.

Location	Training (no.)	Participants (no.)		
		Total	Male	Female
Gazipur	2	240	220	20
Rangpur	6	180	150	30
Habiganj	4	120	102	18
Total	12	540	472	68

Table 18. Total trainings conducted by Training Division during 2021-22.

Name of the training	No. of training	Duration	No. of participants			Designation
			M	F	Total	
Modern technology of rice production training course	1	2 months	21	13	34	SO,SSO,BRRI
Modern rice production training	15	1 week	301	59	360	SAAO,DAE
Training on advanced research data management using R studio	5	1 week	53	26	79	SO,SSO,BRRI
Modern rice production and rice based farming system	6	1 week	105	20	125	SAAO,DAE
Training course on hybrid rice and seed production technology	11	5 days	273	33	306	SAAO,DAE
Training course hybrid rice and seed production technology	2	5 days	40	5	45	SO,SSO,BRRI
Training for operating BRRI central laboratory	4	10-15 days	28	28	56	SO,SSO,BRRI
Training on genome sequence techniques, sequence assembly and bioinformatics analysis	1	5 days	8	2	10	SO,SSO,BRRI
Farmers training on modern rice production technologies	12	1 day	472	68	540	Farmers
Total	57		1301	254	1555	

EFFECTIVENESS OF IMPARTED RICE PRODUCTION TRAINING

It is important to determine the impact of different aspects of imparted rice production training for its better planning and execution in future. This study was conducted at the end of each batch to collect the relevant information. After the completion of data collection, information was compiled and analyzed. This study reveal that both two-month and one- week long RPT courses are very much helpful for the trainees to build up their capacity for modern rice production activities.

Performance of BRRI speakers

Ten batches of 1- week long RPT and one batch from 2- month long PRT were considered for this evaluation. At first, batch wise analysis was done on the basis of five criteria for each speaker. The criteria were: a. presentation style; b. question handling; c. use of training materials; d. time management and e. quality and relevance of handout and its timely supply. Average of five criteria was used to determine the performance of individual speaker in each batch. The overall performances of BRRI's speakers were very good (34.59%) to excellent (45.43%) in both long and short duration courses.

BRRI RS, Barishal

SUMMARY

BRRI RS, Barishal is operating a strong breeding programme to develop suitable high yielding rice varieties for tidal submergence in T. Aman and favoulrable Boro seasons. To achieve the goal, 58 new crosses were made, and 46 crosses were confirmed. Three hundred forty-nine plants from 25 F2 populations were selected and 213 plants were selected out of 708 progenies of 25 F6 populations for observational trial during T Aman 2021. A total of 624 from 44 F3 populations and 1,412 plant progenies from 5 **F**5 generations were selected for generation advancement. Two hundred forty-two lines were selected and harvested as bulk from 21 F**6** populations during Boro 2021-22. In a special programme to develop new generation rice (NGR) dense and erect panicles, a total of 377 plants were fixed as homogeneous lines during Boro 2021-22. To explore the attributes of NGR in exotic populations 1,590 plant progenies were selected from 47 F5 populations during Boro 2021-22. One observational yield trial (OYT) was conducted during T. Aman 2021 the experiment consisting of 130 advanced breeding lines along with five checks and out of those 16 lines were selected for their better performances. One OYT consisting of 137 along with five checks and out of those 13 entries were selected based on yield and yield contributing traits during Boro 2021-22. Two preliminary yield trials (PYTs) were conducted during T. Aman 2021. In PYT-**1**, thirty-two advanced breeding lines along with five checks were evaluated and better.

Performing twelve entries were selected for further trials. In PYT-2, forty-eight advanced breeding lines along with four checks were evaluated and based on their better performce 20 lines were selected for further trials. One PYT was conducted during Boro 2021-22. Fifty-nine advanced breeding lines along with four checks were evaluated and better performing 27 genotypes were selected for further trials. Fourteen regional yield trials (RYTs) were conducted during 2021-22. Out of them, seven RYTs for favourable Boro (long, medium and short duration, Bio, short slender, long slender grain, and Barishal#FBR) , one RYT of AGRiNET, one RYT of IRR_BPH, two RYTs for DRR_BB, one for zinc enriched rice and two RYTs for salt tolerant rice (STR). All the tested RYT materials were obtained from BRRI HQ, Gazipur excepting one Barishal#FBR. One advanced yield trial (AYT) consisting of six poptential breeding lines along with four checks was conducted during T. Aman 2021. Three AYTs were conducted during Boro 2021-22 and out of them one included the NGR lines the other two from BRRI HQ, Gazipur named as FBR_Early and FBR_Late. Thirty-eight entries along with the six checks were evaluated in an International Network for Genetic Evaluation of Rice (INGER) trials during Boro **2021-22.** Ten lines were found out yielded the checks were and aimed to further evaluation in AYT. A confined field trial (CFT) was conducted with eleven transgenic lines of high iron and zinc rice development programme along with non-transgenic control as the standard check variety BRRI dhan28 during Boro 2021-22. A total of 369 local Aman germplasm were grown in six-line plots for characterization, utilization and maintenance during T. Aman 2021. Appearance of insect pests was lower than the previous reporting year. GLH, YSB, WLH, BPH were found in comparatively higher number than the other rice insect pests. The highest catch of natural enemies STPB, CDB, and EW in light trap was recorded. Insect pest peak was observed at October, November and December 2021 and another little peak was observed at March 2022. Natural enemy abundance was found higher at October, November and December 2021 and March 2022. A novel rectangular hand net (RHN) was developed for insecticides free rice seedbeds. RHN performance was found significantly better than traditional round hand net. Early aged rice seedlings possible to sweeping by rectangular hand net. Newly developed rectangular hand net application method is rapidly walking around the seedbed (model seedbed one-meter width and length depends on land condition). After sweeping full seedbed harmful insect pest has been destroyed and beneficial insect released back in the same field. Zinc phosphate and Phostoxin bait found the highest rat dead and its efficacy also better compare

to other market available rodenticides at BRRI, RS Charbadna farm in T. Aman 2021. Yellow stemborer caught had no significand difference among different varieties with pheromone lure at BRRI RS, Charbadna farm in Aus, 2021**.** In Boro 2021-22 BRRI RS Barishal Charbadna and Sagordi farm rice production without insecticides applying perching and sweeping technology. After every field complete sweeping natural enemy released back again in the same plot and harmful insect are damaged. Pests and natural enemies was monitored in BRRI RS Barishal with light trap. In Barishal T. Aman 2021 average bacterial leaf blight incidence (29.9%) was predominant. In Barishal Boro 2022 average narrow brown spot incidence **(**27.38 %) was predominant. From the missing element trial it reveals that for BRRI dhan**67**, N is the most limiting nutrient followed by K, in the tidal flooded soil. Overall findings suggest that all the nutrients (N, P, K, S and Zn) should be applied in required amount in T. Aman while in Boro, application of N and K must be ensured for optimum rice yield. The sediment from tidal water in BRRI RS, Barishal regional station was found slightly alkaline (pH=7.8) and organic matter was high in amount **(**3.27%). Among inorganic nutrient the amount of Sulphur was quite noticeable which is 15.33 µg g-**1.** The experiment needs to be continued for following years. Head to head trial for Boro varieties under TRB project in the Barishal region suggests that BRRI dhan74 could be popular and be disseminated among the farmers as newly released varieties.

In T. Aus 2021, BRRI hybrid dhan7 produced the highest yield (4.77t/ha) followed by BRRI dha82 (4.56 t/ha); in T. Aman 2021, BRRI dhan76 produced (5.92 t/ha) the highest yield followed by BRRI dhan46 (5.79 t/ha) and Boro 2021-22 found BRRI hybrid dhan5 (7.05 t/ha) followed by BRRI dhan74 (6.66 t/ha) in stability analysis experiment at BRRI RS, Barishal. Seven ALARTs, where two for T. Aman 2021 (zinc eenriched rice and stagnant water), and five for boro 2021-22 (salt tolerant rice#1, salt tolerant rice#1, favourable boro rice_ barishal, blast resistant rice, superior high yielding rice) were conducted at differtent sites of the Barishal region. From the results of ALART, in Boro 2021-22: BRBa 3-2-4 for favourable Boro ecosystem (FBR-Barishal) may be selected for the proposed variety trial and, two entries: BRHII-9-11-4-5B and BRH13-2-4-6-4B from superior high yielding rice (SHR) may be selected for the proposed variety trial in next Boro season. BRRI released HYVs were demonstrated under GoB and other projects to disseminate to the farmers. Most of the farmers were motivated to cuttiate varieties such as BRRI dhan76 and BRRI dhan87 in Aman whereas BRRI dhan74, BRRI dhan89 and BRRI dhan92 in Boro. Farmers were also interested to cultivate BRRI hybrid dhan3 and BRRI hybrid dhan4 in Boro. In the reporting year, a total 13,457 kg, 38,749 kg and 56,185 kg paddy were produced respectively for Aus, Aman and Boro in both Sagardi and Charbadna farm BRRI RS, Barishal. Moreover, 40 trainings and 10 field days were conducted by BRRI RS Barishal during this year. Besides, a regional workshop was also arranged in the station.

Table 1. List of F_1 seeds produced in T. Aman 2021.

Cross combination	No. of seeds	Cross combination	No. of seeds
BRBa11-44-2-2-1/BRRI dhan41	15	BRRI dhan87/BRRI dhan76	42
BRBa11-47-1-3-2/BR23	9	Kotiagoni/BRRI dhan41	20
BRBa11-68-1-4-1/BR23	10	Lambu IRRI/BRRI dhan52	17
BRBa11-68-1-4-1/IR16F690	8	Lambu IRRI/BRRI dhan76	8
BRBa19-48-1-2-2/BRRI dhan41	12	Tapushail/BRRI dhan41	5
BRBa19-48-1-2-2/BRRI dhan80	6	Tapushail/BRRI dhan52	190
BRRI dhan44/IR16F1097	110	Tapushail/BRRI dhan77	7
BRRI dhan44/BRRI dhan52	187	Badshabhog/BRRI dhan41	35
BRRI dhan76/BRRI dhan44	46	Badshabhog/BRRI dhan80	18
BRRI dhan87/BRBa11-41-1-1-5-2	20		
Total			765

VARIETY DEVELOPMENT

Hybridization and pedigree nursery

Development of varieties for tidal submergence. Nineteen new crosses were made, and 765 F1 seeds were collected to develop tidal submergence tolerant rice varieties (Table 1). Out of 20 crosses, 24 seven were confirmed and registered in the BRRI cross-list with station code BRBa147 to BRBa170. Three hundred forty-nine plants were selected from 25 crosses of F2 population. Moreover, 213 progenies were selected from 708 progenies of 21 crosses of F5 population during T. Aman 2021.

Breeding for favourable ecosystem

A total of 39 crosses were done and 2,407 F_1 seeds were obtained to develop high yielding Boro rice varieties during Boro 2021-22 (Table 2). Besides, 22 out of 26 crosses were confirmed and registered in BRRI RS, Barishal, code BRBa125 to BRBa146 in Boro 2022. A total of 1,624 plant progenies from 44 F_3 populations, 1,412 plant progenies from 5 F_5 populations., and 242 plant progenies from 21 F_6 populations were selected and bulked during Boro 2021-22.

Breeding for new generation rice (NGR)

To develop improved varieties with dense and erect panicles, 213 homozenious lines were bulked from the F_6 generation during T. Aman 2021. A total of 377 plants were fixed as homogeneous lines during Boro 2021-22. To explore the attributes of new generation rice (NGR) in exotic populations 1,590 plant progenies were selected from 47 F_5 population during Boro 2021-22.

YIELD TRIAL 2021-22

Observational trial (OT) 2021-2022. One OT was conducted to select high yield potential genotype (s) during T. Aman 2021. The experiment was consisted of 130 advanced breeding lines along with five checks BR23, BRRI dhan52, BRRI dhan76, BRRI dhan77 and BRRI dhan87 were grown in BRRI Charbadna farm, Barishal. Based on plant height, growth duration and phenotypic acceptability, 16 genotypes were selected for evaluation in preliminary yield trial.

Table 2. List of F_1 seeds produced in Boro 2020-21.

Cross combination	No. of seeds	Cross combination	No. of seeds
BRBa 2-5-3/BRRI dhan29	121	NGR 1255-2/BRRI dhan92	31
BRBa 2-5-3/BRRI dhan58	114	NGR 1255-2/Kataribhog	51
BRBa 2-5-3/BRRI dhan67	138	NGR 1258-2/BRBa 23-2-3-1-2-P1	9
BRBa 2-5-3/BRRI dhan74	65	NGR 1258-2/BRRI dhan29	7
BRBa 2-5-3/BRRI dhan89	47	NGR 1258-2/BRRI dhan89	31
BRBa 2-5-3/BRRI dhan92	113	NGR 1258-2/Kataribhog	12
BRBa 3-1-7/BRRI dhan29	37	NGR 1277-1/BRBa 23-2-3-1-2-P1	51
BRBa 3-1-7/BRRI dhan58	91	NGR 1277-1/BRRI dhan29	39
BRBa 3-1-7/BRRI dhan67	115	NGR 1277-1/BRRI dhan89	7
BRBa 3-1-7/BRRI dhan89	81	NGR 1277-1/Kataribhog	17
BRBa 3-1-7/BRRI dhan92	119	NGR 736-1/BRRI dhan29	61
IR12A 2854/BRBa 5-4-1	38	NGR 736-1/BRRI dhan89	57
IR12A 2854/BRRI dhan29	20	NGR 736-1/BRRI dhan92	37
IR12A 2854/BRRI dhan89	25	NGR 736-1/Kataribhog	59
IR12A 2854/Kataribhog	13	SVIN 269/BRRI dhan58	73
IR13A 515/BRRI dhan58	53	SVIN 269/BRRI dhan67	76
IR13A 515/BRRI dhan67	65	SVIN 269/BRRI dhan74	125
IR13A 515/BRRI dhan89	11	SVIN 269/BRRI dhan89	119
NGR 1255-2/BRRI dhan29	47	SVIN 269/BRRI dhan92	175
NGR 1255-2/BRRI dhan89	57		
		Total	2407

Observational yield trial (OYT) Boro 2021-22. One OYT was conducted in Charbadna farm, Barishal during Boro 2021-22. The experiment was consisted of 137 entries along with five checks, BRRI dhan58, BRRI dhan67, BRRI dhan74, BRRI dhan92 and BRRI dhan96 were grown. Based on phenotypic acceptability (4-5) and grain yield performance (5.20-5.95t/ha) thirteen genotypes were selected for further evaluation.

Preliminary yield trial (PYT).

Two PYTs were conducted during T. Aman 2021. The first PYT was consisted with 32 advanced breeding lines along with five checks, BRRI dhan23, BRRI dhan52, BRRI dhan72, BRRI dhan76 and BRRI dhan87 were evaluated at Charbadna farm of BRRI RS, Barishal.

Among the tested materials growth duration was ranged from 130 days of BRBa21-13-2-2-1, BRBa23-4-3-1-1-P, BRBa23-4-3-1-1-P2 and BRBa23-6-2-2-4-P1 to 161 days of BR23. The shortest plant height was observed in BRRI dhan72 (119.8cm) while the longest plant height was found in BRBa23-15-3-3-3-P1. Effective number of tillers was ranged from 7 to 17. The highest yield was obtained from BRBa23-4-2-1-1-P2 (5.85 t/ha) followed by BRBa26-1-1-1-1 (5.79 t/ha), BRBa23-15-3-3-3-P1 (5.72 t/ha) and BRBa26-1-1-1-2 (5.50 t/ha) and the lowest yield was obtained from BRBa21-

13-1-2-3 (3.19 t/ha). Twelve entries were selected based on plant height, growth duration, phenotypic acceptability and grain yield compared to the check varieties for AYT in next T. Aman season.

Another PYT was conducted during T. Aman 2021. The experiment consisting of 48 advanced breeding lines along with four checks BRRI dhan23, BRRI dhan52, BRRI dhan76, and BRRI dhan77 at Sagordi and Charbadna farm simultaneously of BRRI RS, Barishal. Among the tested materials, the yield was ranged from 6.77-2.11 t/ha. Twenty entries were selected based on plant height, growth duration, phenotypic acceptability and grain yield compared with the check varieties for AYT in next Aman season.

One PYT was conducted during Boro 2021-22. The experiment consisting of 63 advanced breeding lines along with four checks BRRI dhan58, BRRI dhan67, BRRI dhan74 and BRRI dhan92 were evaluated at Charbadna farm of BRRI RS, Barishal. Among the tested materials, 27 entries were selected compared to the lowest yielded check variety BRRI dhan67 (5t/ha).

Regional yield trial (RYT).

Boro 2021-22. In RYT for favourable Boro (long duration) eleven entries along with the two checks BRRI dhan89 and BRRI dhan92 were grown at Charbadna farm of BRRI RS, Barishal**.** The genotype BR10599-5R-375 produced the highest yield (6.89t/ha) that yielded higher (12.86%) over the highest yielded check variety BRRI dhan89 (6.11t/ha). Five genotypes were found with positive yield advantage (1.54 to 12.86%) over the check variety BRRI dhan89. The growth duration of the positive yielded genotypes were similar to or less than the check varieties (149 days).

A RYT for developing short duration rice variety was conducted at Charbadna farm of BRRI R/S, Barishal during Boro 2021-22. The trial was consucted with six entries along with two check varieties BRRI dhan81 and BRRI dhan96. Two entries producede the better yield than the lowest yielder check variety BRRI dhan81(5.01t/ha). None of the genotypes was found better them the highest yielded check variety BRRI dhan96 (7.07t/ha).

In another RYT (Favourable boro-medium duration), of fifteen genotypes along with two checks viz BRRI dhan81 and BRRI dhan96 ware evaluated at Charbadna farm of BRRI RS, Barishal. The yield range among the tested entries varied from 4.81 to 6.54t/ha and the highest yield was obtained from SVIN109 (6.54 t/ha) which was 11.54% higher than the check variety BRRI dhan96.

In the RYT (AGRiNET), eleven genotypes along with four checks viz BRRI dhan63, BRRI dhan81, BRRI dhan89 and BRRI dhan92 were evaluated at Charbodna farm of BRRI R/S, Barishal. The yield range among the tested entries varied from 5.64 to 7.93t/ha and the highest yield was obtained from IR16A3667 (7.93 t/ha) which was 16.34% higher than the check variety BRRI dhan89 (6.82t/ha). All the tested entries performed better than the lowest yielded check variety BRRI dhan81(5.24t/ha).

In RYT for favourable Boro rice-Bio, four entries along with two checks BRRI dhan88 and BRRI dhan96 were tested at Charbadna farm, of BRRI RS, Barishal, during Boro 2021-22. Test line BR(Bio)10381AC32-3 produced higher yield (6.0t/ha) compared to the check BRRI dhan96 (5.75t/ha). It was also noticed that BR(Bio)10381AC32-3 had three days longer growth duration than the check variety.

In RYT for IRR_BPH, ten genotypes along with two susceptible checks BRRI dhan58 and BRRI dhan88 and, one resistant check T27A were tested at Charbadna farm, BRRI RS, Barishal, during Boro 2021-22. The average yield range of the tested entries were 4.93-6.28t/ha. Incidence of BPH was not observed either on the experimental plots. As a result the susceptible check BRRI dhan58 produced higher yield (5.92 t/ha) compared to the other susceptible and resistant check (4.37t/ha) varieties. Two entries BR11593-5R-73 and BR11595-5R-24 produced higher yield 6.26 t/ha and 6.28t/ha respectively compared to the check BRRI dhan58 (5.92t/ha) with similar growth duration.

In RYT#1 for DRR_BB, fourteen lines along with two standard checks BRRI dhan88 and IRBB60 were tested at Charbadna farm, BRRI RS, Barishal, during Boro 2021-22. The average yield range of the tested entries were 5.44-6.24t/ha. Yield of the standard check was varied from 5.57-5.96t/ha. Three entries BR11607-4R-128 (6.24t/ha), BR11607-4R-42 (6.05t/ha) and BR11607-4R-156 (5.99t/ha) performed better over the standard checks with growth duration 2-4 days longer than BRRI dhan88 (Std. ck.) and, 10-13 days earlier than IRBB60 (Std. ck.).

In RYT#2 for DRR_BB consisting of seventeen lines along with two susceptible checks BRRI dhan58 and BRRI dhan89 and one resistant check IRBB60 were tested at Charbadna farm, BRRI RS, Barishal, during Boro 2021-22. The average yield range of the tested entries were 5.04-6.29t/ha. Among the tested entries one genotype i.e., BR11604-4R-24 producede higher yield (6.29t/ha) over both of the better susceptible check BRRI dhan58 (6.02t/ha) and the resistant check IRBB60 (6.04t/ha) with similar growth duration of BRRI dhan58 (Sus. Ck.) and eight days earlier than IRBB60 (Res. ck.).

In RYT_Long Slender consisting of four lines along with one check (BRRI dhan28) were tested at Sagordi farm, Barishal, during Boro 2021-22. The average yield range of the tested entries were 4.94-6.67t/ha where two entries viz BR10247-4-7-4B (6.67t/ha) and BR10247-14-18-4 (6.63t/ha) producede higher yield over the check variety BRRI dhan28 (5.85t/ha). Test entries had 6-7 days longer growth duration compared to the check variety.

A RYT_Short Slender consisting of Seven lines along with two checks (BRRI dhan28 and BRRI dhan81) was conducted at Sagordi farm, Barishal, during Boro 2021-22. The average yield range of the tested entries were 6.26-6.53t/ha. All the tested entries performed better over the check variety i.e., BRRI dhan28 (6.08t/ha) with more or less similar growth duration. The highest yield was obtained from the tested line BRH10-1-14-2-6B (6.53t/ha).

In RYT for zinc enriched rice**,** five entries along with three checks BRRI dhan29, BRRI dhan74 and BRRI dhan84 were tested at Charbadna farm, BRRI RS, Barishal, during Boro 2020-21. None of the tested entries out yielded the check variety BRRI dhan84 that resulted the highest grain yield 5.63t/ha. BR6974-1-1-5-1-P3 (4.74t/ha) produced higher yield over the lowest yielded check variety BRRI dhan29 (4.54t/ha) with similar growth duration.

A RYT# STR-1 for developing saline tolerant rice variety consisting of eleven entries along with three checks viz BRRI dhan89, BRRI dhan67 and BRRI dhan97 was conducted on farmer's field which is located at Latifpur in Kolapara, Patuakhali under the supervision of BRRI RS , Barishal. The yield range was varied from 3.92t/ha to 5.87t/ha. Among the tested entries three genotypes viz BR10187-1-4-12 (5.87t/ha), BR10187-1-5-11(5.78t/ha) and BR9901-1-3-10(5.87t/ha) performed better than the check variety BRRI dhan67 (5.64t/ha) whereas one genotype BR9926-

7-7-6 (5.64t/ha) producede similar yield as check variety with more or less similar growth duration. The salinity of the experimental plots were measured several times and it was varied from 3.3 to 3.4dS/m.

Another RYT# STR-2 for developing saline tolerant rice variety consisting of eleven entries along with three checks viz BRRI dhan89, BRRI dhan67 and BRRI dhan97 was conducted on farmer's field which is located at Latifpur in Kolapara, Patuakhali under the supervision of BRRI RS, Barishal. The yield range was varied from 4.37t/ha to 5.97t/ha. Among the tested entries two genotypes viz TP20532 (5.54t/ha), and TP24493 (5.97t/ha) performed better than the highest yielded check variety i.e., BRRI dhan67 (5.52t/ha) whereas, one genotype TP21654 (5.52t/ha) producede similar yield as the check variety. The salinity of the experimental plots were measured time to time and it was varied from 3.3 to 3.4dS/m.

RYT Barishal. Twelve entries along with two checks BRRI dhan58 and BRRI dhan89 were evaluated in eleven locations of the BRRI RS and BRRI HQ during Boro, 2021-22. Among the tested materials, the plant height was ranged from 93.53 cm of NGR 1161-3 at Gazipur to 112.67 cm of NGR1255-1 at Kusthia (location wise). NGR 1308-2 took the shortest period (143 days) at Cumilla to get matured while NGR 467-2 took the longest period (168 days) at Kusthia to get matured (location wise). The highest average grain yield (10.17 t/ha) was found in NGR 1255-1 at Bhanga and the lowest average grain yield (5.15 t/ha) was found in NGR1161-3 at Gazipur.The check yields of BRRI dhan 58 was ranged from 6.06 t/ha at Gazipurt to 10.08 t/ha at Bhanga whereas another check variety BRRI dhan89 producede 6.39 t/ha at Barishal to 9.68 t/ha at Bhanga. There was significant yield variation found among 10 test locations. On average, the check variety BRRI dhan89 (7.67t/ha) performed the highest yield over the locations and only four entries NGR 750-1, NGR467-2, NGR414-1 and NGR1255-1 performed 0.88 to 5.77% higher yield over the check variety BRRI dhan 58 (7.13 t/ha) (Table 3).

Advanced yield trial (AYT)

AYT, T. Aman 2021. Ten entries along with four checks BR23, BRRI dhan49, BRRI dhan52 and BRRI dhan87 were grown at Charbadna farm, BRRI RS, Barishal. Growth duration of the tested entries was ranged from 122 days to 157 days. The plant height was ranged from 104.0 cm of BRRI dhan49 to 138.7 cm of IR16F1097. The highest number of effective tillers were produced in BRRI dhan49 (11) and the lowest number of effective tillers were found in BR23 (8). None of the materials out yielded over the check BBRI dhan87 (4.57 t/ha) and BRRI dhan49 (4.24 t/ha).

Table 3. Yield and ancillary characters of RYT (Barishal) genotypes, Boro 2021-22.

Designation	Average PH (cm)	Average GD (day)	Yield (t/ha)		
			Lowest (location)	Highest(location)	Avg.
NGR 414-1	103.33	153	5.66 (Rajshahi)	9.20 (Gopalganj)	7.23
NGR 418-1	103.98	154	5.54 (Rajshahi)	8.84 (Bhanga)	6.83
NGR 467-2	103.98	160	5.42 (Gazipur)	9.04 (Barishal)	7.20
NGR 521-2	104.36	154	5.66 (Cumilla)	9.57 (Bhanga)	7.01
NGR 522-1	104.24	155	5.57 (Rajshahi)	9.83 (Bhanga)	6.98
NGR 750-1	110.03	156	5.85 (Cumilla)	9.24 (Bhanga)	7.19
NGR 796-2	105.79	156	5.65 (Gazipur)	8.79 (Bhanga)	7.10
NGR 1161-3	104.85	155	5.15 (Gazipur)	9.27 (Bhanga)	6.85
NGR 1255-1	113.32	158	6.53 (Barishal)	10.17 (Bhanga)	7.54
NGR 1308-2	104.48	154	5.74 (Cumilla)	8.60 (Bhanga)	6.78
BRRI dhan58 (ck)	104.81	154	6.06 (Gazipur)	10.08 (Bhanga)	7.13
BRRI dhan89 (ck)	112.53	159	6.39 (Barishal)	9.68 (Bhanga)	7.67
LSD at 0.05	4.28	1.39	0.63		0.23
CV (%)	2.44	0.53	5.10		

L1= BRRI HQ Gazipur; L2= BRRI RS, Bhanga; L3= BRRI RS, Kusthia; L4= BRRI RS, Rangpur; L5= BRRI RS, Barishal; L6= BRRI RS, Cumilla; L7= BRRI RS, Gopalganj; L8= BRRI RS, Habiganj; L9= BRRI RS, Rajshahi; L10= BRRI RS, Sunagazi; L11= BRRI RS, Satkhira

AYT, Boro 2020-21. One advanced yield trial of favourable Boro rice consisted of 69 entries along with four checks BRRI dhan58, BRRI dhan74, BRRI dhan89 and BRRI dhan92 was evaluated at Sagordi Farm of BRRI RS, Barishal. The growth duration of the tested materials ranged from 139 to 149 days whereas the growth duration of the check varieties ranged from 140 (BRRI dhan74) to 149 days (BRRI dhan89). The plant height of the tested entries varied from 103 to 124cm. The yield range was 10.02t/ha (NGR 1178-2) to 5.61t/ha (NGR 297-1). Among the tested entries 22 genotypes producede the higher grain yield over the check variety BRRI dhan92 (8.90t/ha) and BRRI dhan89 (8.57t/ha) with a yield advantage ranged from 12.57 to 16.95%. All the tested entries except NGR 297-1(5.61t/ha) out yielded the check variety BRRI dhan74 (6.07t/ha).

AYT-FBR-Early comprising of 36 entries along with four checks BRRI dhan28, BRRI dhan81, BRRI dhan88 and BRRI dhan96 was consducted at Charbadna farm, BRRI RS, Barishal. Among the tested entries, BR11903-5R-56 (7.02t/ha), BR11896-5R-88 (6.20 t/ha), BR11894-5R-376 (6.34t/ha), BR11637-5R-140 (6.22t/ha), BR11896-5R-288 (6.71t/ha), SVIN061 (6.63t/ha) and SVIN175 (6.20t/ha) producede the significantly higher yield than the check BRRI dhan28 (6.10t/ha) and yield advantage was ranged from 1.64 to15.03%. Growth duration of tested entries ranged from 139 to 143 days whereas, in case of BRRI dhan28 it was 140 days. Plant height range of the tested entries was 94 to 117 cm wheras, in case of BRRI dhan28 was it 101cm.

AYT-FBR-Late comprising of forty four entries along with four checks BRRI dhan81, BRRI dhan58, BRRI dhan89and BRRI dhan92 was conducted at Charbadna farm, BRRI RS, Barishal. Among the tested entries, BR9674-3-9-2-1(7.54t/ha) and BR11638-5R-113(7.13t/ha) producede significantly higher yield than the check BRRI dhan58 (7.02t/ha) with a 7.35% 1.54% yield advantage respectively. Plant height was similar but growth duration was 6-7days longer than the check. Plant height was more or less similar but growth duration was three days shorter than the check variety. On the other hand, comparing with the lowest yielded check BBRI dhan81(6.08t/ha), the genotypes BR11894-5R-260 (6.80t/ha), BR11630-5R-26 (6.90t/ha), BR11657-5R-461 (6.86t/ha), BR11660-5R-290 (6.53t/ha), BR11640-5R-178 (6.45t/ha), BR11903-5R-197 (6.45t/ha), BR11660-5R-6 (6.45t/ha), BR11904-5R-290 (6.92t/ha), BR11894-5R-144 (6.93t/ha), HRB215-15-9-1-1R (6.49t/ha), BR9674-3-2-2-4 (6.41t/ha), BR9674-7-3-2-1 (6.67t/ha) and Bongosail (6.70t/ha) producede higher yield with a range of yield advantage 5.1-23.99%. Growth duration range of these tested entries was 140-153days and average plant height range was 93-109 cm.

AYT, New generation rice(NGR). A total 285 promising breeding lines were planted in seven sets such as Set A(8), Set B(46), Set C(38), Set D(23), Set E(117), Set F(23) and Set G(40),for better evalution during Boro 2021-22.

NGR Set A. Twelve entries along with four checks BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were grown in three blocks with a spacing of 20cmX20cm. Among the tested entries, NGR 522-2(6.30t/ha) produced higher yield and NGR 521-1(5.71t/ha) produced lower yield over the lowest yielded check variety BRRI dhan92(4.64t/ha). (Table 4.)

NGR Set-B. Fifty entries along with four checks BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were grown in two blocks with a spacing of 20 cm X 20 cm. None of the tested genotypes found out yielded over the highest yielded check BRRI hybrid dhan5 (7.94t/ha). Among the tested entries, NGR 418-1(7.28t/ha) produced higher yield and NGR 527-1(4.49t/ha) produced lower yield over the other three check varieties BRRI dhan74 (5.56t/ha), BRRI dhan89 (5.02t/ha) and BRRI dhan92 (6.00t/ha).

NGR Set-C. Thirty-two entries along with four checks BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were grown in two blocks with a spacing of 20 cm X 20 cm. Among the tested entries, seven entries out yielded all the check varieties where NGR 1394-1(7.93t/ha) produced higher yield and NGR 721-2 (3.29t/ha) produced lower yield over all check varieties BRRI dhan74 (4.63/ha), BRRI dhan89 (5.59t/ha), BRRI dhan92 (5.96t/ha) and BRRI hybrid dhan5 (6.02t/ha).

NGR Set-D. A total of 27 entries along with four checks BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were grown in two blocks with a spacing of 20 cm X 20 cm. The yield ranged of the tested entries varied from 3.86 to 6.66t/ha. Among the tested entries, NGR 968-1(7.48t/ha) produced higher yield followed by NGR 223-2 (7.25t/ha), NGR 1230-1 (7.00t/ha) and NGR 1255-2 (4.11t/ha) produced lower yield over all the varieties.

NGR Set-E. A total of 121 entries along with four checks, BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were evaluated. Out of those test entries two entries; NGR 994-1(8.67t/ha) and NGR 710-1(8.23t/ha) out yielded the check varieties BRRI dhan74 (5.48t/ha), BRRI dhan89 (4.44t/ha), BRRI dhan92 (3.49t/ha) and BRRI hybrid dhan5 (7.64t/ha).

NGR Set-F. A total of 27 entries along with four checks, BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were evaluated. The yield range of the tested entries varied from 3.86 to 6.66t/ha. Out of these test entriees NGR1203-2 (9.36t/ha) outyelded the check varieties including BRRI hybrid dhan5 (8.98t/ha). The test entries NGR 1203-1 (6.66t/ha) and NGR1203-2(6.66t/ha) produced higher yield and NGR1268-2 (3.86t/ha) produced lower yield over the highest yielded check BRRI hybrid dhan5 (6.23t/ha).

NGR Set-G. A total of 44 entries along with four checks, BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were evaluated. Out of those entries NGR 745-2 (9.63t/ha) produced the highest yield followed by 590-2 (9.48t/ha), NGR566-2(9.19t/ha), NGR710-2(9.06t/ha), and the genotype NGR 730-1(4.78t/ha) producede the lowest yield over the check varieties.

INTERNATIONAL NETWORK FOR GENETIC EVALUATION OF RICE (INGER), BORO 2021-22

A total of 44 entries along with six checks BRRI dhan35, BRRI dhan58, BRRI dhan74, BRRI dhan92, BRRI dhan96 and BRRI dhan101 were grown at Charbadna farm BRRI RS, Barishal during Boro 2020-21. The data of ancilliary characteristics of INGER materials were recorded, the plant height was between 100 cm to 121 cm, the panicles per hill were ranged between 9-14, and the growth durations were ranged between 126 to 144 days. None of the materials out yielded the check variety BBRI dhan74 (7.76t/ha). Ten genotypes out yielded the check BRRI dhan96 (6.97t/ha) with yield advantage ranged from 1-8% whereas all the genotypes producede higher yield than the lowest yielded check variety BRRI dhan35 (4.76t/ha) with yield advantage ranged from 1-59%.

DEVELOPMENT AND VALIDATION OF HIGH IRON AND ZINC RICE IN CONFINED FIELD TRIAL (CFT), BORO 2021-22

Eleven transgenic lines along with non-transgenic control as the standard check variety BRRI dhan28 were evaluated at CFT site of BRRI RS, Barishal. There was a significant variation observed among the transgenic lines in respect of plant height (range 98.5-108.3cm), panicle number per plant (range 14.9-17.7), growth duration (range 143-146 days), thousand-grain weight (range 20.93-21.77) and the spikelet fertility (range 74.76-89.10%). The highest spikelet fertility was observed in IR133904TR-B-B 2-B-25(89.10%) followed by genotypes IR133904TR-B-B-3-B-17(84.78%) and IR133904TR-B-B-3-B-28 (84.61%), whereas the lower lebel of spikelet fertility was observed in IR135161TR-4-B-35 (74.76%), IR135161TR-4-B-6 (75.82%) and IR135161TR-4-B-23 (78.72%). There was variation observed in grain yield which was ranged between 6.53 t/ha to 7.72 t/ha. The transgenic line, IR133904TR-B-B-2-B-25 (7.72 t/ha) produced the highest yield followed by IR133904TR-B-B-1-B-3 (7.51 t/ha) and IR133904TR-B-B-3-B-17(7.40 t/ha). None of the transgenic line out yielded the non-transgenic check BRRI dhan28 (8.25 t/ha).

CHARACTERIZATION AND UTILIZATION OF LOCAL GERMPLASM

A total of 369 local Amangermplasm were grown during T. Aman 2022 with six lines in each plots for characterization, utilization and maintenance. Seven local germplasm viz, Lalpaika, Moulata, Nakuchimota, Sahi Balam, Sada Chikon and Shada Pajam, were utilized in hybridization in breeding programme for developing tidal submergence tolerant rice variety. Seeds were harvested and preserved for further evaluation and utilization.

PEST MANAGEMENT

Insect Management Incidence of insect pest and natural enemies in light trap

Data were collected from July 2021 to June 2022 at Sagordi farm, BRRI RS, Barishal. Light trap was set up at east side of Sagordi farm. Everyday light trap was switched on in the evening and switched off at dawn. After that dead insects were collected from the light trap, sorted and recorded manually. Appearance of insect pest was found lower than the previous reporting year. The highest green leafhopper (GLH) followed by yellow stem borer (YSB), white leafhopper (WLH), and brown planthopper (BPH) was recorded in the reporting year. In case of natural enemy the highest staphylinid beetle (STPB) followed by carabid beetle (CDB) and earwig (EW) was observed. Insect pest was trapped higher in the reporting year than the natural enemy (Table 4).

Insect pest peak was observed in October, November and December 2021 and another little peak was observed in March 2022. Natural enemy abundance was found higher in October, November and December 2021 and March 2022 (Fig. 1). Although insect pest abundance was found throughout the reporting year but higher insect pest was observed in T. Aman season compared to Boro season.

Figure 2 shown the abundance of two major insects namely, yellow stem borer (YSB) and brown planthopper (BPH) was found in the reporting period. YSB was found comparatively higher in T. Aman than Boro season. Higher yellow stem borer was found in October and in November 2021. Otherside brown planthopper (BPH) was found higher in T. Aman season. In this reporting year higher no. of BPH was found in October, November and December 2021.

Table 4. Insect pests and natural enemy population in the period of July 2021 to June 22.

Insect pest	Population	Natural enemy	Population
GLH	9457	CDB	1253
WLH	3170	LBB	764
ZLH	2126	STPB	4000
BPH	2140	GMB	352
WBPH	1426	Dam. Fly	415
SBPH	146	SPD	518
YSB	7205	EW	1186
DHB	947	TB	915
RLF	1284	Total	9403
CW	649		
SHG	170		
LHC	265		
MC	649		
RB	690		
Total	30324		

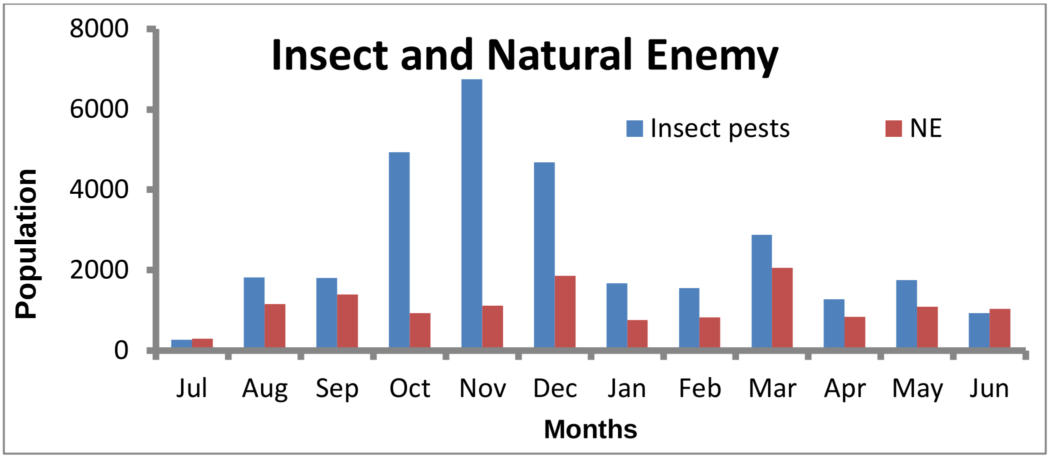


Fig. 1. Monthly insect pest and natural enemies abundance of BRRI RS, Barishal light trap.

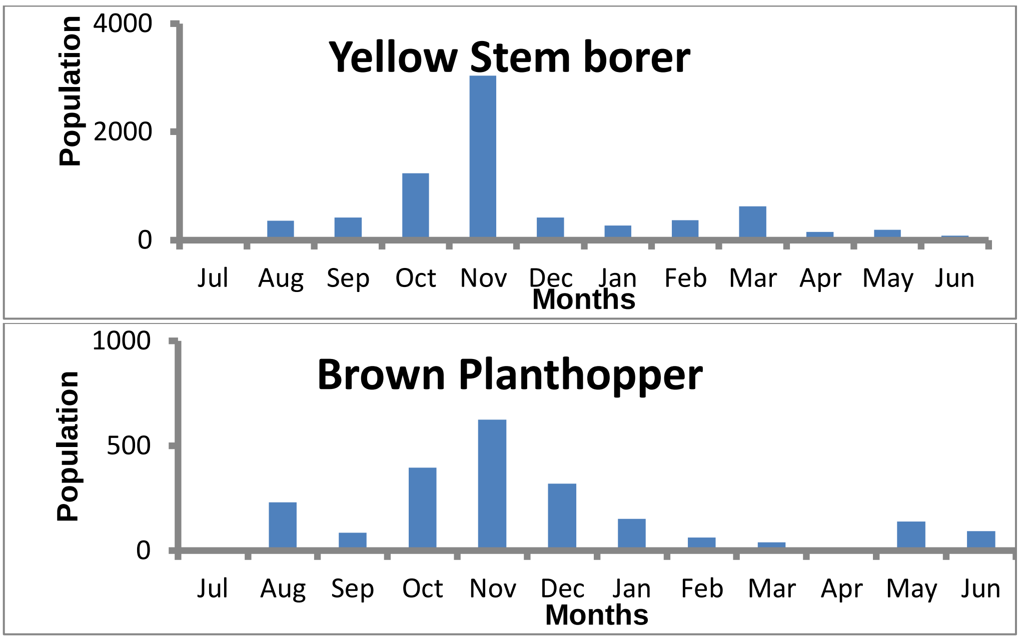


Fig. 2. Monthly yellow stem borer and brown planthopper abundance of BRRI RS, Barishal.

Developed a rectangular hand net (RHN) for insecticide free rice seedbed

A new hand net consists of a rectangular frame is developed that includes 4 mm GI wire and the frame length and width is 50 cm and 20 cm, respectively. It also comprises with a plastic pipe which length is 100 cm, radious 1.90 cm and market available white colour mosquito net, which length is 80 cm strated from the frame. Insect pest first attacks in rice seedbed generally 7-9 days after seed sowing. At this early sensitive to stage, traditional sweep net (round hand net) is not suitable to collect insects because it causes damage rice seedlings and its insect catching efficiency is also lower than rectangular hand net. To alleviate this, a novel rectangular hand net is developed and found higher insect pest caught efficacy for managing insect pest in rice seedbed. All the materials of RHN are locally available, farmers can easily make up. Methods of application is rapidly walking with RHN around the seedbed (Fig.3). A model seedbed one-meter width and length depends on land condition. After sweeping full seedbed harmful insect pest has been destroyed and beneficial insect released back in the same field.

Performance of Rectangular hand net (RHN) in seedbed

Experiments were set up in Boro 2021-22, to test the performance of this novel sweep net at Charbadna farm of BRRI RS, Barishal. Fifteen square meter ($15m^2$) seedbeds followed RCB design with three replication and high yielding rice variety BRRI dhan29, BRRI dhan88 and BRRI dhan89 were used. After each individual sweeping rice insect pest and natural enemies were sorted, counted and recorded manually. Rectangular hand net (48.33) performance found was significantly better than round hand net (26.67) (Fig. 4). Rectangular hand net caught higher insect pest (16.33) than traditional round hand net (7.00). Harmful insect pest yellow stem borer, green leafhopper, grasshopper, rice hispa, thrips, leaf folder etc were caught higher by RHN. Several benefits have been identified by using of this RHN: 1. Can use in sweeping at early seedling age (7 days), 2. Suitable to catch yellow stem borer, green leafhopper, grasshopper, rice hispa, thrips, leaf folder, lady bird beetle, carabid beetle, staphylinid beetle, spider, green mirid bug etc, 3. Harmful insects can be collected and destroyed and beneficial insects can be released back in same seedbed by using with this hand net. 4. Furthermore, insecticides contral can be reduced and safe environment (soil, air and water) will be ensured .

Fig. 3. Insect pest catching of newly developed rectangular hand net.

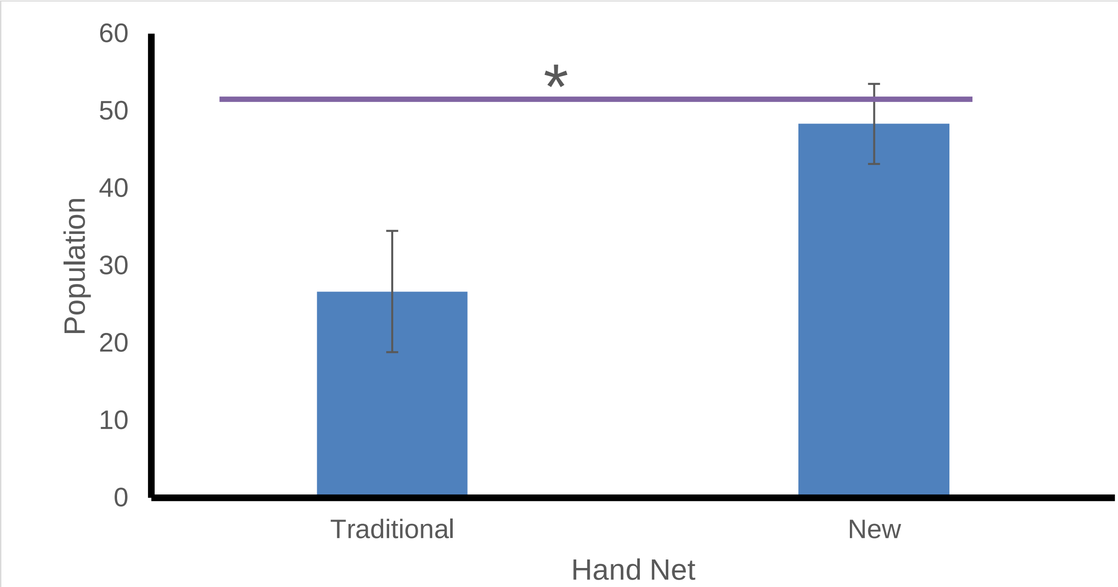


Fig. 4. Insect caught between round and rectangular seedbed.* Significantly different at the 5% level (Student's t-test).

Rat caught efficiency of different rodenticides

An experiment with five treatments: T1=Bromadiolon, T2=Rat-atom magic, T3=ZnPo4, T4=Phostoxin and T5=Control following RCB design with three replications was set up in T. Aman 2021. Treatment to treatment distanced 500 meters were followed at Charbadna farm of BRRI RS Barishal. Number of dead rat was collected and recorded manually 24 hours after set up of the experiment. Zinc phosphate (4.5) bait was found the highest effective for rat dead compared to other treatments. Zinc phosphate tablet was found significantly different at the 5% level of least significance differene of Turkey post hoc. Phostoxin gas tablet and bromadiolon performance was found better compared to the control (0.0) and rat-atom magic treatment (0.5) (Table 5).

Yellow stem borer pheromone lure perfomance of different Aus variety

\Pheromone lure was supplied by Isphahani Biotech. In Aus 2021, ten lures were set up in BRRI dhan48, BRRI dhan82 and BRRI dhan98 at BRRI Charbadna farm at vegetative stage. Data were collected every seven days interval and counted manually. Yellow stem borer caught was found no significance difference among different varieties. Higher average yellow stem borer caught was recorded in case of BRRI dhan82 (4.17) followed by BRRI dhan98 (4.08) and BRRI dhan48 (3.08) after seven days interval (Fig 5). After four weeks yellow stem borer caught in different varieties was as 37 in BRRI dhan48, 50 in BRRI dhan82 and 49 in BRRI dhan98. Finally it was found that, pheromone lure had moderate efficacy in controlling YSB.

Table 5: Rat caught with different treatment within market available rodenticides.

Treatment	Rat caught
T_1=Bromadiolon	2.5 B
T_2=Rat-atom Magic	0.5 C
T_3=ZnPo4	4.5 A
T_4=Phostoxin	2.5 B
T_5=Control	0.0 C
LSD at 0.05	1.96
CV	35.36

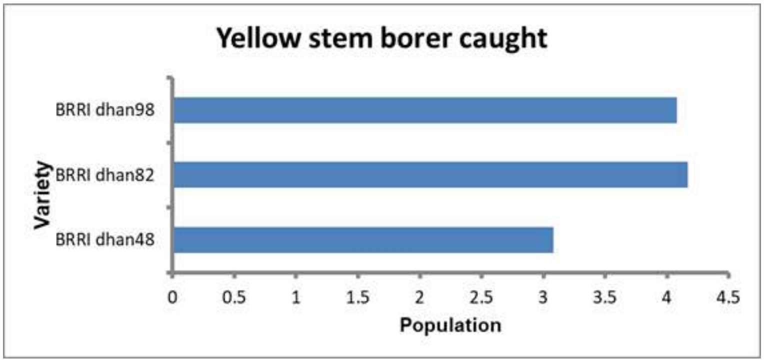


Fig. 5. Yellow stem borer caught by pheromone lure at different varieties with population/wee

DISEASE MANAGEMENT

Survey report of Barishal T. Aman 2021

Average bacterial leaf blight incidence (29.9%) was predominant in T. Aman 2021 at Barishal followed by brown spot and sheath blight and their incidence were 24.3% and 19.5% respectively (Table 6). The average severity score was 2.8, 2.3 and 1.9 in BLB, brown spot and sheath blight respectively (Fig. 6).

Survey report of Barishal Boro 2022

Average brown spot incidence (27.38%) was predominant in Boro 2022 at Barishal followed by BLB and sheath blight and their incidence were 16.23 and 12.70% respectively (Table 7). The average severity score was 1.93, 1.49, 1.28 and 1.24 in brown spot, BLB, neck blast and sheath blight respectively (Fig. 7).

Table 6. Disease Incidence and severity in different varieties in Barishal during T. Aman 2020-21.

Upazila/ Variety	BB		ShB		Blast		FSm		BS		ShR	
	% In	Sev	% In	Sev	% In	Sev	% In	Sev	% In	Sev	% In	Sev
Sadar:												
Sada mota, lal mota, BR23, Tusiyara, Sada chikon, Balam chikon BRRI dhan77, BRRI dhan 49, BRRI dhan44, BRRI dhan34,	10.1	1.50	12.3	2.1	0.8	0.5	1.6	0.6	14.7	1.3	13.2	3
Babuganj:												
Sada mota, lal mota, BR 22, BR23, BRRI dhan41, BRRI dhan52, Bina 7, BRRI dhan49, BRRI dhan76, BRRI dhan77, Swarna, Chinigura, Kalijira, Sakhorkor, Nahuchir, BRRI dhan87	29.7	2.7	14.8	1.9	10.0	1.0	4.2	1.3	15.8	1.5	20.0	1.0
Ujirpur:												
BR 11, BR22, BR23, BRRI dhan76, BRRI dhan52, Bina 7, BRRI dhan49, Chaulamngi, Swarna	50.0	4.1	31.3	2.9	-	-	12.7	1.8	42.4	3.0	20.0	1.3
Mean	29.9	2.8	19.5	2.3	3.6	0.5	6.2	1.2	24.3	1.9	18.3	1.1

BB: Bacterial blight, ShB: Sheath blight, BS: Brown spot, ShR: Sheath rot, FSm: False smut, In: Incidence (%), Sev: Severity score

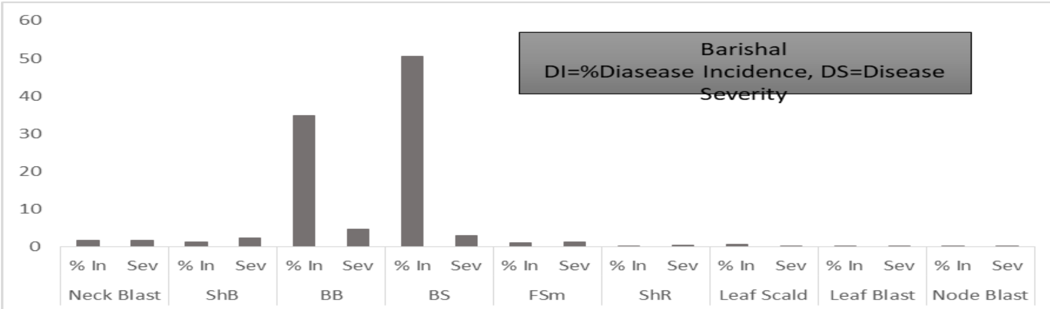


Fig. 6. Incidence and severity of rice diseases during T. Aman 2020-21 in Barishal.

Table 7. Disease Incidence and severity in different varieties in Barishal during Boro, 2020-21.

Upazila/	LB		NB		SB		BB		BS		SR	
Variety	% In	Sev	% In	Sev	% In	Sev	% In	Sev	% In	Sev	% In	Sev
Barishal Sadar: BR26, BRRI dhan28, BRRI dhan35, BRRI dhan64, BRRI dhan74, BRRI dhan89, BRRI dhan92, BRRI hybrid dhan5	3.67	0.63	2.66	0.48	1.42	0.19	16.84	1.73	15.88	1.38	6.19	1.16
Babuganj: BRRI dhan74, BRRI hybrid dhan5, Ispahani	0.00	0.00	10.00	2.40	24.57	2.30	18.83	1.50	29.68	2.04	3.79	1.14
Wazirpur: BRRI dhan29, BRRI dhan67, BRRI dhan74, Sathi, Agrani, Hira	3.70	0.41	5.81	0.96	12.11	1.22	13.00	1.22	36.59	2.37	2.56	0.30
Mean	2.46	0.34	6.16	1.28	12.70	1.24	16.23	1.49	27.38	1.93	4.18	0.87

BB: Bacterial blight, ShB: Sheath blight, BS: Brown spot, ShR: Sheath rot, FSm: False smut, In: Incidence (%), Sev: Severity score

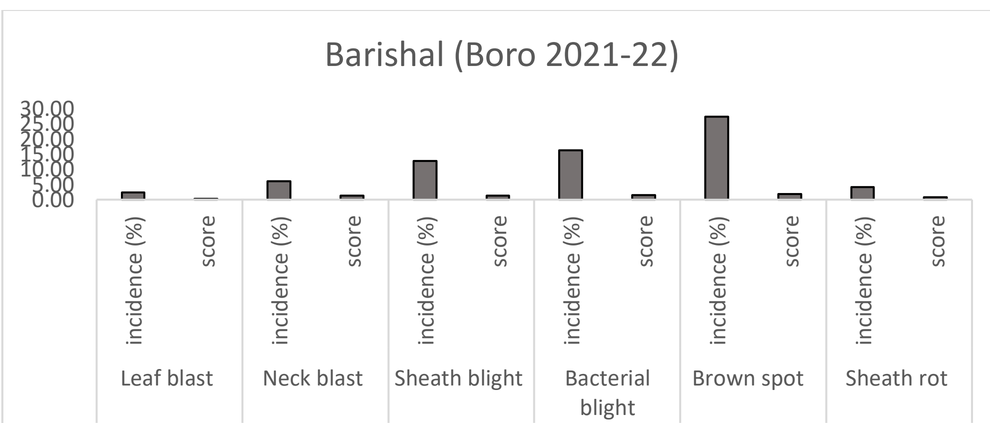


Fig. 7. Incidence and severity of rice diseases during Boro 2021-22 in Barishal.

CROP-SOIL-WATER MANAGEMANT

Long-term missing element trial for diagnosing limiting nutrient in tidal flooded soil

The trial was initiated in a permanent layout at Sagardi farm, BRRI RS, Barisal during Boro 2009 with six treatments, namely NPKSZn, -N (PKSZn), -P (NKSZn), -K (NPSZn), -S (NPKZn) and –Zn (NPKS) in RCB design with four replications. In 2021-22, the fertilizer rate was NPKSZn @ 60-15-50-10-1 kg/ha in T. Aman and 113-10-20-20-1.5 kg/ha in Boro season. The test variety was BRRI dhan52 in T. Aman and BRRI dhan67 in Boro. Grain yield was recorded from 5 m2 area at 14% moisture content. Data were subject to statistical analysis and mean separation were done by DMRT using STAR software. Table-8 presents the results of nutrient omission effect on the grain yield of rice. During T. Aman 2021, the highest grain yield (5.13 t/ha) was observed in the complete treatment in which N, P, K, S, and Zn fertilizer were applied. Grain yield was significantly lower than the complete treatment due to the omission of N (4.45 t/ha), P (4.22 t/ha) and K (4.34 t/ha). Slight decreases in grain yield were also observed in -S and -Zn treatments, although the differences were not significant (Table 8). The lowest yield was recorded in –P plot followed by –K plot. Thus, it is observed from the yield data that all the nutrients (N, P, K, S and Zn) should be applied during T. Aman season to maintain soil nutrient levels as well as for optimum yield of BRRI dhan52. In boro 2021-22, unlike T. Aman season, significant grain yield reduction of BRRI dhan67 was observed only in the plots without N and K in Boro season (Table 8). The other treatments (with missing nutrients) showed tatistically similar grain yield compared to the complete treatment. Thus, the study reveals that for BRRI dhan67, N is the most limiting nutrient followed by K, in the tidal flooded soil. Overall findings suggest that all the nutrients (N, P, K, S and Zn) should be applied in required amount in T. Aman while in Boro, application of N and K must be ensured for optimum rice yield.

Exploring sediment deposition from tidal water in BRRI **RS, Barishal.**

Tidal water flow was trapped from fixed points at BRRI RS, Barishal. For that a pot was fixed in the field of Sagardi farm. After a high tide and low tide, the pot was brought from land and kept in the room for further deposition. After deposition clear water was removed and kept for drying in room temperature. For silt elements analysis, the dried sediment sample was stored and properly leveled to send in the Soil Resource Development Institute (SRDI), Barishal. The deposited silt was collected for analyzing organic and inorganic (nutritional) elements. Results showed that the good quality of sediment with respect to plant nutrients, implies that the soils of the farm are enriched. The sediment was slightly alkaline (pH=7.8) and organic matter was high in amount (3.27%) (Table 9). Among inorganic nutrient the amount of Sulphur was quite noticeable which is 15.33 µg g-1 (Table 9). Every year during Aman season the addition of tidal sediments makes the farm fertile. Thus, the supplementation by tidal sediments may reduce the requirement of huge fertilizer for T. Aman rice in the tidally flooded areas of the country. To draw a final conclusion, the experiment needs to be continued for following years.

Table 8. Effect of long-term omission of nutrient elements on the yield of BRRI dhan52 and BRRI dhan67 during T. Aman and Boro at Sagordi farm, BRRI RS, Barisal 2021-22.

	Grain yield (t/ha)*	
	T. Aman (BRRI dhan52)	Boro (BRRI dhan67)
NPKSZn	5.13a	6.40a
-N	4.45bc	2.74c
-P	4.22c	6.42a
-K	4.34bc	5.82b
-S	4.92ab	6.42a
-Zn	4.84ab	6.39a
CV(%)	8.5	6.3

Table 9. Nutrient quality of sediments in Sagardi Farm, BRRI RS, Barishal during 2021.

pH	Salinity (EC) (ds/m)	Organic Matter (%)	Nitrogen (%)	Potassium (me%)	Phosphorus ($\mu g\ g^{-1}$)	Sulphur ($\mu g\ g^{-1}$)	Zinc ($\mu g\ g^{-1}$)
7.80	1.78	3.27	0.16	0.51	42.15	15.33	1.09

Varietal replacement through head to head trial in Boro 2021-22 under TRB project.

Fouteen modern rice varieties were tested at four locations of Barishal region during Boro 2020-21. BRRI dhan28, BRRI dhan67, BRRI dhan97 and BRRI dhan99 were evaluated at Latifpur and Puranmohipur of kalapara upazila of Patuakhli district. The average yield ranged from 4.52t/ha (BRRI dhan99) to 5.36t/ha (BRRI dhan67). BRRI dhan28, BRRI dhan67, BRRI dhan97, and BRRI dhan99 were also evaluated at Ghotkhali of AmtoliBorguna district. The average highest yield was found in BRRI dhan97 (5.43t/ha) and the lowest yield was observed in BRRI dhan67 (4.95t/ha. A total of ten varieties consisting of BRRI dhan28, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan88, Bangabandhu dhan100, BRRI dhan29, BRRI dhan58, BRRI dhan89 and BRRI dhan92 were tested at Premhar, Nolcity of Jhalokathi district. The average yield was varied from 4.88t/ha of BRRI dhan81 to 6.19t/ha of BRRI dhan74. Eleven entries comprising BINA dhan-24, BRRI dhan28, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan88, Bangabandhu dhan100, BRRI dhan29, BRRI dhan58, BRRI dhan89and BRRI dhan92 were evaluated at Rakudiya, Babuganj of Barishal distrct. The average highest yield was found in BRRI dhan74 (5.76t/ha) whereas the lowest yield was observed in BRRI dhan81(4.58 t/ha). Among the fourteen rice varieties, the highest yield obserd in BRRI dhan74 (6.19 t/ha) whereas the lowest yield was found in BRRI dhan99 (4.52t/ha) at Nolcity of Borguna and Kalapara of Patuakhali district. The trials suggested that the highest yielded modern rice variety BRRI dhan74 could be popular and be disseminated among the farmers. This fact is also reflected in the farmer's choice since farmers stored 20 kg of BRRI dhan74 seed for use in the next Boro season.

Stability analysis of BRRI released variety in Aus 2021

The study was accomplished at Charbadna farm, BRRI RS, Barishal during Aus 2021 season. Twelve BRRI released varieties were tested (Table 10). Three replications with RCB design were followed. Size of unit plot was 3 m × 3 m. Plot to plot distance was 40 cm and block to block distance was 60 cm. Spacing was 20 × 20 cm. Twenty-nine-day-old seedlings were transplanted. Crop management practices were done according to BRRI recommended practice. Among the tested 12 varieties, BRRI hybrid dhan7 producede highest yield (4.77 t/ha) followed by BRRI dha82 (4.56 t/ha), BRRI dhan98 (4.54 t/ha) and BRRI dhan85 (4.03 t/ha). The lowest yield was observed in BR21 (2.76 t/ha) (Table 10).

Table 10. Stability analysis of BRRI released variety in Aus 2021.

Variety	GD (days)	Yield (t/ha)
BR21	110	2.76
BR24	135	3.24
BR26	117	3.77
BRRIdhan27	116	3.47
BRRIdhan43	99	3.46
BRRIdhan48	114	3.76
BRRI dhan65	100	3.26
BRRIdhan82	110	4.56
BRRIdhan83	135	3.53
BRRIdhan85	113	4.03
BRRIdhan98	114	4.54
BRRIHybrid dhan7	110	4.77
LSD $_{0.05}$	15.00	0.16
CV	7.00	2.50

DS: 22 April 21 D/T: 20 May 21 Spacing: 20 cm x 20 cm

Stability analysis of BRRI released variety in Aman 2021

Study was accomplished at Charbadna farm, BRRI RS, Barishal during T. Aman 2021 season. Forty seven BRRI released varieties were tested with three groups namely short duration variety (15 nos), medium duration variety (21 nos) and long duration variety (11nos) (Tables 11, 12 and 13). Three replications with RCB design was followed. Size of unit plot was 3 m × 3 m. Plot to plot distance was 40 cm and block to block distance was 60 cm. Spacing was 20 × 20 cm. Twenty-five-day-old seedlings were transplanted. Crop management practices were done according to BRRI recommended practice. Among the tested 15 short duration varieties, the highest yield was observed in BRRI dhan71 (5.50 t/ha) followed by BRRI dhan73 (4.83 t/ha), BRRI dhan87 (4.80 t/ha) and BRRI hybrid dhan6 (4.80 t/ha). The lowest yield was found in BRRI dhan62 (3.62 t/ha) (Table 11). In medium duration varieties, the highest yield was found in BRRI dhan54 (5.69 t/ha) followed by BRRI dhan94 (5.61 t/ha), and BRRI dhan49 (5.36) t/ha). The lowest yield was observed in BR3 (4.09 t/ha) (Table 12). Finally, in the long duration varieties, the highest yield was in BRRI dhan76 (5.92 t/ha) followed by BRRI dhan46 (5.79 t/ha) and the lowest yield was in BRRI dhan91 (3.89 t/ha) (Table 13).

Table 11. Stability analysis of BRRI released short duration variety in T. Aman 2021.

Variety	GD (day)	Yield
BRRI dhan33	120	3.92
BRRI dhan39	120	4.69
BRRI dhan53	120	4.61
BRRI dhan56	119	4.12
BRRI dhan57	114	3.95
BRRI dhan62	109	3.62
BRRI dhan66	109	4.48
BRRI dhan71	120	5.50
BRRI dhan73	121	4.83
BRRI dhan75	115	4.06
BRRI dhan87	131	4.80
BRRI dhan90	114	3.65
BRRI dhan95	131	5.38
BRR hybrid dhan4	113	4.76
BRR hybrid dhan6	121	4.80
LSD $_{0.05}$	3	0.56
CV	2	7.55

DS: 06 Aug 21   D/T: 30 Aug 21   Spacing: 20 cm x 20 cm

Table 12. Stability analysis of BRRI released medium duration variety in T. Aman 2021.

Variety	GD (day)	Yield (t/ha)
BR 3	131	4.09
BR 4	139	5.22
BR 11	140	4.63
BR 25	136	5.22
BRRI dhan 30	135	4.65
BRRI dhan 32	121	4.47
BRRI dhan31	135	4.17

Variety	GD (day)	Yield (t/ha)
BRRI dhan40	138	4.77
BRRI dhan44	137	5.21
BRRI dhan49	133	5.36
BRRI dhan51	137	5.34
BRRI dhan52	136	4.80
BRRI dhan54	131	5.69
BRRI dhan70	131	4.54
BRRI dhan72	125	4.71
BRRI dhan77	137	4.94
BRRI dhan78	132	4.43
BRRI dhan79	131	4.98
BRRI dhan80	131	4.97
BRRI dhan93	136	5.11
BRRI dhan94	137	5.61
$LSD_{0.05}$	1.11	0.59
CV	0.51	7.32

D/S: 06 Aug 21 D/T: 30 Aug 21 Spacing: 20 cm x 20 cm

Table 13. Stability analysis of BRRI released long duration variety in T. Aman 2021.

Variety	GD (day)	Yield
BR5	144	4.13
BR 10	137	5.18
BR22	153	5.27
BR 23	153	4.70
BRRI dhan 34	138	3.90
BRRI dhan37	144	4.48
BRRI dhan38	142	4.78
BRRI dhan41	139	5.19
BRRI dhan46	143	5.79
BRRI dhan76	138	5.92
BRRI dhan91	153	3.89
$LSD_{0.05}$	**1.87**	**0.57**
CV	**0.77**	**6.87**

D/S: 06 Aug 21 D/T: 30 Aug 21 Spacing: 20 cm x 20 cm

Stability analysis of BRRI released Boro varieties, Boro 2021-22

Forty-seven varieties were evaluated at Charbadna farm, BRRI RS, Barishal during Boro 2021-22 season. The experiment was laid out in RCB design with three replications. Fortyseven BRRI released varieties were tested with two groups namely short duration variety (22 nos.) and long duration variety (25 nos.) (Tables 14 and 15). Forty-five-day-old seedlings were transplanted at a spacing of 20 cm x 20 cm. Each plot size was 3 x 3 m^2. Recommended fertilizer doses were applied with a usual split application of urea in three times at 15, 30 and 45 days after transplanting. Crop management practices were done as and when necessary. Among the tested 22 short duration varieties, the highest yield was observed in BRRI hybrid dhan5 (7.05 t/ha) followed by BRRI dhan74 (6.66 t/ha) BRRI dhan68 (6.62 t/ha) and BRRI dhan96 (6.62 t/ha). The lowest yield was found in BRRI dhan36 (5.07 t/ha) (Table 14). In case of the long duration varieties, the highest yield was in BRRI dhan92 (6.30 t/ha) followed by BRRI dhan89 (6.05 t/ha) and BRRI dhan69 (5.98 t/ha). The lowest yield was observed in BR17 (3.51 t/ha) (Table 15).

Table 14. Yield and ancillary characters of short duration genotypes, Boro 2021-22 BRRI RS, Barishal.

Variety	GD (days)	Yield (t/ha)
BR1	147.33	5.82
BR6	142.67	6.1
BR26	142.00	6.2
BRRI dhan27	142.00	5.51
BRRI dhan28	141.33	5.58
BRRI dhan36	144.33	5.07
BRRI dhan45	140.33	5.74
BRRI dhan55	147.00	5.88
BRRI dhan61	146.67	5.45
BRRI dhan63	142.67	6.23
BRRI dhan67	142.67	6.14
BRRI dhan68	145.67	6.62
BRRI dhan74	142.67	6.66
BRRI dhan81	143.00	5.12
BRRI dhan84	141.00	6.15
BRRI dhan86	137.00	5.88
BRRI dhan88	140.00	5.91
BRRI dhan96	140.00	6.62
BRRI dhan100	142.67	5.75
BRRI hybrid dhan2	144.67	5.2
BRRI hybrid dhan3	147.67	6.43
BRRI hybrid dhan5	146.00	7.05
CV	11.18	11.56
$LSD_{0.05}$	5.65	4.67

D/S: 02 Dec 2021 D/T: 17 Jan 22 Spacing: 20 cm x 20 cm

Table 15. Yield and ancillary characters of long duration genotypes, Boro 2021-22 BRRI RS, Barishal.

Variety	GD (day)	Yield (t/ha)
BR2	148.67	4.56
BR3	150.00	4.55
BR7	151.33	4.95
BR8	149.00	5.16
BR9	148.33	5.06
BR12	143.67	5.4
BR14	146.67	5.09
BR15	151.00	5.5
BR16	150.00	4.98
BR17	142.00	3.51
BR18	148.33	4.58
BR19	149.33	4.94
BRRI dhan29	149.67	5.65
BRRI dhan35	148.00	5.17
BRRI dhan47	143.67	5.21
BRRI dhan50	147.67	5.33
BRRI dhan58	148.33	5.21
BRRI dhan59	145.00	5.65
BRRI dhan60	143.00	5.3
BRRI dhan64	147.00	5.09
BRRI dhan69	144.33	5.98
BRRI dhan89	148.00	6.05
BRRI dhan92	149.00	6.3
BRRI dhan97	146.67	4.84
BRRI dhan99	149	5.53
CV	8.59	10.5
$LSD_{0.05}$	5.03	0.89

D/S: 02 Dec 2021 D/T: 17 Jan 22 Spacing: 20 cm x 20 cm

ALART in T. Aman 2021

ALART zinc enriched rice (ZER), T. Aman 2021. One advanced line viz BR9674-1-1-5-2-P4 with three check varieties i.e. BRRI dhan49, BRRI dhan72 and BRRI dhan87 were evaluated at Nalchity upazila Jhalokathi district during T. Aman 2021. The performance of the tested line BR9674-1-1-5-2-P4 was not satisfactory compared to the check varieties considering yield and yield contributing traits. The yield of the tested line was 4.52 which was 12.57 - 23.78% lower than the tested checks.

ALART Stagnant Water (SW), T. Aman 2021. Two advanced lines viz BR10230-7-19-B and BR9390-6-2-1B with two check varieties BR23 and BRRI dhan91 were tested in Sadar upazila of Barishal district during T. Aman 2021. The yield performance of the tested entries varied from 4.24 t/ha to 4.74t/ha in line BR9390-6-2-1B and BR10230-7-19-B respectively, which was lower than the check BR23 (5.03t/ha). Considering growth duration, no significant difference was observed among the tested entries.

ALART in Boro 2021-2022 ALART, STR#1 (Salinity Tolerant Rice), Boro 2021-2022. Three advanced lines BR11715-4R-186, BR11723-4R-27, BR11723-4R-12 with two check varieties BRRI dhan67 (Tolerant check) and BRRI dhan92 (Sensitive check) were evaluated in Ghatkhali of Amtali upazila under Boguna district and Latifpur of Kalapara upazila of Patuakhali district during Boro 2021-22. None of the advanced line performed better them the tolerant check variety BRRI dhan67 considering yield (5.98t/ha and 5.80t/ha respectively) and growth duration in the both places.

ALART, STR#2 (Salinity Tolerant Rice), Boro 2021-2022. Three advanced lines BR11712-4R-227, BR11716-4R-105, BR11716-4R-102 with two check varieties BRRI dhan67 (Tolerant check) and BRRI dhan92 (Sensitive check) were evaluated in Ghatkhali of Amtali upazila under Boguna district and Latifpur of Kalapara upazila of Patuakhali district during Boro 2021-22. The average yield of the tested entries ranged from 4.73 to 4.85t/ha in Amtali and 4.64 to 4.84 t/ha in Kalapara whereas yield of the check varieties ranged from 5.99 to 6.05t/ha and 4.52 to 5.83 t/ha in Amtali, and Kalapara respectively. Considering yield and yield contributing traits, none of the tested entries was found better over the check varieties in both the places.

ALART, favourable Boro rice-Barishal (FBR-Barishal), Boro 2021-22. Four advanced lines BRBa 1-4-9, BRBa 2-5-3, BRBa 3-1-7 and BRBa 3-2-4 along with check varieties BRRI dhan58 and BRRI dhan89 were tested in Solna, Barishal Sadar, Barishal during Boro 2021-22. Among the advanced lines and check varieties, advanced line BRBa 3-2-4 produced the highest yield (7.98 t/ha) followed by BRRI dhan89 (7.94 t/ha). On average, all the entries matured within 145-150 days. Based on higher yield, growth duration and farmers' opinions BRBa 3-2-4 may be considered for further research programme.

ALART, blast resistant rice (BRR), Boro 2021-22. Four advanced lines BR (Path)12452-BC342-22-11-4, BR(Path)12452-BC6-53-21-11, BR(Path)13784-BC3-61-1-6-HR3, and BR(Path) 13784-BC3-63-6-4-HR6 along with the check varieties BRRI dhan28 and BRRI dhan88 were tested in Solna, Barishal Sadar during Boro 2021-22. Among the advanced line and check varieties, the check variety BRRI dhan88 produced the highest yield (6.95 t/ha) followed by the advanced line BR (Path)12452-BC6-53-21-11 (6.49 t/ha). On average, all the entries matured within 135-140 days. No advanced line could exert superior performance over the check variety.

ALART, Superior High Yielding Rice (SHR), Boro 2021-22. Three advanced lines BRHII-9-11-4-5B, BRH13-2-4-6-4B and BRH13-7-9-3-2B along with the check varieties BRRI dhan63 and Zirashail were tested in Solna, Barishal Sadar during Boro 2021-22. Among the advanced line and check varieties, the advanced line BRHII-9-11-4-5B and BRH13-2-4-6-4B simultaneously produced the highest yield (6.94 t/ha) followed by advanced line BRH13-7-9-3-2B (6.59 t/ha). On average, all the entries matured within 142-147 days. Based on higher yield, growth duration and farmers' opinion BRHII-9-11-4-5B and BRH13-2-4-6-4B may be considered for further research programme.

DEMONSTRATION, SEED PRODUCTION AND SCALING UP OF BRRI RICE VARIETIES DURING T. AMAN 2021.

New HYVs of BRRI i.e. BRRI dhan44, BRRI dhan72, BRRI dhan76, BRRI dhan77, BRRI dhan78 and BRRI dhan87 were demonstrated in 190 acres land as block which covered the 42 upazilas of six district in Barishal Division under GOB. Among them 100 acres land were demonstrated by seed and fertilizer support and the rest 90 acre were demonstrated with only free seed support. Moreover, time to time advice was given to the selected groups of farmers for better crop production. From the demonstrated varieties, BRRI RS, Barishal tried to motivate farmers to replace farmers' local varieties to BRRI released latest Aman varieties. The highest yield was obtained by BRRI dhan76 (4.17t/ha) followed by BRRI dhan72 (4.03 t/ha) and BRRI dhan87 (3.94 t/ha) (Fig.8). As Barishal region is under low tidal submergence ecosystem and is difficult to grow BRRI dhan87 and its growth duration is about 125-130 days only. However, it was chosen by those farmers who wanted to do oil crop after Aman season. On the other hand, farmers preferred BRRI dhan72 and BRRI dhan76 and wanted to cultivate these varieties for the next year along with surrounding farmers.

Demonstration for increasing cropping intensity under GOB, and other projects during Boro 2021-22.

A total of 191 number of demonstrations were conducted where 81 were both seed and fertilizer supported and the rest were supported only with seed by BRRI Barishal. The activity covered 1,492 acres land of 29 upazilas of Barishal Division. For implementing the demonstration every scientific officer was assigned for monitoring the demonstration plot. BRRI released HYV (BRRI dhan29, BRRI dhan47, BRRI dhan50, BRRI dhan67, BRRI dhan74, BRRI dhan84, BRRI dhan88, BRRI dhan89, BRRI dhan92, BRRI dhan96, and BRRI dhan97) and hybrid varieties (BRRI hybrid dhan3, BRRI hybrid dhan5) were allocated for distribution. Farmers under the demonstration were advised for maximizing yield. In ripening stage, the crop cut data were collected for each variety of every demonstration plot.

From graph it is proved that BRRI hybrid dhan5 producede the highest average yield (7.53 t/ha) among the hybrid varieties (Fig. 9). In HYV, BRRI dhan89 and BRRI dhan92 performed about same yield which is 7.04 t/ha and 7.03 t/ha respectively (Fig. 9). However, BRRI dhan74 attracted farmers a lot for its coarseness, tastiness and zinc enriched virtue. Overall, its life duration is lower than BRRI dhan89 and BRRI dhan92. Among saline tolerant varieties BRRI dhan67 did well and farmers liked it for its boldness. Agriculture Minister along with high officials of the Ministry of Agriculture visited some demonstrated plots and some field day programme conducted on that demonstration field. Farmers from supported demonstration ensured that they will cultivate BRRI dhan74 in next years.

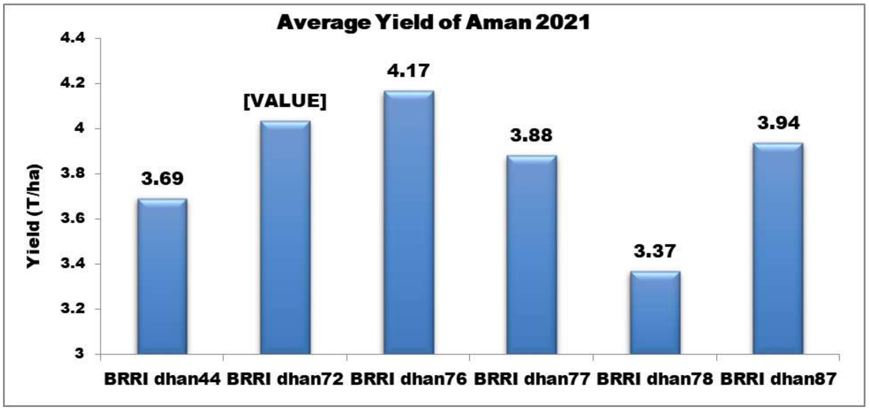


Fig.8. Average Yield Performance of BRRI HYV varieties in T. Aman 2021.

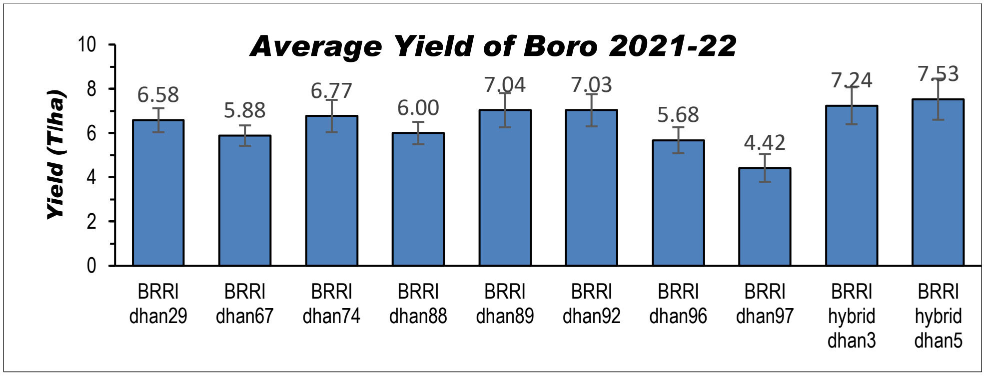


Fig. 9. Average yield performance of BRRI HYVs in T. Aman 2021.

Breeder seed and TLS production

Nucleus seeds of BRRI dhan48, BRRI dhan48 and BRRI dhan98 were sent from BRRI HQ for Aus production in BRRI RS, Barishal. BR23, BRRI dhan34, BRRI dhan49, BRRI dhan52, BRRI dhan76, BRRI dhan77 and BR23, BR26, BRRI dhan28, BRRI dhan29, BRRI dhan47, BRRI dhan48, BRRI dhan67, BRRI dhan74, BRRI dhan89 for T. Aman 2021 and BRRI dhan92 for Boro 2021-22 were collected from GRS Division, BRRI HQ Gazipur. Single seedling was transplanted at 20 x 20 cm spacing. BRRI recommended practices for crop cultivation was followed (BRRI, 2015). In Aus, a total of 1,3457 kg seed was produced in Charbadna farm, BRRI RS, Barishal where 11,617 kg was breeder seed (Table 16). In T. Aman 2021, a total of 18,178 kg (Table 17) and in Boro 2021-22, a total of 31,440 kg (Table 18) breeder seed were produced. In T. Aman 2021, a total of 20571 kg TLS (Table 17) and in Boro 2020-21, a total of 15,095 kg (Table 18) BRRI released varieties would be disseminated quickly to the farmers of this region through these programmes.

Table 16. Breeder seed and TLS production in Aus 2021.

Varieties	Breeder seed (kg)	TLS (kg)
BRRI dhan48	2,520	140
BRRI dhan82	6065	1400
BRRI dhan98	3032	300
Total	11617	1840

Table 17. Breeder seed and TLS production in T. Aman 2021.

Variety	Breeder seed (kg)	TLS (kg)
BR22	-	1,000
BR23	4,550	1,415
BRRI dhan34	2,508	3,400
BRRI dhan41	-	430
BRRI dhan44	-	497
BRRI dhan49	5,400	345
BRRI dhan52	2,000	2,500
BRRI dhan72	-	1,380
BRRI dhan76	2,720	4,150
BRRI dhan77	1,000	600
BRRI dhan78	-	1,556
BRRI dhan87	-	3,178
BRRI dhan90	-	120
Total	18178	20571

Table 18. Breeder seed and TLS production in Boro 2021-2022.

Variety	Breeder seed (Kg)	TLS
BR23	1350	
BRRI dhan26	2000	500
BRRI dhan28	8000	-
BRRI dhan29	4800	840
BRRI dhan47	1150	1225
BRRI dhan48	920	25
BRRI dhan50	-	780
BRRI dhan67	5520	2000
BRRI dhan74	11000	5480
BRRI dhan84		728
BRRI dhan89	3600	-
BRRI dhan92	2750	1850
BRRI dhan96		-
BRRI dhan97		740
Bangabondhu dhan100		927
Total	41090	15095

Farmers' training under different projects/GoB

Farmers' training programmes were conducted at different locations of Barishal region in collaboration with DAE. The farmers were selected with the assistance of local SAAO from different villages of the mentioned locations. The training module was developed considering modern rice production techniques, appropriate rice cultivar for tidal non-saline ecosystem, and pest, disease, irrigation and fertilizer management for better rice production. The training courses were delivered using colorful slides and videos through multimedia projector for easy understanding to the trainees. BRRI RS, Barishal conducted farmers' training in different locations of Barishal region during the reporting period. Forty farmers' trainings were conducted under GoB. A total of 950 male, 73 female farmers, 46 Imam and 11 NGO personnel were trained under GoB training programme. (Table 19). These programmes certainly helped the farmers to create awareness for adopting the BRRI rice production technologies. Trainees were learned on eco-friendly pest management and the dissemination rate of BRRI varieties was accelerated in those areas. Thus, trainings on modern rice production confidently increase the farmers' income as well as improve the livelihood through practicing the farming systems approach.

Table 19. Daylong farmers' trainings at Barishal region on modern rice production technology during 2019-20.

Training programme	Duration	Total training	Participant				Total
			Male	Female	Imam	NGO personnel	
Modern Rice Production Training	1 day	40	950	73	46	11	1080

FARMERS' FIELD DAY UNDER DIFFERENT PROJECTS/GOB AND WORKSHOP

Ten field days were conducted in collaboration with DAE at different locations of Barishal region. Farmers, researchers, extension providers, NGO personnel, administrative peoples, public leaders sincerely participated in this programme. Firstly, the participants gathered and visited the rice field together. A sample area of 10 m^2 was harvested followed by threshing and weighing by the presence. Later, a fruitful discussion was held among the participants. It was perceived that a noticeable number of female farmers were also present and participated on these field days. Ten field days were conducted. Among them one was funded by BMGF and the rest was under GoB. About 1,370 (848 male and 522 female) farmers, extension personnel, administrative peoples, public leaders were targeted to participate in these programmes. Farmers liked BRRI dhan76 for its higher grain yield (4.5 t ha-1 at Amtoli, Barguna) and the ability to survive under tidal water. They also liked BRRI dhan74 for bold grain higher yield (7.45 tha-1 at Nalcity, Jhalokathi). They were embraced with the newly developed high yielding variety BRRI dhan87 (4.87 t ha-1 at Barishal Sadar, Barishal). Farmers were willing to store this seed for next season and agreed to cultivate along with surrounding farmers. Farmers were motivated with the varieties BRRI dhan67, BRRI dhan74, BRRI dhan89 and BRRI dhan92 during Boro season due to satisfactory grain yield.

Workshop. One regional workshop was conducted at BRRI RS, Barishal funded by `Upokulio Barishal o Khulna Anchale Pani Sompod O Matir Labonaktota Bebosthaponar Madhome Fosholer Nibirota Bridhikoron Kormoshuchi'. Personnel from different agriculture related offices were present in the workshop. In the regional workshop, the chair of chief guest was ornamented by Secretery, MoA (Ministry of Agriculture). Executive Chariman of BARC; Additional Secretary, MoA; Director General, DAE; Director (Field Service Wing, DAE); Member Director (Minor Irrigation), BADC and Director (Research), BRRI were special guests. UAO, AEO, SAAO from DAE, scientists from BRRI, BARI, BINA, BJRI, SRDI, and higher officials from BADC and other organizations, and farmers attended the workshop. Director General (DG), BRRI Gazipur presided over the meeting. Welcome speech was delivered by Dr Md Alamgir Hossain, CSO and Head, BRRI RS, Barishal and key Note paper was presented by Dr Md Maniruzzaman, PSO and Head, IWMD, BRRI. Papers were also presented by BARI, BINA and BADC. The title of the workshop was "Barishal Anchale Pani Sompod O Matir Labonaktota Bebosthaponar Madhome Boro Dhaner Abad Bridhi".

Recommendations of the workshop were as follows:

- Irrigation command area have to be increased.
- Need integration related works among all departments related to agriculture.
- Need to change present cropping pattern (Aman-Fallow-Fallow or Boro-Fallow-Fallow) and another extra crop have to be introduced in fallow land.
- Sweet water rivers in Barishal region should be used properly for irrigation purpose.
- Maintenance and operation of sluice gate have to be managed properly.
- Projects may be taken to increase irrigation command area.
- Balance is needed between inbreed and hybrid varieties.
- High yielding rice varieties of BRRI have to be introduced for increasing cropping intensity.
- Demonstration and training must be increased on saline tolerant variety.
- More agricultural machinery should be supplied to Barishal region for improving productivity of rice.

BRRI RS, Bhanga

SUMMARY

In total 13 crosses were made using 12 parents and 316 F_1 seeds were produced for deepwater rice breeding and eight crosses made and 194 F_1 seeds were produced for Aman rice. In Boro 2021-22, a total of 630 progenies from F_4 generation were grown following field RGA technique and 537 progenies of F_5 generation were harvested. In proposed variety trial (PVT) one set in T. Aman 2021 and three sets (Set-I for low glycemic index, Set-II for PQR and Set-III for favourable Boro) during Boro 2021-22 of inbred trials were evaluated at BRRI RS, Bhanga, Faridpur. In ALART (ZER) T. Aman, one entry BR9674-1-1-5-2-P4 was tested against three checks BRRI dhan49, BRRI dhan72, BRRI dhan87. The two replications of the test entry were severely damaged due to rat infestation. In ALART (FBR_Barishal) Boro, BRRI dhan89 (check variety) produced the highest yield (6.33 t ha^{-1}) comparing with all the test entries. Yield of BRBa 3-2-4 was severely reduced because of severe lodging (80%). In ALART (BRR) Boro, check entry BRRI dhan88 produced the highest yield than all other. Mean growth duration of all the test entries was similar (146 days, 147 days) to the check varieties (145 days, 146 days). Seventeen **regional yield trials (RYTs) were conducted in BRRI RS, Bhanga during Boro 202**1-22 **season.**

In RYT (ZER), both advanced lines produced higher yield (7.48 and 7.33 t ha^{-1}) than the checks BRRI dhan29 (6.3 t ha^{-1}), BRRI dhan74 (7.22 t ha^{-1}) and BRRI dhan84 (6.89 t/ha). In RYT (IRR), six advanced lines BR11593-5R-44, BR11593-5R-55, BR11593-5R-70, BR11593-5R-73, BR11593-5R-79 and BR11595-5R-24 produced higher yield (9.15, 8.92, 9.23, 9.09, 8.9 and 9.21 t/ha respectively) than both the susceptible checks BRRI dhan58 (7.85 t/ha), BRRI dhan88 (5.59 t/ha) and the resistant check T27A (5.76 t/ha). In RYT (SHR_LS), all three advance lines BR10247-14-18-4, BR10247-4-7-4B and BRH11-2-4-7B produced higher yield (7.61, 7.02 and 7.51 t/ha) than the check BRRI dhan28 (6.76 t/ha).

In total 26.75 tons of seed was produced in BRRI RS, Bhanga farm. Out of them, 13.75 tons of breeder seed of BRRI dhan29, BRRI dhan89 and BRRI dhan92 and the rest about 16.0 were TLS of short duration Aman varieties such as BRRI dhan39, BRRI dhan71, BRRI dhan75, BRRI dhan79 and BRRI dhan87 as well as Boro varieties of BRRI dhan29, BRRI dhan50, BRRI dhan58, BRRI dhan84, BRRI dhan88, BRRI dhan89 and BRRI dhan92 during Boro 2021 -2022 season.

Six hundred forty eight farmers of greater Faridpur region trained on modern rice production technologies through 24 training programmes in BRRI RS, Bhanga with the cooperation of DAE and the financial assistance of GOB.

VARIETY DEVELOPMENT

Hybridization. In Aman 2021 season, eight crosses were made and 194 F_1 seeds were produced for developing high yielding transplanting Aman rice varieties having desirable characters with emphasis on water stagnation tolerance, anaerobic tillering, earliness, good grain quality.

For deepwater rice variety development, 13 crosses were made and 316 F_1 seeds were produced having desirable characters with emphasis on kneeing ability, nodal tillering, earliness and awnless good grain quality.

FRGA. A total of 630 plants of F_4 generation were grown during *Boro* 2021-22 following Field RGA and 537 progenies of F_5 generation were harvested under breeding programme for 'High yielding rice varieties for semi deep water ecosystem' (Table 1).

PVT (T. Aman). One set (Set-1) of inbred trial (Aman 2021) was evaluated under PVT at BRRI RS, Bhanga. O**ne advanced breeding line I-0**33 **along with two checks (I-0**34 **and I-0**35**)** was **tested. The line no. I-0**33 **produced** 15.32**% and** 6.40**% higher yield than** both **the** check **varieties coded as I-0**34 **and I-0**35**, respectively** (Table 2)**.**

PVT (Boro). Three sets (Set-I, Set-II, Set- III) of inbred trial (*Boro* 2021-22) were carried out at BRRI RS, Bhanga, Faridpur (Table 3).

Set-I. In a proposed variety trial, **one advanced breeding line I-0**36 **along with the check I-0**39 was **tested. The line no. I-0**36 **produced** 7.46 t ha^{-1} **yield which was** 6.75**%** lower

than the check **variety coded as I-0**39 (**8** t ha^{-1}**).** Line I-036 has much lower glycemic index than the check variety. **The growth duration of line no. I-0**36 **was** 151 days which was five days late than the check variety coded as I-039 (145 days).

Set-II. **One advanced breeding line I-0**38 **was evaluated along with check I-0**37. **The line no. I-0**38 (7.29 t ha^{-1}) **yielded 9.**09**% lower than the check I-0**38 (8.019 t ha^{-1}) **with similiar growth duration** (151 days). The test entry I-038 is much long and slender and true basmati type than the test entry.

Set-III. **One advanced breeding line I-0**40 **along with check** I-041 **were tested. The line no. I-**040 **(**5.887 t ha^{-1}**) produced** 19.24**%** lower **yield than the check I-0**41 (**7.2**9 t ha^{-1}**). Average growth duration of the tested line I-0**40 **(1**52 **days) was** seven **days** late **than check I-0**41 **(14**5 **day).**

ALART (ZER) T. Aman. ALART (ZER) was undertaken using one advanced line BR9674-1-1-5-2-P4 along with BRRI dhan49, BRRI dhan72 and BRRI dhan87 as checks at on farm condition in Nagarkanda, Faridpur. Two replications of the advanced line BR9674-1-1-5-2-P4 were severely damaged due to rat infestation and very poor yield was obtained compared to the check entries. Mean growth duration of advanced line BR9674-1-1-5-2-P4 (117 days) was much earlier than the check varieties BRRI dhan49 (128 days), BRRI dhan72 (126 days) and BRRI dhan87 (122 days) (Table 4).

ALART (SHR) *Boro.* Three advanced lines BRH11-9-11-4-5B, BRH13-2-4-6-4B and BRH13-7-9-3-2B were evaluated along with BRRI dhan63 and Zirashail as checks at farmer's field at Krishnanagar, Nagarkanda, Faridpur. BRH11-9-11-4-5B out yielded (6.75 t/ha) all the other two entries as well as both the check entries BRRI dhan63 (6.54 t/ha) and Zirashail (4.70 t/ha). Yield of BRH11-9-11-4-5B was 3.1% and 30% higher than the check variety BRRI dhan63 and Zirashail respectively (Table 5).

ALART (FBR_Barishal) *Boro*: Four advanced lines BRBa 1-4-9, BRBa 2-5-3, BRBa 3-1-7 and BRBa 3-2-4 along with BRRI dhan58 and BRRI dhan89 as checks were evaluated at farmer's field at Krishnanagar, Nagarkanda, Faridpur. Check Variety BRRI dhan89 out yielded all test entries. Yield of BRBa 3-2-4 was reduced due to severe lodging (80%) (Table 6).

ALART (BRR) *Boro.* Four advanced lines BR(Path)12452-BC3-42-22-11-4, BR(Path)12452-BC6-53-21-11, BR(Path)13784-BC3-61-1-6-HR3 and BR(Path)13784-BC3-63-6-4-HR6 with BRRI dhan28 and BRRI dhan88 as check were tested at farmers' field at Krishnanagar, Nagarkanda, Faridpur. BRRI dhan88 out yielded (8.17 t ha^{-1}) all the test entries. . Mean growth duration of all the test entries was similar (146 days, 147 days) to the check varieties (145 days, 146 days). Uniform flowering and maturity were observed in these lines. (Table 7).

RYT (STR_1). Six advanced lines were evaluated against three standard checks BRRI dhan67, BRRI dhan89 and BRRI dhan97 in RYT (STR_1). Advanced line BR10187-1-4-12, BR10187-1-5-11, BR10188-10-1-18, BR9901-1-3-10 and BR9904-1-3-3 produced higher yield (7.89, 7.86, 8.34, 8.2 and 8.3 t/ha) than the check variety BRRI dhan67 (7.1 t/ha). On the other hand, all advance lines produced lower grain yield than the check varieties BRRI dhan89 and BRRI dhan97 (9.34, 8.72 t/ha) (Table 8).

RYT (STR_2). RYT (STR_2) conducted using nine advanced lines. Advance line TP30642 produced higher yield (8.53 t/ha) than check varieties BRRI dhan67 (7.88 t/ha) and BRRI dhan97 (8.24 t/ha). IR 108175-B-22-AJY 3-B-1 produced higher yield (8.19t/ha) than check BRRI dhan 67 (7.88 t/ha). Advance line IR15T1399, TP24493 produced higher yield than check check BRRI dhan 67 (7.88 t/ha). (Table 10) Check variety BRRI dhan89 produced highest yield (8.72 t/ha) than all advance lines (Table 9).

RYT (IRR). Seven advanced lines along with two susceptible check variety BRRI dhan58, BRRI dhan88 and one resistant check T27A were grown. Among seven, six advanced lines BR11593-5R-44, BR11593-5R-55, BR11593-5R-70, BR11593-5R-73, BR11593-5R-79 and BR11595-5R-24 produced higher yield (9.15, 8.92, 9.23, 9.09, 8.9 and 9.21 t/ha respectively) than all the three checks BRRI dhan58 (7.85 t/ha), BRRI dhan88 (5.59 t/ha) and T27A (5.76 t/ha) (Table 10).

RYT (FBR_Barishal). Ten advanced breeding lines along with two check varieties were evaluated. Two test entries NGR 1255-1 and NGR 522-1 out yielded (8.5 and 8.27 t/ha) the check BRRI dhan89 (8.14 t ha). None of the test entries out yielded the check variety BRRI dhan58 (8.62 t/ha) (Table 11).

RYT (DRR_1). Twelve advance lines were evaluated along with one susceptible check and one resistant check. Four advance lines BR11600-4R-82, BR11607-4R-184, BR11607-4R-6 and BR11607-4R-79 produced higher yield (7.35, 7.42, 7.4 and 7.03 t/ha) than both the checks BRRI dhan88 (6.88 t ha) and IRBB60 (6.69 t/ha) (Table 12).

RYT (DRR_2). Fourteen advanced lines were evaluated against two susceptible check varieties, BRRI dhan58, BRRI dhan89 and one resistant check IRBB60. Seven advanced lines BR11604-4R-118, BR11604-4R-122, BR11604-4R-129, BR11604-4R-147, BR11604-4R-24, BR11604-4R-35, BR11604-4R-52, BR11604-4R-72 produced higher yield (6.95,7.47,7.41, 7.16, 7.14, 6.67, 7.79 (t/ha) than the standard check BRRI dhan58 (6.5 t ha^{-1}) and IRBB60 (6.29 t ha^{-1}). All advance lines produced lower yield than the check BRRI dhan89 (8.66 t/ha) (Table 13).

RYT (ZER). Two advanced lines along with two s checks BRRI dhan29, BRRI dhan74 and BRRI dhan84 were grown. Both advanced lines produced higher yield (7.48 and 7.33 t ha^{-1}) than the checks BRRI dhan29 (6.3 t ha^{-1}), BRRI dhan74 (7.22 t ha^{-1}) and BRRI dhan84 (6.89 t/ha). (Table 14).

RYT (Blast_1) *Boro.* Five advanced breeding lines along with three checks BRRI dhan29, BRRI dhan89 and BRRI dhan92 were tested. Test entry BR(Path)1254-BC2-48-10-88-81-32 and BR(Path)1254-BC2-75-32-3139-7 produced higher yield (6.39 and 6.5 t/ha) than the check varieties BRRI dhan29 (5.83 t/ha) and BRRI dhan92 (6.16 t/ha). Check variety BRRI dhan89 produced higher yield (7.13 t/ha) than all the test entries (Table 15).

RYT (Blast_3). Five advanced breeding lines with three checks BRRI dhan29, BRRI dhan89 and BRRI dhan92 were tested. All advance lines gave lower yield (.19, 5.01, 5.53, 5 and 5.79 t/ha) than the three check varieties BRRI dhan29 (6.3 t/ha), BRRI dhan89 (6.71 t/ha) and BRRI dhan92 (6.22 t/ha). (Table 16).

RYT (SHR_SS). Five advanced lines along with two checks BRRI dhan28 and BRRI dhan81 were tested. Three advanced lines BRH10-1-14-2-6B, BRH13-1-9-7B and BRH13-2-4-7-2B produced higher yield (7.66, 7.43 and 7.65 t/ha respectively) than both the check entries BRRI dhan28 (6.85 t/ha) and BRRI dhan81 (5.24 t/ha). (Table 17).

RYT (SHR_LS). Three advanced breeding lines along with one check BRRI dhan28 were tested. All the advanced lines BR10247-14-18-4, BR10247-4-7-4B and BRH11-2-4-7B produced higher yield (7.61, 7.02 and 7.51 t/ha) than the check BRRI dhan28 (6.76 t/ha) (Table 18).

RYT (FBR_SD): Four advanced breeding lines along with two checks BRRI dhan81 and BRRI dhan96 were evaluated. Two advanced lines BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR2(Gaz)-P11-(Hbj) and IR17A1694 produced higher yield (6.66 and 8.44 t/ha) than both the checks BRRI dhan81 (6.36 t/ha) and BRRI dhan96 (5.89 t/ha) (Table 19).

RYT (FBR_LD). A total of seven advance lines were evaluated against two check varieties BRRI dhan89 and BRRI dhan92. Five among the seven advance lines BR11318-5R-84, BR10604-5R-10, BR10599-5R-375, BR11318-5R-106, BR11318-5R-148 produced higher yield (8.62, 7.48, 7.28, 7.14 and 6.97 t/ha) than both the check entries BRRI dhan 89 (6.8t/ha) and BRRI dhan92 (6t/ha) (Table 20).

RYT (FBR_MD). Twelve test entries along with two checks were grown. Among 12 entries four entries BR10317-5R-57, BR11318-5R-63, BR11337-5R-72 and SVIN109 produced higher yield (8.72, 8.91, 8.23, and 8.02 t/ha) than both the check entries BRRI dhan81 (7.98 t/ha) and BRRI dhan96 (7.67 t/ha) (Table 21)

RYT (FBR). Two advanced lines were tested along with two check varieties. Both the check varieties BRRI dhan88 (6.88 t/ha) and BRRI dhan96 (6.29 t/ha) produced higher yield than the test entries BR (Bio) 10381-AC1-2 and BR (Bio) 10381-AC32-3 (5.1 and 5.26 t/ha respectively) (Table 22).

RYT (CTR). Seven advanced breeding lines along with three check varieties were tested. Two advanced lines BR11894-R-R-R-R-134 and BR11894-R-R-R-R-165 produced higher yield (5.51 and 5.47 t/ha) than all three check varieties BRRI dhan67 (5.35 t/ha), BRRI dhan89 (4.74 t/ha) and BRRI dhan92 (5.2 t/ha). Two entries BR11894-R-R-R-R-299 and BR11894-R-R-R-R-304 produced higher yield (5.01 and 5.27 t/ha) than check BRRI dhan89. All other entries have lower yield than the check varieties (Table 23).

RYT (AGGRiNET). Seven breeding lines along with four check varieties were evaluated. Two lines IR08N134 and IR17A1650 produced higher yield (6.33 and 6.28 t/ha) than all four check entries BRRI dhan63 (5.43 t/ha), BRRI dhan81 (4.94 t/ha), BRRI dhan89 (5.06 t/ha) and BRRI dhan92 (5.18 t/ha). All other entries gave lower yield than the check variety BRRI dhan63 but higher than BRRI dhan81 (Table 24).

FARMING SYSTEMS RESEARCH

Introduction of intercropping system in different farmer led cropping pattern for medium low land area in Faridpur region

Bangladesh has the biggest agriculture based economy. Improving productivity and efficiency are the two fundamental economic development strategies. Therefore, agricultural productivity growth and resource efficiency improvement remain a top priority for Bangladesh to meet the food needs of its rapid growing population. In different agricultural environment occupies some important crop which is cultivated over the years. Behind this some driving forces are responsible here: land topography, soil type, weather pattern, different natural stress, farmer's preferences, resource availability, marketing facility etc. So to change this cropping pattern by replacing some new crops is quite impossible regarding this. Instead of replacing, introducing of intercropping system in different popular farmer led cropping patterns could be an option to increase the productivity of selected region. Faridpur region is synonymized by crop herbarium zone. Different major and minor crop are cultivated here. 123 cropping pattern, persist in Faridpur region. Considering medium low land of this region, 43.49% regional NCA is occupied by Jute in where, different rabi crops (Onion, wheat, lentil, mustard) is cultivated. Among these, four cropping patterns occupied major area where T. Aman is also cultivated. It represents medium low land where water logged condition is not prevailed. For this study, four T. Aman based cropping patterns (Onion-Jute-T.Aman, Wheat-Jute-T.Aman, Lentil-Jute-T. Aman, Mustard-Jute-T. Aman) take into account and modified them by incorporation some crop through intercropping. *Aman* production areas is high in Faridpur district followed by Rajbari, Madaripur, Gopalganj and Shariatpur. There were six crop which were dominated these large areas over the years. But by modifying, 11 crops can be cultivated in these areas. Among the tested cropping pattern, the highest Rice equivalent yield (REY) was obtained from Potato+Maize-Jute-T.Aman (26.73 t/ha) followed by Mustard+Watermelon-Mungbean-Jute-T. Aman (25.58 tha). The turnover time in these two cropping patterns was 30 days and 20 days respectively.

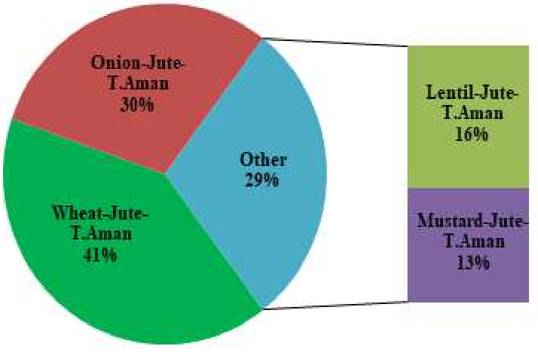


Fig. 1. Four major T. Aman cultivated cropping patterns in Faridpur region.

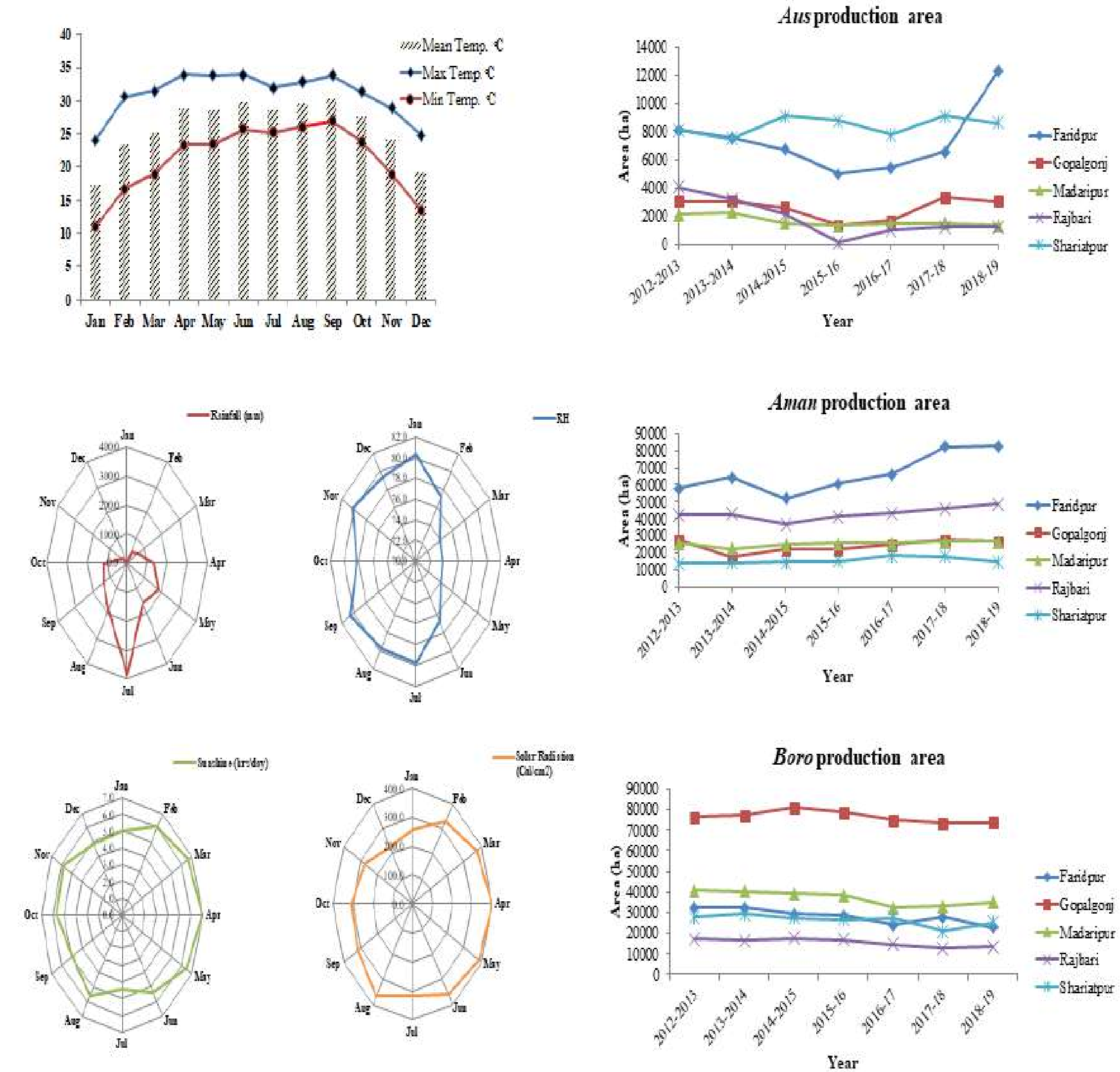
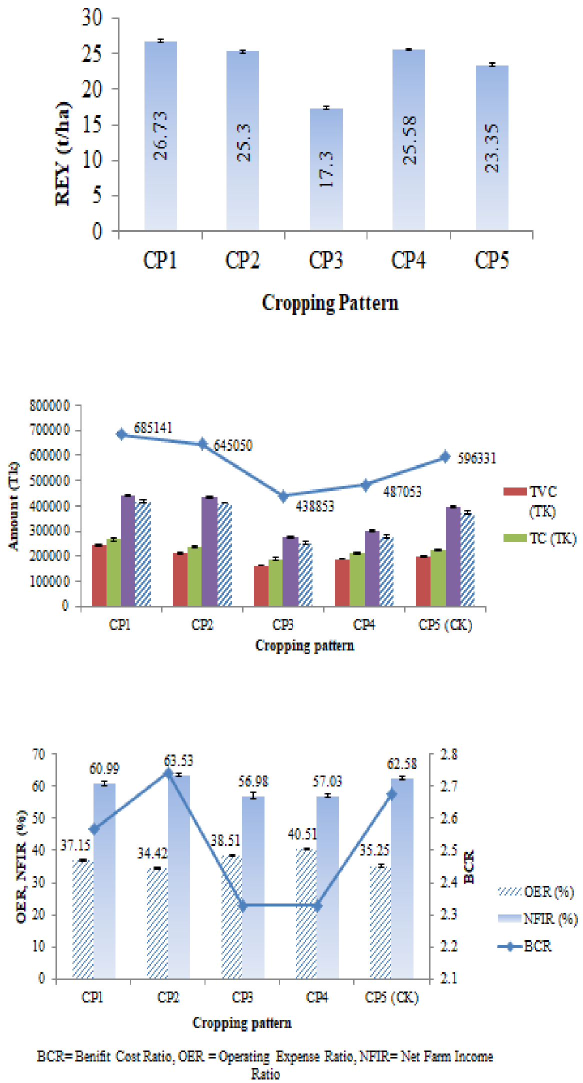


Fig. 2. **a)** Conditions of weather parameter in Faridpur region (Average from 2015- 2021)
b) Rice production area (ha) in Faridpur region.



CP1= Potato+Maize-Jute-T.Aman
CP2= Onion+Pumpkin-Jute-T.Aman
CP3= Lentil+Maskmelon-Jute-T.Aman
CP4= Mustard+watermelon-Mungbean-Jute-T.Aman
CP5= Onion-Jute-T.Aman (CK)

Fig. 3. Average comparative profitability performance of different cropping patterns with the existing one.

CROP-SOIL-WATER MANAGEMENT
SOCIO-ECONOMICS AND POLICY

Stability analysis

For short duration Aman varieties, BRRI dhan90, BRRI dhan73 and BRRI hybrid ddhan6 produced 3.43 t ha^{-1}, 3.28 t ha^{-1} and 2.71 t ha^{-1} which was higher yield than the other varieties like BRRI dhan39, BRRI dhan75 and BRRI dhan57 (Table 24). In medium duration *Aman* varieties based on yield BRRI dhan78, BRRI dhan80 and BRRI dhan51 produced the highest grain yield 3.59

t ha^{-1}, 2.84 t ha^{-1} and 2.66 t ha^{-1} followed by BRRI dhan72 (2.29 tha-1), BRRI dhan44 (2.22 tha-1) and BRRI dhan49 (2.18 tha-1). (Table 25). In long duration T. Aman varieties BRRI dhan46 yielded high (2.62 t ha^{-1}) followed by BRRI dhan41 (2.07 t ha^{-1}) and BRRI dhan38 (1.83 t ha^{-1}) (Table 26).

In Boro season, for short duration Boro varieties BRRI hybrid dhan5 yielded high (8.12 t ha^{-1}) followed by BRRI dhan67 (7.75 t ha^{-1}) and BRRI hybrid dhan2 (7.62 t ha^{-1}) (Table 28). For long duration, BRRI dhan89, BRRI dhan92 and BRRI dhan29 gave the highest grain yield 8.85 t ha^{-1}, 8.74 t ha^{-1} and 8.25 t ha^{-1} followed by BRRI dhan58 (7.50 t ha^{-1}) and BRRI dhan99 (7.32 t ha^{-1}) (Table 29).

TECHNOLOGY DISSEMINATION

Demonstrations of modern rice varieties during Aus, T. Aman 2021 and Boro 2021-22 were done in Sadar, Faridpur; Sadar, Rajbari; Kalkini, Madaripur; Nagarkanda, Faridpur; Rajoir, Madaripur under BRRI RS, Bhanga, Faridpur with the financial assistance of BRRI-SPIRA project.

In Aus 2021, twenty-two demonstrations were established under the supervision of BRRI RS, Bhanga. For those, BRRI dhan48, BRRI dhan82, BRRI dhan83, BRRI dhan85, BRRI dhan98 and BRRI hybrid dhan7 were used. The highest yield 5.46 tha-1, 5.25 t ha^{-1}, 4.5 t ha^{-1}, 4.74 t ha^{-1}, 5.46 t ha^{-1}, 6.59 t ha^{-1} was obtained respectively.

Similarly, in Aman 2021, sixty-five demonstrations were carried out by using BRRI dhan79, BRRI dhan87 and BRRI hybrid dhan4. The maximum grain yield was found in crop cut was 4.76 tha^{-1}, 7.36 tha^{-1} and 7.53 tha^{-1} respectively.

In Boro 2021-22, a total of nine varieties such as BRRI dhan58, BRRI dhan67, BRRI dhan89, BRRI dhan92, BRRI dhan96, BRRI Hybrid dhan3, BRRI Hybrid dhan5 were included in 480 demonstrations at six upazilas of four districts namely Faridpur, Shariatpur, Madaripur and Rajbari under BRRI RS, Bhanga. In total 365 crop cuts done in different upazilas. The highest grain yield in different locations were: 7.52 t ha^{-1} with BRRI dhan58; 7.86 t ha^{-1} with BRRI dhan67 ; 9.29 tha^{-1} with BRRI dhan89; 9.42 tha^{-1} with BRRI dhan92; 7.36 tha^{-1} BRRI dhan96 in Bhanga; 8.76 tha^{-1} BRRI Hybrid dhan3; 8.57 tha^{-1} BRRI hybrid dhan5. The trial farmers stored their seeds except hybrid seed according to their demand for growing in the next Boro season.

In Aman, 2021 three varietal replacement through head to head trials were conducted in five upazilas of two districts namely Faridpur and Madaripur under the supervision of BRRI RS, Bhanga with the financial assistance of BRRI-TRB project. Ten genotypes such as BRRI dhan51, BRRI dhan71, BRRI dhan75, BRRI dhan80, BRRI dhan87, BRRI dhan93, BRRI dhan94, BRRI dhan95, Binadhan-17, Binadhan-22 were included in this trial. The highest grain yield in different locations were as follows: in long duration trial 5.61 t ha^{-1} in BRRI dhan87 at Nagarkanda, Faridpur; 5.80 t ha^{-1}in BRRI dhan87 at Kalkini, Madaripur. The short duration head to head trial was submerged twice during the active tillering stage resulting in very poor yield. The highest yield 3.15 t ha^{-1} was produced by BRRI dhan75 at Bhanga, Faridpur.

Similarly, in Boro 2021-22, five varieties like BRRI dhan28; BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan88 and Bangabondhu dhan100 were included in BRRI dhan28 group while BRRI dhan29, BRRI dhan58, BRRI dhan89, BRRI dhan92 and Binadhan-24 are included in BRRI dhan29 group. The six (two BRRI dhan28 group and four BRRI dhan29 group) varietal replacement through head to head trials were conducted in six upazilas of three districts namely Faridpur, Madaripur and Rajbari districts under BRRI RS, Bhanga with the financial assistance of BRRI-TRB project. The highest grain yield with growth duration in different locations were as follows: in short duration group 7.27 t ha^{-1} with BRRI dhan88 in Khalilpur, Rajbari sadar, Rajbari; 10.935 t ha^{-1} with BRRI dhan88 in Raynagar, Bhanga, Faridpur. In long duration group, 8.33 t ha^{-1} with BRRI dhan89 in Rajbari sadar, Rajbari; 9.17 t ha^{-1} with BRRI dhan89 in Kanaipur, Faridpur sadar, Faridpur; 8.64 t ha^{-1} BRRI dhan92 in Sutarkandi, Rajoir, Madaripur; 10 t ha^{-1} BRRI dhan89 in Krishnonagar, Nagarkanda, Faridpur. The trial farmers stored their seeds according to their choice for growing in the next Boro season.

In total 26.75 tons of seed was produced in BRRI RS, Bhanga farm. Out of them, 13.75 tons of breeder seed of BRRI dhan29, BRRI dhan89 and BRRI dhan92 and the rest 16.0 toes were TLS of short duration Aman varieties such as BRRI dhan39, BRRI dhan71, BRRI dhan75, BRRI dhan79 and BRRI dhan87 as well as Boro varieties of BRRI dhan29, BRRI dhan50, BRRI dhan58, BRRI dhan84, BRRI dhan88, BRRI dhan89 and BRRI dhan92 during Boro 2021 -2022 season.

Six hundred forty-eight farmers of greater Faridpur region have been trained on modern rice production technologies through 24 training programmes in BRRI RS, Bhanga with the cooperation of DAE and the financial assistance of GOB.

Table 1. List of generation in FRGA.

BR Reg no.	Cross	Progeni grown	Progeni harvested
BRBh10-2R	BR11723-4R-12/BRRI dhan67	188	140
BRBh11-2R	BR11716-4R-129/BRRI dhan67	75	65
BRBh12-2R	BR11712-4R-218/BRRI dhan67	71	65
BRBh13-2R	BR11716-4R-113/DR(6)	124	105
BRBh14-2R	IR107989-13-BRGA-BRGA-396/ WAXXIAN7777-P8	100	90
BRBh15-2R	BR11723-4R172/IR58443-6B-10-3	72	72
	Total	630	537

Table 2. Performance of Proposed Variety Trial in Aman 2021-22 at BRRI RS, Bhanga.

PVT set	Location	Code no.	Growth duration (day)	Yield (t ha-1)
Set-1	BRRI RS Bhanga	**I-0**33		**5.**92
		I-034		**5.**013
		I-035		5.541

Table 3. Performance of proposed variety trial in Boro 2021-22 at BRRI RS, Bhanga, Faridpur.

PVT set	Location	Code no.	Growth duration (day)	Yield (t ha^{-1})
Set-1	BRRI RS, Bhanga	**I-0**36	151	7.46
		I-039	145	8.00
Set-2	BRRI RS, Bhanga	**I-0**38	151	7.29
		I-037	151	8.02
Set-3	BRRI RS, Bhanga	**I-0**40	152	5.88
		I-041	145	7.29

Table 4. Grain yield and agronomic characters of ALART ZER, Aman 2021at Nagarkanda.

Designation	Plant height (cm)	Panicle/m^2	Growth duration (day)	Yield (t ha^{-1})
BR9674-1-1-5-2-P4	129	213	117	3.44
BRRI dhan49	116	366	128	
BRRI dhan72 (ck)	130	261	126	4.04
BRRI dhan87 (ck)	133	266	122	3.44

Table 5. Grain yield and agronomic characters of ALART SHR, Boro 2020-21 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	Panicle/m2	GD (day)	Yield (t ha^{-1})
BRH11-9-11-4-5B	104.73	360	153	6.75
BRH13-2-4-6-4B	97.30	364	154	6.5
BRH13-7-9-3-2B	118.74	354	158	5.67
BRRI dhan63 (Ck)	96.90	371	149	6.54
Zirashail (Ck)	111.70	361	145	4.7

Table 6. Grain yield and agronomic characters of ALART (FBR_Barishal) Bhanga, 2021-2022at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	Panicle/m2	GD (days)	Yield (t ha^{-1})
BRBa 1-4-9	106.63	275.00	154	5.84
BRBa 2-5-3	105.27	345.33	154	6.03
BRBa 3-1-7	107.07	373.33	154	5.74
BRBa 3-2-4	105.77	289.00	151	5.04
BRRI dhan58 (ck)	102.90	314.33	152	5.22
BRRI dhan89 (ck)	120.23	320.33	157	6.33

Table 7. Grain yield and agronomic characters of ALART (BRR) Bhanga, 2021-22 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	Panicle/m2	GD (day)	Yield (t ha^{-1})
V1=BR (Path) 12452-BC342-22-11-4	119.93	388	146	6.81
V2=BR (Path) 12452-BC6-53-21-11	122.90	269	147	6.81
V3=BR (Path) 13784-BC3-61-1-6-HR3	113.27	305	144	8.02
V4=BR (Path) 13784-BC3-63-6-4-HR6	110.43	280	147	8.04
V5=BRRI dhan28 (ck)	118.83	342	145	7.33
V6=BRRI dhan88 (ck)	106.47	352	146	8.17

Table 8. Grain yield and ancillary characters of RYT (STR_1) Boro, 2021-2022 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (Day)	Yield (t ha^{-1})
BR10187-1-4-12	106.63	151	7.89
BR10187-1-5-11	107.33	151	7.86
BR10188-10-1-18	112.87	156	8.34
BR9901-1-3-10	103.8	152	8.2
BR9904-1-3-3	130.7	155	8.3
BR9926-7-7-6	111.67	148	6.4
BRRI dhan67	113.52	150	7.1
BRRI dhan89	116.33	156	9.34
BRRI dhan97	118.33	155	8.72
Mean	113.5	152	8.02
LSD (0.05)	5.012	2.110	1.810
CV(%)	1.520	0.475	7.770

Table 9. Grain yield and ancillary characters of RYT (STR_2) Boro, 2021-2022at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BRRI dhan67	108.13	150	7.88
BRRI dhan89	119.93	160	8.72
BRRI dhan97	118.8	154	8.24
IR 108175-B-22-AJY 3-B-1	138.47	158	8.19
IR 108604-2-1-AJY 3-B-1	102.13	154	7.5
IR 108604-2-3-AJY 3-B-1	128.6	154	7.27
IR15T1399	106.67	153	7.95
TP20532	102.12	149	6.19
TP21654	104.73	152	6.98
TP24493	97.73	151	7.94
TP30629	112.2	152	7.15
TP30642	112.8	156	8.53
Mean	112.7	153	7.71
LSD (0.05)	18.790	2.740	NS
CV(%)	5.620	2.604	12.040

Table 10. Grain yield and ancillary characters of RYT (IRR) Boro, 2021-22 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR11592-5R-11	114.53	148	7.23
BR11593-5R-44	122.6	152	9.15
BR11593-5R-55	122.47	154	8.92
BR11593-5R-70	122.4	154	9.23
BR11593-5R-73	121.93	154	9.09
BR11593-5R-79	120.33	150	8.9
BR11595-5R-24	123.27	150	9.21
BRRI dhan58	105.33	147	7.85
BRRI dhan88	96.33	143	5.59
T27A (ck)	153.8	143	5.76
Mean	120.3	149	8.09
LSD (0.05)	7.85	3.91	1.48
CV(%)	2.23	0.89	6.25

Table 11. Grain yield and ancillary characters of RYT (FBR_Barishal) Boro, 2021-22at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha-1)
BRRI dhan58	105.7	145	8.62
BRRI dhan89	116.5	151	8.14
NGR 1161-3	106.5	147	7.81
NGR 1255-1	123.6	150	8.5
NGR 1308-2	109.3	145	7.23
NGR 414-1	100.3	146	7.34
NGR 418-1	105.5	149	7.37
NGR 467-2	107.1	154	7.47
NGR 521-2	105.1	146	8.1
NGR 522-1	108.3	147	8.27
NGR 750-1	116.7	149	7.93
NGR 796-2	108.1	149	7.57
Mean	109.4	148	7.86
LSD (0.05)	5.41	1.35	NS
CV(%)	1.67	0.31	7.74

Table 12. Grain yield and ancillary characters of RYT (DRR_1) Boro, 2021-22 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR11600-4R-105	110	154	6.47
BR11600-4R-140	110.1	153	6.74
BR11600-4R-82	103.3	153	7.35
BR11604-4R-77	125.8	155	5.74
BR11607-4R-111	94.1	150	6.56
BR11607-4R-128	86.2	144	5.77
BR11607-4R-156	93.3	151	6.26
BR11607-4R-184	98.5	151	7.42
BR11607-4R-42	100.3	152	6.32
BR11607-4R-46	90.4	149	6.71
BR11607-4R-6	91.4	147	7.4
BR11607-4R-79	95.1	149	7.03
BRRI dhan88	90.5	142	6.88
IRBB60	85.55	154	6.69
Mean	98.18	150	6.67
LSD (0.05)	11.99	4.80	1.73
CV(%)	3.03	0.79	6.43

Table 13. Grain yield and ancillary characters of RYT (DRR_2) Boro, 2021-22 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR11600-4R-287	106.7	145	5.86
BR11604-4R-110	128.7	156	5.82
BR11604-4R-118	115.8	149	6.95
BR11604-4R-122	134.6	155	7.47
BR11604-4R-129	127.9	149	7.41
BR11604-4R-147	120.9	146	7.16
BR11604-4R-24	120.7	149	7.14
BR11604-4R-35	118	149	6.67
BR11604-4R-52	117.3	151	6.76
BR11604-4R-72	118.8	153	7.79
BR11607-4R-153	87.6	144	6.37
BR11607-4R-2	103.1	149	6.51
BR11607-4R-20	101.1	151	6.48
BR11607-4R-258	96.5	146	5.57
BRRI dhan58	101.1	143	6.5
BRRI dhan89	115.9	144	8.66
IRBB60	89.2	151	6.29
Mean	112	148	6.88
HSD (0.05)	11.17	5.88	2.39
CV(%)	2.46	2.9769	8.68

Table 14. Grain yield and ancillary characters of RYT (ZER) Boro, 2021-22 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR9674-1-1-5-1-P3	116.67	162	7.48
BR9674-4-2-10-5-P9	120	160	7.33
BRRI dhan29	116	162	6.3
BRRI dhan74	101.67	152	7.22
BRRI dhan84	113	146	6.12
Mean	113.47	156	6.89
LSD (0.05)	3.71	3	NS
CV(%)	1.74	2.9	8.77

Table 15. Grain yield and ancillary characters of RYT (BRR_1) Boro, 2021-2022at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR(Path)1254-BC2-13-81-88-87-HR	123.1	159	6.15
BR(Path)1254-BC2-48-10-88-81-32	118.8	158	6.39
BR(Path)1254-BC2-56-81-27-3-30	125.1	168	5.65
BR(Path)1254-BC2-75-32-3139-7	127.4	158	6.5
BR(Path)1254-BC2-87-24-32-1-29	121.1	161	5.58
BRRI dhan29	111.8	159	5.83
BRRI dhan89	123.5	155	7.13
BRRI dhan92	128.7	174	6.16
Mean	122.44	161	6.18
LSD (0.05)	9.30	2.42	1.25
CV(%)	1.85	4.37	4.92

Table 16. Grain yield and ancillary characters of RYT (BRR_3) Boro 2021-22 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR (Path)1254-BC2-13-81-88-87-HR	127.73	167	6.09
BR (Path)1254-BC2-48-10-88-81-32	127.2	168	5.01
BR (Path)1254-BC2-56-81-27-3-30	125.33	167	5.53
BR (Path)1254-BC2-75-32-3139-7	131.2	168	5
BR (Path)1254-BC2-87-24-32-1-29	129.73	167	5.79
BRRI dhan29	125.73	163	6.3
BRRI dhan89	130.8	165	6.71
BRRI dhan92	129	168	6.22
Mean	128.34	166	5.83
LSD (0.05)	NS	0.889	0.875
CV(%)	2.850	3.185	5.210

Table 17. Grain yield and ancillary characters of RYT (SHR_SS) Boro 2021-22at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BRH10-1-14-2-6B	96.0	139	7.66
BRH13-1-9-7B	100.3	137	7.43
BRH13-2-4-7-2B	98.8	138	7.66
BRH17-23-8-2-7B	100.6	137	5.57
BRH9-3-2B	100.5	143	6.23
BRRI dhan28	101.8	136	6.85
BRRI dhan81	99.3	136	5.24
Mean	99.6	138.0	6.7
HSD (0.05)	NS	2.11	1.50
CV(%)	3.7	3.54	7.89

Table 18. Grain yield and ancillary characters of RYT (SHR_LS) Boro 2021-22 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR10247-14-18-4	107.8	141	7.61
BR10247-4-7-4B	111.7	141	7.02
BRH11-2-4-7B	105.7	141	7.51
BRRI dhan28	100.3	143	6.76
Mean	106.4	141.0	7.2
LSD (0.05)	3.06	NS	NS
CV(%)	4.44	2.82	5.12

Table 19. Grain yield and ancillary characters of RYT (FBR_SD) Boro 2021-22 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR1(Gaz)-P8-(Hbj)	82.33	134	4.51
BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR2(Gaz)-P11-(Hbj)	98	136	6.66
BRRI dhan81	97.33	136	6.36
BRRI dhan96	83.33	139	5.89
IR17A1694	102	144	8.44
IR17A1723	91.67	134	5.74
Mean	92.44	137	6.3
HSD (0.05)	3.4215	0.6684	2.3134
CV(%)	4.31	4.1718	13.01

Table 20. Grain yield and ancillary characters of RYT (FBR_MD) Boro 2021-22 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR10317-5R-57	104.1	144	8.72
BR10601-5R-74	111.7	144	7.72
BR11303-5R-53	111.5	146	7.32
BR11318-5R-63	110.6	144	8.91
BR11337-5R-72	103.6	147	8.23
BR11342-5R-21	111.1	146	7.18

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR11342-5R-23	114.9	145	7.74
BR8899-14-4-1-2-2-1	92.0	141	6.21
BR9945-5R-21	114.1	144	7.53
BR9945-5R-25	104.9	144	7.34
BRRI dhan81	103.9	144	7.98
BRRI dhan96	97.7	140	7.67
IR17A2433	131.3	154	6.09
SVIN109	105.6	148	8.02
Mean	108.3	145.0	7.6
HSD (0.05)	10.7856	2.166	2.5078
CV(%)	3.31	3.4961	10.94

Table 21. Grain yield and ancillary characters of RYT (FBR_Bio) Boro 2021-22 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR (Bio) 10381-AC1-2	123.6	151	5.1
BR (Bio) 10381-AC32-3	96	138	5.26
BRRI dhan88	90.2	143	6.88
BRRI dhan96	95.93	146	6.29
Mean	101.4	144	5.88
LSD (0.05)	7.0202	0.9418	1.1617
CV(%)	3.46	2.0	9.88

Table 22. Grain yield and ancillary characters of RYT (CTR) Boro, 2021-22 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR10715-5R-1	104.87	155	4.32
BR10715-5R-9	100.47	154	4.32
BR11894-R-R-R-R-110	106.8	146	3.85
BR11894-R-R-R-R-134	110.4	145	5.51
BR11894-R-R-R-R-165	104	138	5.47
BR11894-R-R-R-R-299	113.27	145	5.01
BR11894-R-R-R-R-304	105.6	142	5.27
BRRI dhan67	113.4	140	5.35
BRRI dhan89	110.6	150	4.74
BRRI dhan92	115.8	167	5.2
Mean	108.521	148	4.904
HSD (0.05)	12.68	12.93	NS
CV(%)	3.99	2.98	13.9

Table 23. Grain yield and ancillary characters of RYT (AGGRiNET) Boro, 2021-22 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BRRI dhan63	90.5	140	5.43
BRRI dhan81	99.5	136	4.94
BRRI dhan89	119.5	155	5.06
BRRI dhan92	126.8	150	5.18
IR08N134	110.5	143	6.33
IR12A173	111.9	149	5.14
IR16A3667	115.7	147	4.97
IR17A1650	109.7	141	6.28
IR17A1694	110.4	147	4.85
IR17A2241	107.4	146	5.16
IR17A2433	127.9	156	5.26
Mean	111.8	146.0	5.3
HSD (0.05)	16.61	3.53	0.63
CV(%)	5.04	3.14	11.92

Table 24. Grain yield and agronomic characters of BRRI released short duration Aman varieties under stability analysis in T. Aman 2020 at BRRI RS, Bhanga, Faridpur.

Variety	GD (day)	PH (cm)	Tillers/hill	Panicle/hill	Panicle length (cm)	Yield (t ha^{-1})
BRRI dhan33	132	91.27	9.9	9	22.47	1.79
BRRI dhan39	139	94.27	10.3	9	23.00	1.86
BRRI dhan53	137	90.27	10.3	9	21.67	2.27
BRRI dhan56	132	91.73	8.6	8	22.27	1.81
BRRI dhan57	127	80.60	9.3	8	21.73	1.88
BRRI dhan62	130	88.20	9.1	9	20.80	1.37
BRRI dhan66	133	95.60	8.8	9	21.20	1.84
BRRI dhan71	135	99.40	8.6	8	23.80	1.84
BRRI dhan73	139	90.33	9.8	9	21.67	3.28
BRRI dhan75	133	85.47	8.7	8	21.33	1.22
BRRI dhan87	123	96.13	9.7	9	22.53	2.66
BRRI dhan90	131	95.07	9.1	9	21.67	3.43
BRRI hybrid dhan4	133	98.80	12.3	11	24.53	2.67
BRRI hybrid dhan6	133	87.53	11.5	11	22.07	2.71

Table 25. Grain yield and agronomic characters of BRRI released medium duration Aman varieties under stability analysis in T. Aman 2020 at BRRI RS, Bhanga, Faridpur.

Variety	GD (days)	PH (cm)	Tiller/hill	Panicle/hill	Panicle length (cm)	Yield (t ha^{-1})
BR3	152	59.53	9.5	8.1	23.13	1.05
BR4	153	93.13	11.8	10.7	24.60	2.03
BR11	158	90.80	10.7	9.5	24.13	1.56
BR25	153	108.40	11.9	9.7	24.47	1.18
BRRI dhan30	159	106.33	12.1	10.3	25.47	2.44
BRRI dhan31	154	101.47	11.2	9.7	27.27	2.17
BRRI dhan32	154	98.33	10.3	9.3	34.13	1.56
BRRI dhan44	159	98.27	10.7	8.9	31.53	2.22
BRRI dhan49	158	79.93	13.1	10.9	22.47	2.18
BRRI dhan51	161	82.40	12.7	11.1	24.47	2.66
BRRI dhan52	156	97.00	11.7	10.1	24.40	1.34
BRRI dhan54	168	103.73	11.3	9.8	25.20	1.61
BRRI dhan72	165	76.73	13.0	11.1	23.73	2.29
BRRI dhan77	160	121.67	11.3	9.2	33.33	1.61
BRRI dhan78	159	99.13	11.5	10.2	23.80	3.59
BRRI dhan79	155	95.80	11.7	9.9	24.60	1.82
BRRI dhan80	153	95.20	11.1	9.4	24.67	2.84
BRRI dhan93	159	75.87	11.9	10.1	23.33	2.03
BRRI dhan94	160	82.80	12.1	10.4	23.73	1.59

Table 26. Grain yield and agronomic characters of BRRI released long duration Aman varieties under stability analysis in T. Aman 2021 at BRRI RS, Bhanga, Faridpur.

Variety	GD (day)	PH (cm)	Tillers/hill	Panicle/hill	Panicle length (cm)	Yield (t ha^{-1})
BR5	146	95.20	7	6	22.1	1.04
BR10	168	84.53	11	10	24.0	1.42
BR22	155	82.13	12	10	20.5	1.62
BR23	162	110.60	11	9	24.1	0.68
BRRI dhan34	145	95.53	7	7	23.1	1.31
BRRI dhan37	170	100.00	10	9	23.5	1.33
BRRI dhan38	143	86.13	10	10	22.7	1.83
BRRI dhan41	149	91.20	8	7	24.0	2.07
BRRI dhan46	146	84.47	8	7	21.5	2.62
BRRI dhan76	165	101.73	11	9	25.3	1.77
BRRI dhan91	165	127.07	11	10	24.3	1.26

Table 27. Grain yield and agronomic characters of BRRI released short duration Boro varieties under stability analysis in Boro 2020-21 at BRRI RS, Bhanga, Faridpur.

Varieti	GD	PH (cm)	Tiller/hill	Panicle/hill	PL (cm)	Yield (t ha^{-1})
BR1	154	87.2	14	13	22.5	5.45
BR6	145	99.5	13	13	22.8	5.78
BR26	142	108	13	13	21.4	5.58
BRRI dhan27	135	119.23	13	12	23.2	5.75
BRRI dhan28	143	92.12	13	12	23.12	6.5
BRRI dhan36	145	91.54	15	12	22.5	5.23
BRRI dhan45	138	102	12	11	23.2	4.8
BRRI dhan55	148	98.78	12	12	24.8	5.12
BRRI dhan61	152	95.42	11	11	23.21	5.35
BRRI dhan63	150	86.31	13	12	22.5	6.35
BRRI dhan67	148	97.15	16	16	23.87	7.75
BRRI dhan68	152	96.14	13	11	22.12	6.35
BRRI dhan74	148	96.12	14	12	23.45	6.5
BRRI dhan81	144	101.42	15	15	23.21	6.86
BRRI dhan84	145	95.12	14	13	23.5	6.75
BRRI dhan86	143	95.42	15	12	23.75	5.64
BRRI dhan88	145	94.56	16	15	22.78	7.25
BRRI dhan96	146	85.32	15	15	22.56	7.23
BRRI hybrid dhan2	148	103.42	16	15	24.52	7.62
BRRI hybrid dhan3	147	102.14	16	16	23.85	7.51
BRRI hybrid dhan5	147	107.45	17	16	25.57	8.12

Table 28. Grain yield and agronomic characters of BRRI released long duration Boro varieties under stability analysis in Boro 2020-21 at BRRI RS, Bhanga, Faridpur.

Varieti	GD	PH (cm)	Tiller/hill	Panicle/hill	PL (cm)	Yield (t ha^{-1})
BR2	165	115.28	13	13	21.95	5.25
BR3	173	93.84	13	12	22.75	5.75
BR7	157	118.34	13	13	23.24	6.65
BR8	161	118.42	13	13	22.13	6.55
BR9	157	117.45	13	13	22.95	5.46
BR12	169	103.48	12	12	23.14	5.87
BR14	158	115.26	13	13	22.72	5.67
BR15	168	89.36	11	11	22.74	5.46
BR16	167	88.46	11	11	23.45	6.12
BR17	158	118.47	12	12	22.42	5.98
BR18	173	113.47	12	12	22.36	5.92
BR19	171	108.12	11	11	23.18	6.32
BRRI dhan29	158	92.53	16	16	24.85	8.25
BRRI dhan35	154	101.42	13	13	22.65	5.41
BRRI dhan47	146	101.48	14	12	24.1	5.24
BRRI dhan50	158	78.95	14	12	23.12	5.5
BRRI dhan58	149	97.42	15	15	24.62	7.5
BRRI dhan59	148	81.47	13	12	22.31	5.56
BRRI dhan60	147	96.23	12	12	22.14	5.55
BRRI dhan64	156	85.98	12	12	23.24	6.21
BRRI dhan69	154	102.45	11	11	23.63	5.37
BRRI dhan89	158	104.14	17	16	23.85	8.85
BRRI dhan92	160	105.42	16	16	24.75	8.74
BRRI dhan97	154	99	15	15	23.75	7.12
BRRI dhan99	157	93	15	14	23.45	7.32

Investigators: M Akhlasur Rahman, Tusher Chakrobarty, M Asadulla Al Galib and Rowmika Jahan Promee.

BRRI RS, Cumilla

SUMMARY

Altogether 56 crosses were made and 30 crosses were confirmed during T. Aman and Boro seasons. A total of 13231, 2596, 14120 and 25100 plants were selected from F_2, F_3, F_4 and F_5 generation respectively. Fifty-seven breeding lines were bulked from F_5 to F_6 generation. In B. Aman season, one entry performed better than the check varieties and the heritability obtained from yield was 88%, indicating higher level of precision of this experiment in RYT (Hbj) and in Early T. Aman season, due to excessive flood water none of entries performed well along with the check varieties in ALART (SW).

In T. Aman season none of the entries performed better than the check varieties in AYT-Cum (WS). In RYT#1 (RLR), three genotypes performed better than the check varieties on the basis of yield and the heritability. In RYT (ZER), two genotypes performed better than the check varieties on the basis of yield and the heritability. In RYT#1(STR) three genotypes, and in RYT#2 (STR), five genotypes performed better than the check varieties. In MLT(DRR)-on station, two entries performed better than check varieties. In MLT(DRR)- Debidwar, one entry performed better than check varieties.

In Boro season, based on high yield performance, disease reaction and other good agronomic characters four genotypes performed better than the check varieties in OYT#1(Cum). Five and three entries were selected from PYT#1 and PYT#2 respectively. Three genotypes were selected from SYT#1 and SYT#2 respectively. genotypes 2, 5, 1, 4, 5, 3 , 4, 6, 4, 5, 2, 2, 2, 2 , 1 performed better than the check varieties in RYT_FBR_LD, RYT_FRB_MD, RYT_FBR_SD, RYT_AGGRiNet, RYT_Barishal, RYT(IRR_BPH), RYT#1(DRR_BB), RYT#2(DRR_BB), RYT#3(DRR_Blast_on station), RYT#3(DRR_Blast_Debidwar), RYT#1(STR), RYT#2(STR), RYT#1(SS), RYT#3(LS), RYT(PQR), RYT (Biotech) and no entries performed better than the check varieties in RYT(ZER).

Under transforming rice breeding (TRB) Project, in T. Aus season**,** in OYT, 129 genotypes performed better out of 384 genotypes and produced yield more than 4.96 t/ha. In PYT, eight genotypes performed better than the check varieties. In T. Aman season, 19, 65, 59, 73 genotypes performed better than check varieties in OYT#1 (RLR), OYT#2 (RLR), OYT#3 (RLR) and OYT#4 (RLR). In OYT (DRR-BB), five genotypes performed better than the standard check varieties. In OYT (IRR-BPH), 65 genotypes produced more than 6.0 t/ha yield. In PYT (DRR-BB), two genotypes produced higher yield than the check varieties. In AYT (IRR-BPH), 44 genotypes performed better out of 92 genotypes compared to the check varieties. Under the breeding value estimated (BVE) trial, 19 genotypes performed better out of 180 genotypes compared to the check varieties.

In Boro season, 20, 6, 14, 14 genotypes performed better than check varieties in OYT_FBC, AYT_FBR_LATE, AYT_FBR_EARLY, OYT#1(DRR). In AYT#1(DRR), AYT#2(DRR), AYT#3(DRR) 12, 11, 2 genotypes performed better than standard check varieties. In OYT(IRR_BPH), 30 entries performed better than the check varieties. In PYT_(IRR-BPH), 15 genotypes produced higher yield than the check varieties. In AYT (IRR_BPH), 28 genotypes performed better out of 60 genotypes compared to the check varieties. Under the BVE trial, 11 genotypes performed better out of 215 genotypes compared to check varieties.

AGGRi Alliance Project. In T. Aman season, eight genotypes performed better out of 255 genotypes compared to the check varieties. In Boro season, 15 genotypes performed better out of 265 genotypes compared to the check varieties

Pest management. A low cost, low input, low hazard, high output tungro disease management package (chemical and mechanical) was developed in Cumilla region. Neck blast in aromatic rice, sheath blight, bacterial blight, tungro, false smut in T. Aman, and neck blast, bacterial blight, sheath blight diseases in Boro season were found predominant in Cumilla region. Rice yield loss was saved 69-88 % in T. Aman and 80-95% in Boro seasons by managing neck blast disease following BRRI developed blast disease management technology in all the areas.

C-S-W management. Nitrogen was the most yield limiting factor for T. Aman and Boro seasons. A combination of 200 kg K and 100 kg N for BRRI dhan87 and 200 kg K and 140 kg N for BRRI dhan89 were observed suitable for desired yield. For DAP experiment, treatments T_2 (DAP + Urea 100% STB) and T_7 (DAP + urea 60% STB) were observed producing higher yield in BRRI dhan96 and BRRI dhan87, respectively compared to the other treatments. BRRI dhan93 (4.2 t ha^{-1}) and BRRI dhan89 (7.67 t ha^{-1}) produced higher grain yield upto 4 August and 30 November planting respectively. The best sowing time for long duration varieties (>140 days) was 15 and 30 November. Polythene covering for all time with round shape opening at both ends of the seedbed highly performed in terms of seedling dry weight and height.

Socio-economics and policy. Under stability analysis BRRI hybrid dhan7 (4.29 t/ha), BRRI dhan87 (5.68), BRRI hybrid dhan3 (8.96 t/ha) and BRRI dhan92 (8.12 t/ha) produced the highest yield in T. Aus 2021, T. Aman 2021, Boro 2021-22 (SD) and Boro 2021-22 (LD) respectively.

Technology transfer. A total of 150 demonstration trials were conducted under head to head (TRB-ARD project), SPIRA project and GoB funded programmes. Among the demonstration farmers' first preference was BRRI dhan71 (SD), BRRI dhan87, BRRI dhan94 (medium short duration) for T. Aman; BRRI dhan81 (SD), BRRI dhan89 (long duration) and BRRI dhan92 for Boro season due to their grain quality, panicle length and higher yield. Fourteen farmers' trainings and 11 field days were conducted in the block demonstration areas at Cumilla region. BRRI Cumilla also participated in two Krishimela, one agricultural fair and one development fair.

In total 91.417 tons of breeder and TLS seeds were produced during Aus, Aman and Boro 2021-22 seasons.

RESULTS

VARIETY DEVELOPMENT

Aman season. In B. Aman season, one entry performed better than the check varieties and and the heritability obtained from yield was 88%, indicating higher level of precision of this experiment in RYT (Hbj) and in early T. Aman season, due to excessive flood water ware of the entres performed well (Table 1) along with the check varieties in ALART (SW).

In T. Aman season, 25 crosses were made, 14 F1 were confirmed and considering improved plant type, earliness, acceptable grain quality and high yield potentiality 231, 596, 120 and 100 plants were selected from F2, F3, F4 and F5 generations respectively and 13 breeding lines were bulked from F6 generation. No entry performed better than the check varieties in AYT-Cum (WS). In RYT#1 (RLR), three genotypes (SVIN209, SVIN172, BR8492-9-5-3-2-HR1) performed better than the check varieties on the basis of yield and the heritability obtained from yield was 85%, indicating higher level of precision of this experiment. In RYT (ZER), two genotypes (BR10005-25-8-4-7-20 and BR10022-2-8-9-5-22) performed better than the check varieties on the basis of yield and the heritability obtained from yield was 86%, indicating higher level of precision of this experiment. In RYT#1(STR), three genotypes (BR11716-4R-108, BR11723-4R-12 and BR11716-4R-147) performed better than the check varieties and the heritability obtained from yield was 92%, indicating higher level of precision of this experiment. In RYT#2 (STR), five genotypes (BR11723-4R-172, BR11716-4R-102, BR11715-4R-186, BR11723-4R-27 and BR11716-4R-105) performed better than the check varieties and the heritability obtained from yield was 73%, indicating higher level of precision of this experiment. In MLT(DRR)-on station, BR10397-3-2-1-1-8 (Xa21) and BR10401-5-1-3-4-1 (Xa21) performed better than the check varieties and the heritability obtained from yield was 90%, indicating higher level of precision of this experiment. In MLT(DRR)- Debidwar, BR10397-3-2-1-1-8 (Xa21) performed better than the check varieties and the heritability obtained from yield was 85%, indicating higher level of precision of this experiment.

Table 1. Performances of entries in ALART, SW, E. T. Aman 2021.

Designation	GD (day)	PH (cm)	Yield (t/ha)
V1= BR10230-7-19-B	188	150	0.92
V2= BR9390-6-2-1B	190	142	1.38
V3= BR23 (ck)	209	128	1.01
V4= BRRI dhan91 (ck)	192	143	0.16
LSD (0.05)	0.59	4.25	0.22
Heritability	1.00	0.97	0.98

Location: Kochua, Chandpur DS: 16.05.2021 DT: 09.06.2021

Water levels in ALART, SW, E. T. Aman 2021 were 19 cm (06.07.21), 15cm (28.07.21), 40 cm (15.8.21), 48 cm (29.8.21), 50 cm (14.9.21), 75 (30.9.21), 65 cm (13.10.21), 35 cm (2.11.21).

Boro season: Thirty-one crosses were made, 16 F_1 were confirmed and 13,000 plant progenies were selected from F_2 generation. Considering earliness, strong culm, high yield potential, disease and insect resistance 2000, 14,000 and 25,000 plants were selected from F_3, F_4 and F_5 generation, respectively and 44 breeding lines were bulked from F_5 to F_6 generation. Based on high yield performance, disease reaction and other good agronomic characters 4 genotypes (BRC529-15-2-1-3, BRC535-11-1-2-1A, BRC539-17-1-1-1B, BRC550-23-1-1-1A) performed better than check varieties in OYT#1(Cum). Five (BRC471-1-1-1- B1, BRC471-1-1-2- B3, BRC472-19-1-1-B1, BRC477-2-1-4-B2, BRC480-14-1-1-B2) and three (BRC491-5-2-1-B1, BRC491-5-2-1-B2, BRC491-5-2-1-B3) entries were selected from PYT#1 and PYT#2 respectively. Three (BRC546-19-1-10, BRC468-14-3-2-10, BRC454-36-3-1-4-5) and three (BRC548-22-1-6, BRC468-7-1-3-3, BRC480-2-1-1-2) genotypes were selected from SYT#1 and SYT#2 respectively. Two (BR10604-5R-10, BR11318-5R-148), five (SVIN109, IR17A2433, BR8899-14-4-1-2-2-1, BR11318-5R-63, BR11337-5R-72), one (IR17A1694), four (IR17A2433, IR12A173, IR17A1694, IR17A1650), five (NGR 414-1, NGR 522-1, NGR 796-2, NGR 1161-3, NGR 1255-1), three (BR 11593-5 R-55, BR 11595-5 R-24, BR 11593-5 R-44), four (BR11607-4R-111, BR11600-4R-140, BR11607-4R-156, BR11607-4R-6), six (BR11604-4R-72, BR11607-4R-153, BR11600-4R-287, BR11604-4R-118, BR11604-4R-52, BR11607-4R-258), four (BR (Path)12454-BC2-71-91-6-23-26, BR (Path)12454-BC2-75-32-31-39-7, BR (Path) 12454-BC2-48-10-88-81-32, BR (Path) 12454-BC2-13-81-88-87-HR), five (BR (Path) 12454-BC2-56-81-27-3-30, BR (Path) 12454-BC2-69-97-39-5-44, BR (Path) 12454-BC2-71-91-6-23-26, BR (Path) 12454-BC2-48-10-88-81-32, BR (Path) 12454-BC2-13-81-88-87-HR), two (BR10182-5-4-2, BR9904-1-3-3), two (IR 108604-2-1-AJY 3-B-1, TP20532), two (BRH10-1-14-2-6B, BRH9-3-2B), two (BRH11-2-4-7B, BR10247-4-7-4B), 2 (BR10322-23-1-2-4, BR10322-23-6-3-7-B2) and one (BR(Bio)10381-AC1-2) genotypes performed better than the check varieties in RYT_FBR_LD, RYT_FRB_MD, RYT_FBR_SD (Table 2), RYT_AGGRiNet, RYT_Barishal, RYT (IRR_BPH), RYT#1 (DRR_BB), RYT#2 (DRR_BB), RYT#3 (DRR_Blast_on station), RYT#3 (DRR_Blast_Debidwar), RYT#1 (STR), RYT#2 (STR), RYT#1(SS) (Table 3), RYT#3(LS), RYT(PQR), RYT(Biotech) and no entries performed better than the check varieties in RYT(ZER).

Table 2. Performance of entries in RYT_FBR_SD, Boro 2021-22.

Designation	GD(day)	PH(cm)	Yield (t/ha)
IR17A1694**	142	87	6.71
BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR1(Gaz)-P8(Hbj)	135	80	6.04
BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR2(Gaz)-P11(Hbj)	Not germinated		
IR17A1723	141	79	5.70
BRRI dhan81 (ck)	141	83	6.21
BRRI dhan96 (ck)	Not germinated		
LSD (0.05)	2.76	15.76	0.83
Heritability	0.9	0.07	0.65

** selected entries DS: 18 Nov 2021 DT: 28 Dec 2021

Table 3. Performance of entries in RYT#1(SS), Boro 2021-22.

Designation	GD(day)	PH(cm)	ET	Yield (t/ha)
BRH10-1-14-2-6B**	142	103	11	6.45
BRH9-3-2B**	140	98	11	6.38
BRH13-1-9-7B	137	95	10	5.84
BRH17-23-8-2-7B	138	97	12	6.13
BRH13-2-4-7-2B	137	105	12	5.74
BRRI dhan28(Ck)	137	103	11	6.24
BRRI dhan81(Ck)	140	94	12	6.15
LSD(0.05)	1.2608	4.3143	ns	ns
Heritability	0.94	0.87	0.09	0.44

** selected entries DS: 16 Dec 2021 DT: 29 Jan 2022

Investigators: A K M Shalahuddin, I Zahan, N Jahan, A Islam, M R Islam and K M Iftekharuddaula

Table 4. Yield and agronomic performances of genotypes in preliminary yield trial (PYT), T. Aus 2021, BRRI RS, Cumilla.

Designation	**PH (cm)**	**GD (day)**	**Y (t/ha)**
BR11864-5R-84	103	114	4.48
BR11864-5R-80	105	106	4.40
BR11863-5R-295	107	111	4.13
BR11869-5R-15	108	111	4.41
BR11864-5R-63	108	111	4.12
BR11864-5R-60	104	120	4.35
BR11863-5R-82**	103	106	5.00
BR11869-5R-98**	107	105	4.74
BR11874-5R-40	111	105	4.57
BR11864-5R-12	104	114	4.66
BR11869-5R-89	108	116	4.36
BR11866-5R-186	111	106	4.31
BR11869-5R-275	110	113	4.40
BR11867-5R-323	91	115	4.45
BR11869-5R-133	104	105	4.38
BR11864-5R-16	106	115	4.06
BR11874-5R-64	110	109	4.27
BRR11864-5R-99**	105	116	4.85
BR11864-5R-68**	103	120	5.17
BR11863-5R-231	105	105	4.40
BR11864-5R-31	103	118	4.18
BR11863-5R-256**	106	115	5.42
BR11864-5R-40	103	115	4.69
BR11863-5R-110	105	106	4.30
BR11864--5R-17	107	116	4.66
BR11864-5R-38**	103	114	4.88
BR11869-5R-270	104	115	4.52
BR11863-5R-50	108	105	4.25
BR11869-5R-16	107	117	4.26
BR11863-5R-51	110	114	4.33

Designation	PH (cm)	GD (day)	Y (t/ha)
BR11863-5R-197	109	114	4.69
BR11864-5R-75**	102	113	5.33
BR11864-5R-11	105	114	4.50
BR11874-5R-49	110	105	4.35
BR11868-5R-2	117	111	4.33
BR11863-5R-237**	105	107	4.93
BR11864-5R-1	104	109	4.25
BRRI dhan48 (Ck)	104	109	5.15
BRRI dhan82 (Ck)	105	113	4.69
BRRI dhan98 (Ck)	104	111	5.07

performed better DS: 27 Apr 21 DT: 17 May 2021

TRB Project:

T. Aus season. Under Transforming Rice Breeding (TRB) Project, in OYT, 129 genotypes performed better out of 384 genotypes and gave yield more than 4.96 t/ha. In PYT, eight genotypes (BR11863-5R-82, BR11869-5R-98, BRR11864-5R-99, BR11864-5R-68, BR11863-5R-256, BR11864-5R-38, BR11864-5R-75 and BR11863-5R-237) performed better than the check varieties (Table 4).

In T. Aman season, 19 genotypes performed better than check varieties in OYT#1 (RLR), 65 genotypes performed better than the check varieties in OYT#2 (RLR), 59 genotypes performed better than the check varieties in OYT#3 (RLR), 73 genotypes performed better than the check varieties in OYT#4 (RLR). In OYT (DRR-BB), five genotypes (BR12098-4R-208-1, BR12098-4R-157-1, BR12098-4R-41-1, BR12098-4R-120-1 and BR12098-4R-185-1) performed better than the standard check varieties. In OYT (IRR-BPH), 65 genotypes produced more than 6.0 t/ha yield. In PYT (DRR-BB), two genotypes (BR11874-5R-109, BR11994-5R-15) produced higher yield than the check varieties. In AYT (IRR-BPH), 44 genotypes performed better out of 92 genotypes compared to check varieties. Under the BVE trial, 19 genotypes performed better out of 180 genotypes compared to the check varieties.

Investigators: A K M Shalahuddin, I Zahan, N Jahan, A Islam, M R Islam and K M Iftekharuddaula

In Boro season, 20 genotypes performed better than the check varieties in OYT_FBC, six (BR11660-5R-290, BR11640-5R-105, HRB205-33-17-8-B-4R, HRB-181-30-5-2-2R, BR9674-3-5-10-1 (1), FBC-2) genotypes performed better than check varieties in AYT_FBR_LATE, 14 genotypes performed better than the check varieties in AYT_FBR_EARLY, 14 genotypes performed better than the check varieties in OYT#1(DRR). In AYT#1(DRR), 12 genotypes performed better than the standard check varieties, in AYT#2(DRR), 11 genotypes performed better than the standard check varieties and in AYT#3(DRR), two (BR12096-4R-103-1, BR12096-4R-124-1) genotypes performed better than check varieties. In OYT(IRR_BPH), 30 entries performed better than the check varieties. In PYT_(IRR-BPH), 15 genotypes produced higher yield than the check varieties. In AYT (IRR_BPH), 28 genotypes performed better out of 60 genotypes compared to the check varieties. Under the BVE trial, 11 genotypes performed better out of 215 genotypes compared to the check varieties.

Investigators: A K M Shalahuddin, A Islam, M R Islam, PS Biswas, M Faruqee, M U Islam, PS Saha and M R Islam

AGGRi Alliance Project. In T. Aman season, eight genotypes (IR19A5050, IR19A6959, IR19A1850, IR19X1004, IR20X1008, IR15F1710, IR16F1097 and IR 96321-315-294-B-1-1-1-8-B) performed better out of 255 genotypes compared to the check varieties. In Boro season, Fifteen (IR14F690, IR20X1004, IR19A1862, IR19A2823, IR19A5012, IR19X1005, IR19A5447, IR19A2084, IR19A4985, IR19A5712, IR19A1146, IR19A3338, IR18T1340, IR19A3799, IR19A4828) performed better out of 265 genotypes compared to the check varieties.

Transferable Technology BRRI RS, Cumilla
Rice Tungro Disease Management Technology

Rice tungro disease management technology. Several experiments were conducted from 2018-19 to 2021-22 to develop a complete management package for preventing rice tungro disease devastation in Cumilla region. Preventive measure is the only way to control tungro disease devastation. Recommended rice tungro disease management technology is given below:

Chemical Control

1. Seedbed along with surroundings should be free from GLH by light trapping/hand sweeping/insecticide spray.

2. Spray registered systemic insecticide viz MIPC 2.6g /Cartap 2.4g /Carbaryl 3.4g / Chorpyriphos 2ml / Carbosulfan 2ml per litre water are the most effective) in the seedbed for 2 times control GLH. The season-wise spray times are as follows:

a) During Aus season, 10 days after seeding (DAS) and about 3-5 days before transplanting

b) During T. Aman season, 10-15 DAS and about 5 days before transplanting

c) During Boro season, 15-20 DAS and about 5 days before transplanting.

Mechanical Control

Five days interval hand sweeping along with light trap at night in the seedbed reduces the GLH population as well as the tungro disease infection in the main field.

Investigators: M M Rashid, M S Mian, M Hossain, S A I Nihad, M A I Khan, A Islam, MR Islam, M A Latif.

Survey and monitoring of rice diseases in selected areas during 2020-21. Digital disease survey was conducted in 565 spots of six Upazilas; Adarsha Sadar (151), Sadar Dakshin (12), Burichang (174), Debidwar (86), Laksham (52), Nangalkot (90) during T. Aman 2021 season and 373 spots of six Upazilas; Adarsha Sadar (79), Sadar Dakshin (90), Burichang (91), Debidwar (27), Laksham (39), Nangalkot (35), Barura (12) during Boro season in Cumilla district using ODK mobile Apps to know the present status of different rice diseases under various climatic environments**.** Disease incidence and disease severity data of major rice diseases were recorded following SES, IRRI 2013. During T. Aman 2021, neck blast disease was found predominant in the aromatic rice varieties. In case of BRRI dhan34 it was 27% DI, DS 9 and in kalijira 1% DI and DS 7. Rice tungro disease was found in BR22, BR23, BRRI dhan49, BRRI dhan71, BRRI dhan87, Binadhan-17, Hybrid Balia2, Hybrid oryzae, Hybrid Sonar Bangla varieties with % DI ranged from 10-72 and DS 5-7. The disease incidence of sheath blight, bacterial blight, false smut and brown spot were 20-90 (DS 3-9), 10-55 (DS 3-5), 1-11 (DS 1-3) and 27-43 (DS 1-2) respectively. During Boro 2021-22 season, major rice diseases neck blast, bacterial blight, sheath blight diseases were recorded as 1-90 % DI (DS 3-9), 5-80 % DI (DS 3-7) and 20-70 % DI (DS 3-7) respectively.

Investigators: M M Rashid, M Hossain, M A I Khan, T H Ansari, A Islam, M R Islam, M A Latif.

Validation of rice neck blast disease management technology under farmer’s field condition. Rice blast disease management technology (5 kg MOP/bigha additionally apply during last top dress of urea, spray Fungicide Trooper or Tricyclazole group fungicides @ 1 g/L water for 2 times as preventive 1st at split booting stage and 2nd at flowering stage in the evening was validated to build up farmers’ awareness on rice blast disease management and minimize yield loss in BRRI farm Cumilla and Ossodia, Nangalkot, Cumilla during T. Aman 2021 season using highly susceptible T. Aman rice variety BRRI dhan34. Neck blast disease got severe 95 % disease incidence (DI) in BRRI dhan34 at farmers practice compared to BRRI practice (2 % DI) at BRRI farm, Cumilla during T. Aman 2021 season. In the farmers field condition % DI was obtained 70-90 with DS 9. Rice yield loss was saved 69-88 % by managing neck blast disease following BRRI developed blast disease management technology in all the areas. In Boro 2021-22 season, 11 field demonstrations were conducted in the farmers’ field condition using highly susceptible BRRI dhan81 variety in Burichang, Sadar Dakshin and Nangalkot upazila of Cumilla. Farmers yield was saved 80-95% by protecting neck blast disease using rice blast management technology.

Investigators: M M Rashid, M Hossain, A Islam, M R Islam, M A I Khan, T H Ansari, M A Latif

CROP-SOIL-WATER MANAGEMENT

Effect of planting time on growth and grain yield of newly released rice varieties in T. Aman Season. An Experiment was conducted at BRRI RS, Cumilla farm in Aman 2021. Newly released four T. Aman varieties were tested against local check. The experiment was conducted to identify the optimum planting time and suitable variety for Cumilla region. During T. Aman 2021 four newly released varieties viz BRRI dhan75, BRRI dhan87, BRRI dhan90, BRRI dhan95 along with the check BR22 were evaluated in a time series of planting date (T1 = 05 Jul, T2 = 20 Jul, T3 = 5 Aug, T4= 20 Aug and T5= 5 Sep). Thirty- day-old seedlings were transplanted at 20 cm × 20 cm spacing. The experiment was laid down in Split-plot design with three replications where planting date was set in main plot and varieties in sub-plot. Fertilizer were applied N-P-K-S @ 76-20-42-9 kg/ha. All fertilizer except urea were applied as basal during final land preparation. Urea was applied as top dress in three equal splits at 12 DAT, 30 DAT ant 45 DAT respectively.

All varieties produced higher yield in planting time of 5 August. After 20 Aug, the yield of all tested varieties decreased sharply. Among all the varieties, BRRI dhan87 produced higher grain yield (5.43 t ha^{-1}) upto 5 august planting. Because of photosensitive nature growth duration of BR22 became longer in case of early transplanting. The growth duration of tested varieties exhibited decreasing trend with the advancement of planting dates. However, all the varieties except BRRI dhan90 displayed higher yield (t/ha) than BR22.

Effect of planting time on growth and grain yield of newly released rice varieties in Boro Season. In Boro 2021-22 season, BRRI dhan88, BRRI dhan89.BRRI dhan92 and BRRI dhan96 were tested and compared with the check varieties BRRI dhan28 and BRRI dhan29. Thirty-five-day-old seedlings were transplanted at 20 cm × 20 cm spacing. Fertilizer were applied @145-31-77-13-1.5 kg/ha N-P-K-S-Zn as Urea, DAP, MoP, gypsum and $ZnSO_4$. Boro varieties were transplanted from 20 December to 19 February with 15 days interval. BRRI dhan89, BRRI dhan92 and BRRI dhan29 produced higher grain yield within 156-159 days in first two planting times. BRRI dhan88, BRRI dhan96 and BRRI dhan28 showed expected higher yield with varying range of planting time. It was observed that the best Planting time for duration long varieties (>140 days) was the last week of December to the first week of January.

Investigators: T Ferdous, B Saha, MM Rashid, A Islam and MR Islam

Effect of potassium fertilizer management at different growth stages of BRRI dhan87 in T.Aman seaon.

A field experiment was conducted in T. Aman season of 2021 at BRRI RS Cumilla farm with one HYV rice variety BRRI dhan87 was grown with 110 kg ha^{-1} N and a basal dose of fertilizer at the rate of 20 kg^{-1} P, 09 kg^{-1} S and applied uniformly in all the plots and thoroughly incorporated into the soil at the time of final land preparation. Potassium in the form of MOP was applied in the experimental plots in different growth stages of rice: tillering, maximum tillering, panicle initiation stage i.e. 15, 30 and 50 DAT. The experiment was laid out in a randomized block design with three replications. Unit plot size was 15 m^2. Thirty-day-old seedlings were transplanted on 7 August 2021 maintaining two to three seedlings in each hill. Seedlings were transplanted in rows 20 cm apart and the distance between the hills was 20 cm. Intercultural operations and plant protection measures were taken as and when necessary. Ten hills from each plot were selected randomly prior to harvest for recording data on crop characters and the yield was estimated from the harvest of whole plot.

Effect of additional application of potassium @ 20 $kgha^{-1}$ in three different growth stages with varying combination, on plant height (cm), panicle

m^{-2}, grains panicle^{-1}, thousand grain weight, grain yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest index were studied. An increased application of potassium from 0 to 102 kg ha^{-1} increased the number of panicle m^{-2} and increased grain yield over the untreated control. Though the highest number of grains panicle^{-1} was observed in split application of potassium in 15, 30 and 50 DAT (T8), grain yield was also significantly the highest (5.58 t ha^{-1}) in this treatment.

Effect of potassium fertilizer management at different growth stages of BRRI dhan88 in Boro season. In Boro season, BRRI dhan88 was tested for additional dose of K@20 kgha^{-1} in three different growth stages with varying combination. The experiment was laid out in a randomized block design with three replications. Unit plot size was 15 m^2. Thirty-five-day-old seedlings were transplanted maintaining two to three seedlings in each hill. with 20 cm × 20 cm spacing. An increased application of potassium from 0 to 137 kg ha^{-1} increased tiller m^{-2}, number of panicle m^{-2} and increased grain yield over the control. The highest number of grains panicle^{-1} was observed in T9 where potassium was applied basally as well as additional application at maximum tillering and panicle initiation stage. Grain yield was also significantly higher (7.07 tha^{-1}) in this treatment.

Potassium application significantly increased the number of filled grains panicle^{-1}, 1000-grain weight grain yield and harvest index. Basal application along with two additional application of potassium showed superiority over split application of 1, 2 and 4 additional applications.

Investigators: T Ferdous, B Saha, M M Rashid, A Islam and M R Islam

Long-term missing element trial at BRRI RS, Cumilla 2020-21. The experiment was conducted to assess long-term yield trend of rice under different nutrients managements. For this trial, six fertilizer treatments viz T_1= N omission (-N), T_2= P omission (-P), T_3= K omission (-K), T_4= S omission (-S), T_5= Zn omission (-Zn) and T_6= NPKZnS (STB) were imposed in the subplots and rice varieties in the main plots following split-plot design with three replications in T. Aman season. During Boro 2021-22, seven fertilizer treatments viz T_1= N-P-K-S-Zn (all), T_2 = N omission (-N), T_3 = P omission (-P), T_4 = K omission (-K), T_5 = S omission (-S), T_6 = Zn omission (-Zn) and T_7 = N-P-K-S-Zn (all missing) were imposed following RCBD design with three replications. Fertilizer doses were NPKSZn @ 110-15-42-9-1.5 kg/ha in T. Aman and NPKSZn @ 145-31-77-13-1.5 kg/ha in Boro season respectively. Twenty-five-day-old seedlings of BRRI dhan87, BRRI dhan93 and BRRI dhan94 and forty-day-old seedlings of BRRI dhan88 were transplanted at 20 cm × 20 cm spacing during T. Aman 21 and Boro 21-22 season respectively.

In T. Aman 2021, BRRI dhan87, BRRI dhan93 and BRRI dhan94 produced 5.39, 5.00 and 5.22 t/ha grain yield, respectively with NPKZnS fertilizers. However, yield differences of P missing plots were found significant among the tested three varieties viz BRRI dhan87, BRRI dhan93 and BRRI dhan94. On the other hand, omission of N from complete treatment had a significant effect on grain and straw yield of tested varieties indicating that a soil test based dose of fertilizer is enough for these varieties.

In Boro 2020-21, BRRI dhan88 produced the highest grain yield (6.35 t/ha) with NPKZnS fertilizers and the lowest grain yield (3.82 t/ha) with all missing element fertilizers. On the other hand, omission of N from complete treatment had a significant effect on grain yield (4.54 t/ha) and straw yield (5.57 t/ha) among the treatments indicating that a maintenance dose of fertilizer was enough for this variety.

Investigators: B Saha, T Ferdous, M M Rashid, A Islam

Effects of P rates on the yield of BRRI released new variety in BRRI Farm Cumilla

The experiment was conducted to update the P rates of BRRI released new varieties in BRRI farm Cumilla. Five doses of P (0, 10, 20, 30 and 50 kg/ha) were tested with BRRI dhan87 in T. Aman 2021 and BRRI dhan88 in Boro 2021-22 season. The experimental design was RCB with three replications. Twenty-five-day-old seedlings in T. Aman season and thirty-nine-day-old seedlings in Boro season were transplanted maintaining 20×20 cm spacing. Data on yield parameter were recorded at harvesting stage.

In T. Aman season, 20 kg/ha rate of P produced the highest grain yield (6.01 t ha-^{1}) and 30 kg/ha rate of P produced the highest grain yield (6.01 t ha-^{1}) during Boro 2021-22 season. Grain yield was increased with the increasing rate of phosphorus up to a level and then produced the statistically similar grain yield.

Investigators: B Saha T. Ferdous, M M Rashid, A Islam

SOCIO-ECONOMIC AND POLICY

Stability analysis of BRRI developed rice varieties. During T. Aus 2021, T. Aman 2021 and Boro 2021-22, a total of 13, 47 and 47 varieties, respectively were evaluated to determine the stability index at BRRI RS, Cumilla. Around 20, 25 and 35-day-old seedlings were used in the respective seasons. The experiment was laid out in RCB design with three replications. During Aus 2021 season, among the 13 varieties, BRRI hybrid dhan7 (4.29 t/ha) produced the highest yield followed by BRRI dhan85 (3.60 t/ha). Growth duration of those varieties was found 109 and 110 days respectively. During T. Aman 2021 season, among the 47 varieties BRRI dhan87 (5.68 t/ha) produced the highest yield followed by BRRI hybrid dhan6 (5.67 t/ha), BRRI dhan52 (5.63 t/ha) and BRRI dhan94 (5.57 t/ha)**.** Growth duration of those varieties ranged from 118-140 days. During Boro 2021-22, in short durational varieties, BRRI Hybrid dhan3 produced the highest yield (8.96 t/ha) followed by BRRI hybrid dhan2 (8.20 t/ha), BRRI dhan67 (7.85 t/ha) and BRRI dhan96 (7.81 t/ha). In long durational varieties, BRRI dhan92 produced highest yield (8.12 t/ha) followed by BRRI dhan89 (7.93 t/ha), BRRI dhan69 (7.69 t/ha) and BRRI dhan99 (7.09 t/ha).

Investigators: A K M Shalahuddin, T Husna, A Islam and M R Islam

TECHNOLOGY TRANSFER

Varietal dissemination through field demonstration (GoB). In Aus 2021 season 43 field demonstrations of BRRI dhan58, BRRI dhan85, BRRI dhan98 and two block demonstrations were conducted. BRRI dhan98 the highest yield displayed (5.30 t/ha^{-1}).

During T. Aman 2021 season, 141 field demonstrations were conducted in different upazilas of Cumilla region. The yield range of BRRI dhan75, BRRI dhan87, BRRI dhan90, BRRI dhan93 and BRRI dhan95 were 4.01-5.34, 3.74-6.65, 3.75-4.04, 3.81-6.30 and 3.51-6.26 t/ha respectively. Farmer's acceptance of BRRI dhan87 and BRRI dhan95 was found very high in those respective areas for their grain size, panicle length and high yield. The highest grain yield was observed in BRRI dhan93 (6.30t/ha) followed by BRRI dhan95 (6.26t/ha).

In Boro 2021-22 season, 400 field demonstrations (1 bigha each) of newly released BRRI dhan74 and BRRI dhan81, BRRI dhan84, BRRI dhan86, BRRI dhan88, BRRI dhan89, BRRI dhan92, BRRI dhan96 and Bangabandhu dhan100 was conducted in 34 upazilas of Cumilla, Brammanbaria and Chandpur districts. The yield range of BRRI dhan74, BRRI dhan81, BRRI dhan86, BRRI dhan88, BRRI dhan89, BRRI dhan92, BRRI dhan96 and Bangabandhu dhan100 were 3.86-7.27, 3.69-7.52, 3.95-6.56, 4.63-7.52,4.42-8.16,4.66-9.17 and 4.40-7.55 t/ha respectively.

Investigators: T Ferdous, B Saha, M M Rashid, A Islam and M R Islam

Varietal dissemination through field demonstration (Kormosuchi): In total 60 field demonstrations were conducted in different upazilas of Cumilla region during Boro 2021-22 season. In cumilla district the maximum yield was recorded in BRRI hybrid dhan3. BRRI dhan92 performed better than the other in all the three districts of Cumilla region.

Investigators: M M Rashid, B Saha , T Ferdous, A Islam and M R Islam

Varietal replacement through Head to Head (HTH) Trial (TRB-BRRI project. During

T. Aman 2021 season, six HTH trials with nine rice varieties and during Boro 2021-22, six HTH trials with 11 varieties were conducted to test the adaptability and replacement ability of newly released rice varieties in Cumilla, Brahmanbaria and Chandpur districts. Seedling age was 20-25 and 35-40 days for the respective seasons. One bigha of land was used for each trial. Among the tested T. Aman varieties, in HTH (SD) BRRI dhan71 produced the highest yield (up to 5.57 t/ha) followed by BRRI dhan75 (up to 4.92 t/ha), Binadhan-17 (up to 4.45 t/ha) and Binadhan-22 (4.43 t/ha). In HTH (LD) BRRI dhan93 produced the highest yield (up to 7.37 t/ha) followed by BRRI dhan87 (up to 6.87 t/ha), BRRI dhan95 (up to 6.27 t/ha), BRRI dhan94 (up to 6.00 t/ha) and BRRI dhan80 (up to 5.65 t/ha). Among the tested Boro varieties, in HTH (SD) BRRI dhan74 produced the highest yield (upto 7.20 t/ha) followed by Bangabandhu dhan100 (up to 7.52 t/ha), BRRI dhan28 (up to 7.23 t/ha), BRRI dhan88 (up to 7.06 t/ha), BRRI dhan81 (upto 6.66 t/ha) and BRRI dhan84 (upto 6.29 t/ha). In HTH (LD) BRRI dhan89 produced the highest yield (up to 8.15 t/ha) followed by BRRI dhan29 (up to 7.30 t/ha), BRRI dhan92 (up to 7.34 t/ha), Binadhan-24 (upto 7.43 t/ha) and BRRI dhan58 (up to 7.76 t/ha). Farmers' first preference was BRRI dhan71 in HTH (SD) and BRRI dhna93 and BRRI dhan87 in HTH (LD) for T. Aman season. Farmers' first preference was BRRI dhan74 and Bangabandhu dhan100 in HTH (SD) and BRRI dhna89 and BRRI dhan29 in HTH (LD) for Boro season.

Investigators: A K M Shalahuddin, I Zahan, N Jahan, A Islam and M R Islam

Farmer's training, field day and fair. 25 farmers' trainings were conducted in different locations of Cumilla region. A total of 675 farmers and 75 Sub-Assistant Agricultural Officers were trained up. Two field days were conducted in the block demonstration areas Cumilla region. About 300 farmers as well as extension personnel's were attended in the field days. Most of the farmers got interested to cultivate new rice varieties in their areas specially BRRI dhan87, BRRI dhan88, BRRI dhan89, BRRI dhan92 and BRRI dhan96. BRRI RS, Cumilla also participated in development fair.

Investigators: T. Ferdous, B Saha, A K M Shalahuddin, M M Rashid, A Islam and M R Islam

Seed production. During Aus 2021 season, 2.445 ton TLS seed (BRRI dhan82, 85, 98) and in T. Aman 2021 season, 3.58 ton breeder seed (BRRI dhan49, 93, 94, 95) and 7.812 tons TLS seeds (BR22, BRRI dhan48, 34, 49, 87, 91, 93, 94, 95, Bangabandhu dhan100) were produced. During Boro 2021-22, 40.35 ton breeder seeds (BR23, BRRI dhan28, 29, 58, 74, 88, 89, 92, 96, Bangabandhu dhan100) 7.23 ton TLS seeds (BRRI dhan28, 29, 58, 74, 81, 84, 86, 88, 89, 92, 96, Bangabandhu dhan100) were produced in BRRI RS, Cumilla farm and 30.00 ton TLS seeds (BRRI dhan88, 96, 89, 92 and Bangabandhu dhan100) were purchased from farmers which was funded by MoA.

BRRI RS, Habiganj

SUMMARY

Two advanced yield trials (AYT) and one regional yield trial (RYT) for the deep-water ecosystem were conducted at BRRI RS, Habiganj during B. Aman 2021-22. Sixteen RYTs were conducted at BRRI RS, Habiganj during Boro 2021-22. Two muti-location trials for disease resistance rice (DRR) were conducted in the farmers' fields of Baniachong, Habiganj during Boro 2021-22. An IIRON trial consisting of 38 entries along with two check varieties, BRRI dhan28 and BRRI dhan29 were evaluated at BRRI RS, Habiganj farm during Boro 2021-22. Ten genotypes were selected for the AYT.

Screening of pre-harvest sprouting of some newly released BRRI varieties was done at BRRI RS, Habiganj. On the basis of germination percentage, BRRI dhan50, BRRI dhan60, BRRI dhan69, BRRI dhan86 and BRRI dhan89 were found highly susceptible to pre-harvest sprouting, in which a minimum of one fourth of the spikelets of a panicle were germinated at 80% maturity stage.

Monitoring of insect pest and natural enemy incidence by using light trap was recorded during the reported period. The highest peaks of YSB and GLH were observed in April and May. Among the natural enemies, ladybird beetle (LBB) populations were found to be the highest, followed by carabid beetle (CBB), damselfly, and dragonfly.

A disease survey was conducted in Habiganj during Boro 2021-22 on the dates from 20 to 22 April 2022. The brown spot incidence (30.0%) was predominant, followed by leaf blast and sheath blight, and their incidence levels were 7.56 and 6.04%, respectively. The severity score of brown spot, leaf blast, and sheath blight was 2.50, 3.25, and 4.33 respectively.

Stability analysis of BRRI released Boro varieties was conducted at BRRI RS, Habiganj during Boro 2021-22. The variety BRRI dhan55 yielded the highest, which was 7.9 t/ha with a growth duration of 155 days. It was closely followed by BRRI dhan92 and BRRI dhan74. Both the varieties produced 7.1 t/ha with a growth duration of 155 and 148 days, respectively.

One ALART during T. Aman 2021-22 and five ALART during Boro 2021-22 were conducted at the farmers' field. One genotype BRBa 3-2-4 from ALART-FBR was recommended for further testing due to higher yield and less disease and insect infestation.

VARIETAL DEVELOPMENT PROGRAM AREA

Advanced Yield Trial (AYT)

Two AYTs for deep water ecosystem were conducted at BRRI RS, Habiganj during B. Aman 2021-22. AYT-Advanced Genotype, comprising eight advanced deep water rice genotypes along with two checks Hbj.A-IV and Hbj.A-I were evaluated. Grain yield of the genotypes ranges from 0.86 to 1.38 t/ha. Three deep water rice genotypes BR7735-1-1-2B (1.32 t/ha), BR7733-2-1-2B (1.38 t/ha) and BR7737-1-2-2B (1.41 t/ha) produced higher grain yield than the checks Hbj.A-IV and Hbj.A-I. In AYT-Local Genotype, nine promising local deep water rice entries were evaluated. All the genotypes produced almost similar grain yield ranging from 0.61-1.18 t/ha.

Regional Yield Trial (RYT), B. Aman 2021-22

One RYT for deep water ecosystem was conducted at BRRI RS, Habiganj during B. Aman 2021-22. Three genotypes along with the standard check BRRI dhan91 and one local check (Dud Laki, Balam, Lal laki, Hijaldigha) in each trial were evaluated at four locations of Habiganj, Cumilla, Gazipur and Bhanga. One genotype BR7730-1-1-2B produced the highest grain yield at Habiganj (1.36 t/ha) and Cumilla (1.59 t/ha). The breeding line BR7919-1-1-3B produced the highest grain yield (1.93 t/ha) at Bhanga. In Gazipur, the standard check BRRI dhan91 produced the highest grain yield. Over the locations, one advanced breeding line BR7730-1-1-2B produced the similar grain yield but 10 days earlier than the standard check BRRI dhan91 and produced higher grain yield than the local checks.

Regional Yield Trial (RYT), Boro 2021-22

A total of 16 RYTs were conducted during Boro 2021-2022.

RYT-FBR, Boro 2021-22. Four RYTs for favorable Boro rice (FBR) were conducted. In RYT-FBR_SD, four entries along with two checks BRRI dhan81and BRRI dhan96 were evaluated. But, one genotype BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR2(Gaz)-P11(Hbj) and the check BRRI dhan96 were not included in the trial due to germination failure. The two genotypes IR 17A1723 (6.37 t/ha) and IR 17A1694 (6.81 t/ha) produced the higher grain yield than the check BRRI dhan81 (5.81 t/ha). In RYT-FBR_MD, a total of 13 entries along with the two checks BRRI dhan81 and BRRI dhan96 were evaluated. The genotype SVINI09 (8.37 t/ha) produced the higher yield with similar growth duration than the check varieties BRRI dhan81 (6.61 t/ha) and BRRI dhan96 (7.34 t/ha). The four genotypes namely BR11342-5R-23 (7.46 t/ha), BR11337-5R-72 (7.59 t/ha), BR10317-5R-57 (6.60 t/ha) and BR10601-5R-74 (7.74 t/ha) produced the similar grain yield with the check BRRI dhan96 (7.34 t/ha) but produced the higher grain yield than the check BRRI dhan81 (6.61 t/ha). In RYT-FBR_LD, a total of nine entries along with two checks BRRI dhan89 and BRRI dhan92 were evaluated. One genotype BR11318-5R-84 (7.20 t/ha and 169 days) produced similar grain yield and took two days duration longer to mature than the check variety BRRI dhan89 (7.20 t/ha and 167 days) but produced the higher grain yield than the check variety BRRI dhan92 (6.37 t/ha). Three genotypes namely BR11318-5R-10 (6.41 t/ha), BR11318-5R-148 (6.61 t/ha) and BR11318-5R-148 (6.75 t/ha) produced similar grain yield but 3-9 days shorter growth duration than the check variety BRRI dhan92 (6.37 t/ha). In RYT_FBR-Bio, two entries along with the two checks were grown. None of the entries performed better than the check varieties BRRI dhan88 and BRRI dhan96. In **RYT-Barishal**, ten advanced breeding lines along with the two check varieties BRRI dhan58 and BRRI dhan89 were evaluated. The three genotypes NGR 521-2 (7.17 t/ha), NGR 1255-1 (7.31 t/ha) and NGR 750-1 (7.41 t/ha) produced grain yield similar to the check variety BRRI dhan89 (7.13 t/ha) but produced higher grain yield than the check BRRI dhan58 (6.59 t/ha). Two genotypes NGR 796-2 (6.83 t/ha) and NGR 414-1 (6.97 t/ha) produced the similar grain yield with the check BRRI dhan58 (6.59 t/ha).

In RYT-AGGRiNET, a total of seven entries along with four checks BRRI dhan63, BRRI dhan81, BRRI dhan89 and BRRI dhan92 were evaluated. Two genotypes IR 17A2241 (7.13 t/ha) and IR 17A1694 (6.78 t/ha) produced higher yield than all the check varieties (5.83-6.44 t/ha). The genotype IR 12 A 173 (6.72 t/ha) produced the similar grain yield with the check BRRI dhan89 (6.44 t/ha) but produced higher yield than the check BRRI dhan63, BRRI dhan81 and BRRI dhan92. In **RYT-Zinc,** two entries along with three check varieties BRRI dhan29, BRRI dhan74 and BRRI dhan84 were evaluated. The genotype BR9674-4-2-10-5-P9 (7.25 t/ha) produced the higher grain yield than all the checks (6.33-6.76 t/ha and 156 days). The genotype BR9674-1-1-5-1-P3 (6.81 t/ha) produced similar grain yield with the checks BRRI dhan29 (6.76 t/ha) and BRRI dhan74 (6.57 t/ha) but produced the higher grain yield than the check BRRI dhan84 (6.33 t/ha). In RYT-PQR #LS, a total of three entries along with BRRI dhan28 were evaluated. The two genotypes BR10247-4-7-4B (6.46 t/ha and 147 days) and BRH 11-2-4-7B (6.70 t/ha and 159 days) produced higher grain yield and took 2-4 days longer duration than the check BRRI dhan28 (6.04 t/ha and 155 days). The RYT-PQR #SS comprised with five entries along with two checks BRRI dhan28 and BRRI dhan81. None of the entries out performed the check varieties BRRI dhan28 and BRRI dhan81. But, the genotype BRH10-1-14-2-6B (6.24 t/ha and 155 days) produced the grain yield and growth duration similar to the check varieties BRRI dhan28 (6.14 t/ha and 155 days) and BRRI dhan81 (6.09 t/ha and 155 days).

In RYT-CTR, nine entries including three checks BRRI dhan67, BRRI dhan89 and BRRI dhan92 were evaluated. None of entries performed better than the check varieties BRRI dhan89 and BRRI dhan92. The two genotypes BR 11894-R-R-R-R-309 (6.72 t/ha) and BR 11894-R-R-R-R-80 (7.09 t/ha) produced similar grain yield the check BRRI dhan67 (6.65 t/ha). Two RYTs were conducted for salt tolerance rice. In RYT-STR_1, eight entries along with the three checks BRRI dhan67, BRRI dhan89 and BRRI dhan97. None of the entries out performed the check varieties BRRI dhan89 and BRRI dhan97. The genotype BR9904-1-3-3 (7.19 t/ha and 164 days) produced the higher grain yield but with eight days longer growth duration than the check BRRI dhan67 (6.69 t/ha and 156 days). The genotype BR9901-1-3-

10 (7.27 t/ha and 156 days) produced the higher grain yield and similar growth duration with the check BRRI dhan67 (6.69 t/ha and 156 days). The genotype BR 10187-1-5-11 (6.82 t/ha and 157 days) produced the similar grain yield and growth duration with the check BRRI dhan67 (6.69 t/ha and 156 days). Under RYT-STR_2, a total of nine entries along with the three checks BRRI dhan67, BRRI dhan89 and BRRI dhan97 were evaluated. None of the entries performed better than the checks. The genotype TP30629 (7.04 t/ha and 150 days) produced the similar grain yield but six days earlier than the check BRRI dhan67 (6.91 t/ha and 156 days).

Three RYTs were conducted under disease resistance rice (DRR). The RYT#BB-1 consisted a total of twelve entries along with two checks BRRI dhan88 and IRBB60. The genotype BR11600-4R-140 (6.98 t/ha) produced the highest grain yield than the checks BRRI dhan88 (6.15 t/ha) and IRBB60 (5.44 t/ha). The four genotypes namely BR11607-4R-79 (6.29 t/ha), BR11607-4R-42 (6.32 t/ha), BR11600-4R-82 (6.36 t/ha) and BR11600-4R-105 (6.43 t/ha) produced similar grain yield with the check BRRI dhan88 (6.15 t/ha). In RYT#BB-2, fourteen entries along with the three checks BRRI dhan58, BRRI dhan89 and IRBB60 were evaluated. The genotype BR11607-4R-153 (7.39 t/ha and 163 days) produced similar grain yield and growth duration to the check variety BRRI dhan89 (7.21 t/ha and 162 days). The genotype BR11607-4R-2 (7.12 t/ha) produced higher grain yield but took eight days longer duration than the check variety BRRI dhan58 (6.62 t/ha and 158 days). The RYT# Blast was conducted with seven entries along with two checks. None of the entries outperformed the check varieties BRRI dhan29 and BRRI dhan89. The RYT-BPH Resistance was conducted with seven entries along with the three check varieties BRRI dhan58, BRRI dhan88 and T27A were grown. Two genotypes BR11593-5 R-79 (6.85 t/ha) and BR11593- 5 R-70 (6.87 t/ha) produced the higher yield than all the check varieties (4.83-6.53 t/ha). The genotypes BR 11595-5 R-24 (6.68 t/ha) and BR 11593-5 R-44 (6.54 t/ha) produced similar grain to with the check BRRI dhan58 (6.53 t/ha) but produced higher yield than the check BRRI dhan88 and T27A. The genotype BR11593-5 R-73 (6.51 t/ha) produced higher grain yield than the check BRRI dhan88 (5.90 t/ha).

Multi-location trial (MLT), disease resistance rice (DRR). Two MLT for DRR was conducted in the farmers field of Nagura, Baniachong, Habiganj during Boro 2021-22. The MLT # Blast+BLB consisted eight genotypes along with three checks BRRI dhan29, BRRI dhan58 and BRRI dhan88. The genotype BR (Path)13800-BC3-109-181 performed better than all the check varieties. In MLT#Blast, seven genotypes along with two checks BRRI dhan29, BRRI dhan89 were evaluated. None of the tested entries performed better than the check BRRI dhan89. But, the genotype BR (Path)12454-BC2-69-97-39-5-44 produced higher grain yield than the check BRRI dhan29.

International Irrigated Rice Observational Nursery (IIRON)

A total of 38 entries along with two checks BRRI dhan28 and BRRI dhan29 were evaluated at BRRI RS. Habiganj farm during Boro 2021-22. Two genotypes SV2017 (7.27 t/ha) and SV0916 (7.24 t/ha) produced similar grain yield with the checks BRRI dhan28 (6.91 t/ha) and BRRI dhan29 (7.24 t/ha). Eight entries IRRI199, SV1084, SV0914, SV1072, SV1075, SV1074, SV2007 and SV2021 (6.95-7.20 t/ha) produced the similar grain yield with the check BRRI dhan28 (6.91 t/ha).

CROP-SOIL-WATER MANAGEMENT

Screening of pre-harvest sprouting of some newly released BRRI varieties

Thirty-six BRRI varieties were evaluated to investigate pre harvest sprouting (PHS) of spikelet. At the research field, artificial condition was created to sprout the seed by wrapping the selected panicle with wet cloth at 50 and 80% maturity stage for seven days. After seven days, the panicles were harvested and counted the germinated spikelet. Based on germination percentage BRRI dhan50, BRRI dhan60, BRRI dhan69, BRRI dhan86 and BRRI dhan89 were found highly susceptible to pre-harvest sprouting of which minimum one fourth of the spikelet of the panicles were germinated at the 80% maturity stage.

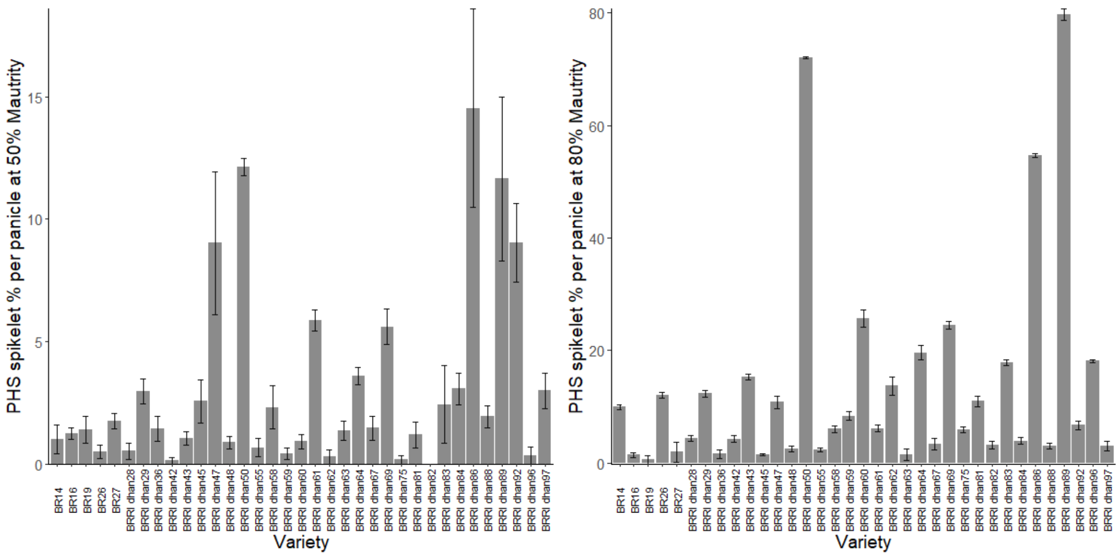


Fig.1. Pre-harvest sprouting spikelet percentage at the 50 and 80% maturity.

Long-term missing element trial for diagnosing the limiting nutrient in soil

Long term experiments were initiated at BRRI RS, Habiganj farm in 2007-08 to identify the yield limiting nutrient (s). The experiment was conducted with eight treatments in RCB design with three replications. The treatments were- T_1= NPKS (Complete), T_2 =PKS (-N), T_3= NKS (-P), T_4= NPS (-K), T_5= NPK (-S), T_6= KS (-NP), T_7= PS (-NK) and T_8= all missing (-NPKS). Boro 2021-22 was the 14th year continuation of this experiment. NPKSZn @ 120-38-50-9-3 kg ha^{-1}, respectively were used. Tested cropping pattern was Boro-Fallow-Fallow. BRRI dhan92 was used as a test crop. Balance fertilizer treatment (NPKSZn) showed significantly higher grain yield and yield parameters of rice. The highest panicle m^{-2} was obtained with balanced fertilized (T_1) plot followed by other omission plots. The highest grain yield was obtained in T_1 (7.55 t ha^{-1}) followed by T_5 (7.12 t ha^{-1}). The N and K omission treatment (T_2 and T_4) produced significantly lower yield (6.02-6.47 t ha^{-1}) than the other treatments. From the experiment, it may be concluded that, besides N, K and NK is the most yield limiting nutrient element in BRRI Habiganj farm (Table 1).

Table 1. Effects of nutrient element omission from the complete treatment on grain yield of BRRI dhan92, Boro 2021-22, Habiganj.

Treatment	Panicle m^{-2}	Grain yield (t ha^{-1})
T_1 (NPKSZn)	375	7.55
T_2 (-N)	285	6.02
T_3 (-P)	340	7.08
T_4 (-K)	335	6.47
T_5 (-S)	356	7.12
T_6 (-NP)	350	6.96
T_7 (-NK)	320	6.88
T_8 (All missing)	222	5.65
$LSD_{0.05}$	7.50	0.32

T_1= NPKS (Complete), T_2= PKS (-N), T_3= NKS (-P), T_4= NPS (-K), T_5= NPK (-S), T_6= KS (-NP), T_7= PS (-NK) and T_8= All missing (-NPKS)

Influence of nitrogen and potassium rates on performance of modern rice

The objectives of the present study were to find out suitable ratio of N and K for MV rice cultivation, and N and K dynamics in soil and plant. The experiments were conducted at BRRI RS farm, Habiganj during Boro 2021-22. Five doses of K (0, 50, 100, 150 and 200 kg ha^{-1}) in the main plot and four doses of N (0, 100, 120 and 140 kg/ha) in the subplots were tested with BRRI dhan92. The experiment design was split-plot with three replications. Phosphorus and S was applied as blanket dose. Forty-five-day-old seedlings were transplanted maintaining 20 cm × 20 cm spacing. Grain yield was recorded at 14% moisture content. The results showed that in potassium deficient condition, application of increasing N significantly decreased grain yield, whether in N deficient condition, K rates were not responsible for increased grain yield. Application of N @ 140 kg ha^{-1} with 50 kg K ha^{-1} produced significantly higher grain yield (8.49 t ha^{-1}) than the other combinations of N and K fertilization (Table 2).

Table 2. Effect of N and K rates on grain yield (t ha^{-1}) of BRRI dhan92, Boro 2021-22, BRRI RS, Habiganj.

K dose (kg ha^{-1})	N dose (kg ha^{-1})			
	0	100	120	140
0	6.03c B	6.46 c A	6.72 c A	6.78 c A
50	6.50 b D	7.22 b C	7.57 a B	8.19a A
100	6.00 c C	7.60 a B	8.02 a A	8.04 a A
150	7.00 a B	7.70 a A	7.00 bB	6.77 b B
200	7.02 a B	7.69 a A	7.57 a A	7.01 b B
CV (%)	4.41			

Means with same lowercase letter in a column and same uppercase letter in a row are not significantly different at the 5% level of probability

Greenhouse gas emission and global warming potential under organic amendment at Kushtia region

Field experiment was conducted at farmer's field, Kushtia in 2021-22 in collaboration with BRRI RS, Kushtia. Treatments were; chemical fertilizers Farmers practice, (NPKSZn), cow dung (CD) and vermicompost (VC) as integrated plant nutrient system (IPNS) based inorganic fertilizations. The static closed-chamber method were used to measure CH_4, CO_2 and N_2O emission rates during T. Aman season. Results revealed that VC fertilization treatment decreases GHG and GWP than CD treatment. The CD significantly increased total CH_4, N_2O and GHGI about 38% and GWP around 31% of VC fertilization with Boro rice cultivation (Table 3). There was also significant difference of rice yield between organic amendment and chemical fertilization systems in Boro season (Table 3). It can be concluded that the VC organic manure could be useful for soil management strategy to reduce about 28 % of GHGI, 24% of GWP and increase about 6% of rice yield than that of CD.

Table 3. Yield, GHG intensity and GWP with Boro rice season under organic amended rice soil.

Treatment	Yield and GHG intensity (kg ha^{-1})		Global warming potential (kg CO_2 eq. ha^{-1})
	Yield	GHGI	
Farmers practice	6200	1.17	7249
NPKSZn	6500	1.05	6813
Cowdung with IPNS	7200	1.50	10767
Vermicompost with IPNS	7600	1.08	8231
$LSD_{0.05}$	210.10	0.14	533

Greenhouse gas emission and global warming potential as influenced by water management in rice cultivation

In this study we evaluated the hypothesize that vermicompost organic fertilizer under varied water management options greatly influences green house gas (GHG) emission patterns and global warming potential (GWP). The experiment was conducted at the experimental farm of BRRI HQ, Gazipur during January to May 2022 in collaboration with Soil Science Division. Incorporation of vermicompost into soil was as integrated plant nutrient system (IPNS) under different water management systems. We have used RCB design with three replications for imposing treatments in 4 m X 5 m plots. BRRI dhan92 was grown as irrigated rice culture. Three water management systems were applied; continuous flooding (CF), alternate wetting and drying (AWD) with 15 cm and Irrigation suspension at 20-40 days after transplanting (DAT) with AWD (ISAWD). In CF, plots were kept flooded until harvesting and in AWD, plots were irrigated when water level fell below 15 cm. In ISAWD, there was 5-7 cm water up to 20 DAT and no water was applied after 20-40 DAT and then using AWD system before harvesting. Four perforated PVC pipes were installed with 15 cm depth for monitoring water depth in the AWD and ISAWD plots. We followed standard gas sampling techniques for recording N_2O and CH_4 emission patterns.

The results showed that CH_4 emission pattern was significantly lower with AWD and ISAWD treatment than CF irrigation system. However, N_2O emission pattern was lower under CF than other water management. The total CH_4 flux were 250-152-155 kg ha^{-1} under CF-AWD-ISAWD irrigation system and N_2O flux were 0.23-0.64 kg ha^{-1} under different water condition during the study period (Table 4). The AWD and ISAWD irrigation systems significantly reduced total CH_4 fluxes by 61-62% over CF. The AWD and ISAWD irrigation system was mainly responsible for increased total N_2O fluxes by 143% and 178% over CF system, respectively. The AWD and ISAWD irrigation system significantly reduced about 62-64% of total GWP and 64-75% of GHG intensity than continuous flooding because of reducing CH_4 emission rates (Table 4). Grain yield was not different among the AWD and CF system.

Table 4. Total GHG and GWP under varying irrigation management during Boro 2021-22.

Treatment	Greenhouse gas emission (kg ha^{-1})				Yield (kg ha^{-1})
	CH_4	N_2O	GWP	GHGI	
CF	250	0.23	7061	1.14	6200
AWD	152	0.56	4404	0.73	6050
ISAWD	155	0.64	4510	0.86	5250
$LSD_{0.05}$	50	0.20	325	0.08	540

(Note: CF= continuous flooding, AWD= alternate wetting and drying and ISAWD= Irrigation suspension at 20-40 days after transplanting (DAT) with AWD).

Performance of greenhouse gas emission and grain yield under new rice verities at Sylhet regions

The experiment was conducted at farmers' field to determine the grain yield and GHG with newly released rice varieties compared to the existing rice varieties under different districts of Sylhet region, Bangladesh. Cool farm tools Beta-3 was used for measuring CH_4 emission. The newly released rice varieties BRRI dhan84, BRRI dhan88, BRRI dhan96, BRRI dhan89 and BRR dhan92 and existing rice cultivars BRRI dhan28 and BRRI dhan29 were used. Short duration rice varieties; such as BRRI dhan84, BRRI dhan88 and BRRI dhan96 produced significantly higher yield (6.5-8.2 t ha^{-1}) than BRRI dhan28 (6.0-7.2 t ha^{-1}). However GHG emission was not different during the study period. Long duration BRRI dhan89 and BRRI dhan92 showed significantly higher grain yield

($7.5-8.5$ t ha^{-1}) than BRRI dhan29. BRRI dhan89 and BRRI dhan92 also reduced about 7-10% CH_4 emission than BRRI dhan29 (Table 5).

Table 5. Grain yield and CH_4 emission compare to existing rice varieties and newly released rice varieties during 2021-22.

Short duration variety			Long duration variety		
Variety	Yield (t ha^{-1})	CH_4 (kg ha^{-1})	Variety	Yield (t ha^{-1})	CH_4 (kg ha^{-1})
BRRI dhan28	6.0-7.2	62.9	BRRI dhan29	7.2-8.0	72.3
BRRI dhan84	6.5-7.5	60.8	BRRI dhan89	7.5-8.2	67.6
BRRI dhan88	7.0-8.2	60.8	BRRI dhan92	7.5-8.5	65.6
BRRI dhan96	6.6-7.6	60.8			
$LSD_{0.05}$	0.50	0.73	LSD (5%)	0.47	0.82

(Note: CH4 = Methane)

Effect of planting time on growth and yield of some BRRI released Boro varieties

Research activities were done to identify the suitable planting time and variety for Haor areas. Eight Boro varieties were evaluated in a time series of sowing date (T_1 = 25 Oct, T_2 =5 Nov, T_3 = 15 Nov, T_4 = 25 Nov and T_5= 5 Dec) during Boro 2021-22. Seedlings of 35 days were transplanted in 5.4 m × 12 rows plot using 2-3 seedlings $hill^{-1}$ in RCB design with three replications. Fertilization with P:K:S:Zn @ 20:60:20:3.6 kg ha^{-1} from TSP, MP, gypsum and $ZnSO_4$ ha^{-1} were done at final land preparation. Nitrogen @ 120 kg ha^{-1} from urea was applied in three equal splits at 15 and 30 DAT and five days before PI stage. The results showed that irrespective of variety and sowing time BRRI dhan89 produced the highest yield (8.12 t ha^{-1}) in sowing time of 5 December with 152 days growth duration (Tables 6 and 7). Besides, BRRI dhan28 and BRRI dhan88 also produced the higher yield (6.80 and 7.24 t ha^{-1}) in the sowing time of 25 November whereas, BRRI dhan29, BRRI dhan67, BRRI dhan84, BRRI dhan89, BRRI dhan92, BRRI dhan96 and Bangabandhu dhan100 produced maximum yield when seeded in 25 October where maximum growth duration occurred.

Table 6. Yield (t ha^{-1}) of different Boro varieties in different sowing times.

Sowing time	BRRI dhan28	BRRI dhan29	BRRI dhan67	BRRI dhan84	BRRI dhan88	BRRI dhan89	BRRI dhan92	BRRI dhan96	Bangabandhu dhan100
T_1	6.12	7.22	6.88	6.33	6.30	7.05	7.12	6.29	6.05
T_2	6.05	7.10	6.76	6.28	6.46	7.53	7.50	6.36	6.10
T_3	6.34	7.34	6.62	6.19	6.62	7.36	7.45	6.50	6.30
T_4	6.80	7.68	6.90	6.78	7.24	7.48	7.53	6.68	6.68
T_5	6.65	7.83	6.75	6.90	6.98	8.12	7.99	7.10	7.16
$LSD_{0.05}$						0.36			

Sowing date (T_1 = 25 Oct, T_2 = 5 Nov, T_3 = 15 Nov, T_4 = 25 Nov and T_5= 5 Dec)

Table 7. Yield of different Boro varieties in different sowing timey.

Sowing time	BRRI dhan28	BRRI dhan29	BRRI dhan67	BRRI dhan84	BRRI dhan88	BRRI dhan89	BRRI dhan92	BRRI dhan96	Bangabandhu dhan100
T_1	160	166	156	156	154	167	166	155	155
T_2	156	162	153	149	149	158	158	148	148
T_3	146	160	146	145	145	158	158	146	148
T_4	144	150	152	145	146	152	152	144	148
T_5	147	149	142	147	144	152	152	145	147
CV (%)						3.39			

Sowing date (T_1 = 25 Oct, T_2 = 5 Nov, T_3 = 15 Nov, T_4 = 25 Nov and T_5= 5 Dec)

Demonstration of wet-direct seeding crop establishment technique

The demonstration was conducted at BRRI RS farm, Habiganj during Boro 2021-22. Germinated rice seeds of three BRRI varieties including BRRI dhan29 and BRRI dhan92 and sown in line by hand with the help of a rope. The plot size was 33 decimals for each variety. The line to line spacing was 25 cm. Five to six days after sowing pre-emergence herbicide Laser@ 125 g ha^{-1} was applied. Thinning was done 20 days after sowing (DAS) followed by one hand weeding at 30 DAS. BRRI recommended practice were followed for crop production. The highest grain yield was observed in BRRI dhan29 and BRRI dhan92 (8.04 and 8.15 t ha^{-1}) in hand seeding at BRRI RS farm, Habiganj with a growth duration 148-152 days (Table 8). The growth duration of the tested varieties reduced 7-10 days in direct seeding than transplanting.

Table 8. Growth duration and yield of different demonstration during Boro 2021-22, BRRI RS, Habiganj (direct wet seeding).

Variety	Seeding date	Maturity date	Growth duration (day)	Yield (t ha-1)	Remark
BRRI dhan29	13 Nov. 21	16 Apr. 22	152	8.04	Seeding by hand
BRRI dhan92	21 Nov. 21	17 Apr. 22	148	8.15	Seeding by hand
BRRI dhan29	13 Nov. 21	25 Apr. 22	162	7.78	Transplanting
BRRI dhan92	21 Nov. 21	26 Apr. 22	155	7.88	Transplanting

PEST MANAGEMENT

Monitoring of insect pest and natural enemy incidence by using light trap

The abundance of yellow stemborer (YSB), green leafhopper (GLH), white leafhopper, white-backed plant hopper (WBPH), brown plant hopper (BPH), caseworm (CW), grasshopper (GH), and long horned cricket (LHC) were found in the light trap during the reporting period 2021-22. Among the insect pests, YSB populations were found the highest followed by GLH, WLH, WBPH, BPH GH, CW and LHC. The highest peak of YSB and GLH was observed in April-May. Another peak of YSB, GLH. BPH and WBPH was found in November-December. Among the natural enemies, ladybird beetle (LBB) population was found thehighest followed by carabid beetle (CBB), damselfly and dragonfly. Peak period of LBB and CBB was observed in April-May and November-December.

Survey of Diseases

Disease survey was conducted in Habiganj during Boro 2021-22 on 20 to 22 April 2022. The brown spot incidence (30.0%) was predominant followed by leaf blast and sheath blight and their incidence were 7.56 and 6.04%, respectively. The severity score of brown spot, leaf blast and sheath blight was 2.50, 3.25 and 4.33, respectively and did not follow the incidence pattern.

SOCIO-ECONOMIC POLICY PROGRAM

Stability analysis of BRRI released Boro varieties. The stability experiment was carried out in the research field of the BRRI RS Habiganj during Boro 2021-22. To examine the stability of BRRI rice varieties, 46 released rice varieties were tested using an RCBD design with three replications. The yield range for Boro varieties was 3.8 to 7.9 t/ha. Among the varieties, BRRI dhan55 yielded the highest, which was 7.9 t/ha with a growth duration of 155 days. It was closely followed by BRRI dhan92 and BRRI dhan74. Both the varieties produced 7.1 t/ha with a growth duration of 155 and 148 days, respectively.

TECHNOLOGY TRANSFER PROGRAMME AREA

Advanced line adaptive research trial (ALART) ZER, T. Aman 2021-22.

ALART-ZER was conducted at the farmer‘s field of Bahubol upazila in Habiganj during T. Aman 2021-22. One zinc enriched line, namely BR9674-1-1-5-2-P4, along with three standard check varieties BRRI dhan49, BRRI dhan72 and BRRI dhan87 were evaluated. The yield ranges of advanced line and three check varieties were 5.47 t/ha and 6.01-6.60 t/ha, respectively. The tested line did not perform better than the check varieties. The genotype was susceptible to sheath bilght, having segregation and low tiller number than the check varieties. So, the advanced line was not recommended for further testing.

ALART, Boro 2021-22.

In total five advanced line adaptive research trial (ALART) were conducted during Boro 2021-22. The ALART(BRR) was evaluated at the farmer‘s field of Baniachong upazila in Habiganj. Four blast resistant lines, namely BR(Path)12452-BC3-42-22-11-4, BR(Path)12452-BC6-53-21-11, BR(Path)13784-BC3-61-1-6-HR3, BR(Path)13784-BC3-63-6-4-HR6, along with two standard check varieties, BRRI dhan28 and BRRI dhan88 were evaluated in this experiment. The yield ranges of four lines and two check varieties were 4.97–5.72 t/ha and 4.85–5.29 t/ha, respectively. But the disease incidence in respect to leaf blast and neck blast was higher in all lines than the check varieties. The tested genotypes were not attractive to the ALART monitoring team and the farmers due to their poor phenotypic acceptance, higher disease infestation. None of the lines can perform better than the check varieties. So, none of the advanced lines was recommended for further testing.

The ALART#CTR experiment was conducted in three locations of Ajmiriganj upazila in Habiganj. Baniachong upazila in Habiganj and Taherpur upazila in Sunamganj. Three cold tolerant rice lines namely, IR100722-B-B-B-B-11, IR100723-B-B-B-B-61, TP16199 along with two standard check varieties BRRI dhan28 and BRRI dhan67 were evaluated. The grain yield ranges from 3.69-5.26 t/ha in Ajmiriganj, 4.70-5.50 t/ha in Baniachong and 2.31-3.76 t/ha in Taherpur. However**,** all **t**he tested genotypes including checks were highly susceptible to lodging ranges from 10-80% in Ajmiriganj, 10-40% in Baniachong and 100% in Taherpur. The genotypes IR100722-B-B-B-B-11 and IR100723-B-B-B-B-61 were more susceptible to blast disease. The tested genotypes were not attractive to the ALART monitoring team and the farmers due to their poor phenotypic acceptance, higher disease infestation and lodging incidence. None of the lines performed better than the check varieties. So, none of the advanced lines was recommended for further testing.

ALART, FBR. In ALART-FBR, the four genotypes namely BRBa 1-4-9, BRBa 2-5-3, BRBa 3-1-7 and BRBa 3-2-4 along with two standard check varieties BRRI dhan58 and BRRI dhan89 were evaluated at the farmer‘s field of Baniachong upazila in Habiganj.. The grain yield ranges from 5.32-6.69 t/ha. The insect and disease incidence were lower in all lines than the check varieties. The genotype BRBa 3-2-4 performed better than the check varieties. The tested genotype BRBa 3-2-4 was attractive to the ALART monitoring team and the farmers due to higher yield, less disease and insect infestation. So, this advanced line was recommended for further testing. The ALART#PQR was evaluated at the farmer‘s field of Baniachong upazila in Habiganj. Two premium quality rice lines, namely BR9930-2-3-2-2 and BR9930-2-3-3-1 along with three standard check varieties namely, BRRI dhan50, BRRI dhan63 and BRRI dhan81, were evaluated in this experiment. The grain yield ranges from 4.73-6.12 t/ha. None of the lines performed better than the check varieties. The disease incidence of brown spot and BLB was higher in all the genotypes. Lodging incidence was also higher in advanced lines than the check varieties. The tested genotypes were not attractive to the ALART monitoring team and the farmers due to their poor phenotypic acceptance, higher disease infestation and higher lodging incidence. So, none of the advanced lines was recommended for further testing.

The ALART # SHR was conducted at the farmer's field of Baniachong upazila in Habiganj. Three lines, namely BRHII-9-11-4-5B, BRH13-2-4-6-4B and BRH13-7-9-3-2B along with two standard check varieties BRRI dhan63 and Zirashail, were evaluated in this experiment. The yield ranges of three lines and two check varieties were 5.0-5.6 t/ha and 4.5-5 t/ha, respectively. None of the lines performed better than the check varieties. The disease and lodging incidence was higher in all the genotypes. The tested genotypes were not attractive to the ALART monitoring team and the farmers due to their poor phenotypic acceptance, higher disease infestation and low yield. So, none of the advanced lines was recommended for further testing.

Truthfully labeled and breeders seed production

About 27 tons Breeders seeds (BS) were produced and sent to the Genetic Resource and Seed Division. Also, 17 tons truthfully labeled seeds (TLS) were distributed and sold to the researchers and local farmers according to their demand. More than 20 tons TLS were produced during the reporting year.

Technology transfer and seed dissemination

The station conducted one special workshop where high officials from MoA, DAE and different NARS Institutes participated. It also conducted training courses on "Rice cultivation technology" for 480 farmers in which they were trained with rice production technology for different ecosystems especially on submergence and cold environment. The training courses were conducted at BRRI training center and different upazilas of Sylhet region. Seeds of different varieties were distributed among the participated farmers for dissemination of those varieties.

BRRI RS, Rajshahi

SUMMARY

In Aus season, one observational yield trial (OYT) and one preliminary yield trial (PYT) were conducted at BRRI RS, Rajshahi farm in the reposting year. Out of 384 breeding lines in OYT, 12 entries werefound promising. In PYT, two entries showed significantly higher grain yield with shorter growth duration (GD) than BRRI dhan48.

In hybridization programme during T. Aman season of the reposting year, 364 F1 seeds were produced from seven crosses. Twenty-five crosses were selected in T. Aman and confirmed as true F_1s and 24,834 individual progenies were harvested from rapid generation advance of segregating populations. Nine RYTs and one MLT were conducted in T. Aman in which 44 breeding lines were evaluated and 15 were entries found promising for further advancement. In T. Aman season, 3 OYTs consisted of 729 genotypes were evaluated. In OYT#1, nine entries produced higher yield with shorter GD than BRRI dhan71, In OYT#2, 55 entries showed higher yield and BR11254-6R-47 entry produced 7.39 t/ha yield with two days longer GD than BRRI dhan71. In OYT#3, five entries performed better against BRRI dhan71. In OYT-BB, six entries were found promising for further advancement. Among them one entry BR11987-4R-161-1 produced higher yield of 7.03 t/ha with five days shorter GD (116 days) than BRRI dhan87. Under the AGGRiNet trial in T. Aman, 172 entries were evaluated in OYT (short duration) programme where eight entries produced best performance on grain production and the entry IR18R1088 produced significantly higher yield than BRRI dhan71. Under the OYT (Irrigated medium. duration) programme, out of 95, two entries- IR19A7068 and IR14T156 produced high yield than BRRI dhan93. Under AYT#1 (drought) programme, two tested entries- IR15L172 and IR15L1718 performed better yield.

In Boro 2021-22 season, 261 F1 seeds were produced from 19 crosses. In total 17,141 individual progenies were harvested from rapid generation advance of segregating populations of F4-F6 generations. During Boro, 20 RYTs with 139 breeding lines were evaluated of which 20 lines found promising for further advancement. Under the TRB project, seven trials were conducted. In OYT-BB, 24 entries from 122 tested entries produced higher grain yield against BRRI dhan88. BR12116-5R-48 produced the highest yield amongst all tested entries. Among the three AYTs of BB programme, in AYT#1, 27 entries out of 50 produced higher yield than BRRI dhan58**.** BR11867-5R-87 produced the highest yield with 19 days longer GD than BRRI dhan58. In AYT#2, 9 entries out of 37 produced the higher yield than BRRI dhan89 and the entry-BR11867-5R-421 did the highest performance. In AYT#3, the entry-BR12096-4R-124-1 produced significantly high yield than BRRI dhan89. Three OYT of PQR program were conducted, in OYT#1, six lines out of 33 produced higher yield, among them BR11359-4R-236 disslayed better yield. In OYT#2, a total of 22 tested lines out of 119 showed higher performance. BR11359-4R-409 produced significantly higher yield with seven days longer GD than BRRI dhan58. In OYT#3, none of the entries produced the hihger yield than BRRI dhan92.

In Boro 2021-22 under AGGRiNet trial, 255 advanced breeding lines with 10 global and five national check varieties under OYT (dry season) programme were evaluated. The entries showed a wide range of variations on grain yield. Seventy-nine entries showed more than 8.64-9.87 t/ha yield.

In Boro season, five ALART trials were conducted, in ALART- FBR-Barishal, two advanced lines BRBa 1-4-9 and BRBa 2-5- produced higher yield than the check BRRI dhan89. In ALART-SHR, two genotypes BRHII-9-11-4-5B and BRHI3-2-4-6-4B produced significantly higher yield than the check BRRI dhan63.

Fipronil 50SC and Cartap 50SP were found as the most effective fungicides against stem borer control. Across the all-surveyed spots of Rajshahi region, incidences of bacterial blight, bacterial leaf streak, sheath blight and brown spot were higher whereas neck blast and false smut were comparatively lower. In BRRI ,RS Rajshahi farm, brown spot and bacterial blight disease were in

medium to lower incidence with less severity scale during T. Aman season. On the other hand, medium incidence of sheath blight disease was observed in this season. Results from integrated approaches sheath blight disease control programme suggested that less disease incidence and severity was observed in MOP and Amistar Top treated plot.

Five four-crops cropping pattern and one three-crops cropping pattern were evaluated. Out of five, only one four-crops cropping pattern (Mustard-Onion-T Aus-T. Aman (BRRI dhan75) produced higher rice equivalent yield (REY) than the three crops cropping pattern (Potato-Maize-T. Aman (BRRI dhan87). Pair row Potato/Pair row Maize-T Aus (BRRI dhan82)-T. Aman (BRRI dhan75) was also found as a highly productive pattern. Considering cropping system yield, the rice equivalent yield (REY) remained higher in strip tillage dry seeded rice followed by strip tillage maize followed by strip tillage mungbean systems. Yield performance of BRRI dhan89 remained higher in early seeding (up-to 30 November) while it was remained higher of BRRI dhan58 in late planting situation (up-to 30 January seeding). Among the 17 varieties, BRRI hybrid dhan7 were top ranked followed by BRRI dhan85. Among the 12 varieties in Aus stability trial, BRRI dhan82 were top in rank followed by BRRI dhan65. Among them, BRRI hybrid dhan6 was top ranked in terms of yield followed by BRRI dhan94. In Boro, top four varieties were BRRI hybrid dhan3, BRRI hybrid dhan2, BRRI dhan74 and BRRI dhan29.

BRRI RS, Rajshahi arranged 43 training programmes on modern rice cultivation, farm mechanization, cropping pattern etc where 1,150 participants took part. Around 80 crop cut was done in Aus season from the demonstration's plots and the highest yield found in BRRI dhan48 while the local Pariza recorded the lowest grain yield. A total of 850 demonstrations were established in Aman season where the highest yield was found in BRRI dhan94 followed by BRRI dhan9. In Boro season, around 900 demonstration were established in farmer's field where the highest yield was found in BRRI followed by BRRI dhan92 and the lowest yield was found in BRRI dhan81. In Head-to-Head adaptive trial in Boro season, the highest grain yield was found in BRRI dhan28 in short duration package while the grain yield remained higher in BRRI dhan89 in long duration package. In Aman season, the highest grain yield was found in BRRI dhan71 and BRRI dhan75 while the lowest grain yield was found in BINA dhan17. In long duration package, the highest grain yield was found in BRRI dhan94 and that was the lowest in BRRI dhan80. Considering three seasons, 24 tons breeder seed and 17 ton of TLS seed were produced in BRRI RS, Rajshahi.

VARIETAL DEVELOPMENT

Observation yield trial (OYT) under TRB project, T. Aus 2021.

In total 384 advanced breeding lines were evaluated with three checks BRRI dhan48, BRRI dhan82 and BRRI dhan98 at BRRI RS, Rajshahi farm. Among them 12 tested lines produced higher grain yield (5.25-7.33 t/ha; GD 101-112 days) than the checks (4.69-5.24 t/ha; GD 98-102). Three entries produced more than 6 t/ha yield and these were BR12102-4R-162-1 (yield 7.33 t/ha, GD 112 days), BR12090-5R-91-1 (yield 6.60 t/ha; GD 104 days) and BR12091-4R-48-1 9 (yield 6.14 t/ha; GD 101 days).

Preliminary Yield Trial (PYT) under TRB project, T. Aus 2021.

In total 37 genotypes along with the checks BRRI dhan48, BRRI dhan82 and BRRI dhan98 were evaluated at BRRI RS, Rajshahi farm, among them two entries BR11864-5R-75 (yield 5.90 t/ha, GD 104 days) and BR11863-5R-82 (yield 5.82 t/ha, GD 98 days) showed significantly higher grain yield with 4-10 days shorter GD than the check variety BRRI dhan48 (5.31 t/ha and 108 days) and 7-13 days than BRRI dhan98 (5.14 t/ha and 111 days). Some of entries were lodged at maturity stage.

Hybridization T. Aman 2021.

For development of high yielding cold and drought tolerant rice, a total of 364 F_1 seeds were produced from seven crosses using eight parents in T. Aman 2022 season.

F_1 Confirmation, T. Aman 2021.

Out of 32 crosses, 25 were selected and confirmed as true F_1s comparing with their parents respectively and registered in the BRRaj cross register. Seeds of these selected F_1 plants were selfed to produce F_2 seeds. At maturity, F_2 seeds of all selected plants were harvested individually, dried, cleaned and preserved.

Rapid generation advance of segregating nursuries, T. Aman 2021.

In total 24834 individual progenies were harvested from rapid generation advanced of segregating populations of different generations (F_3, F_4 and F_5). Overall recovery of the lines across the generations was 86%.

Yield trial (RYT and MLT), T. Aman 2021.

A total of 44 breeding lines were evaluated in ten different YTs (two rainfed lowland rice (RLR), two salt tolerant rice (STR), one drought tolerant rice (DTR), one zinc enriched rice (ZER), three premium quality rice (PQR) and one disease resistance rice (DRR) at BRRI RS, farm, Rajshahi against eight different standard checks (BRRI dhan49, BRRI dhan56, BRRI dhan70, BRRI dhan71, BRRI dhan73, BRRI dhan87, IRBB60 and Zirasail). In RLR, genotypes SVIN172 (5.93 t/ha), BR9840-52-1-2-1 (6.21 t/ha), BR8492-9-5-3-2-HR1 (6.16 t/ha), BRH15-24-7-B (5.73 t/ha, 106 days) and BRH14-9-13-16B (5.67 t/ha, 105 days) produced higher grain yield than all the checks (BRRI dhan49, BRRI dhan71 and BRRI dhan87). The genotypes BR11723-4R-48 (6.10 t/ha, 117 days) and BR11716-4R-123 (6.11 t/ha, 120 days) and BR11716-4R-102 (5.84 t/ha, 115 days) performed the highest yield, but almost similar yield and growth duration of the check BRRI dhan87 (5.79 t/ha, 121 days and 5.72 t/ha, 123 days) in STR. out of four, the genotype BRI0539-43-1-1-1-1 (avg. 5.24 t/ha) and BRI0540-4-1-2-4-1 (avg. 5.41 t/ha) produced higher grain than the checks BRRI dhan56 (avg. 5.4 t/ha) and BRRI dhan71 (avg. 5.02 t/ha)) at both the locations (BRRI RS, Rajshahi and Alimganj) in the trial of drought. In the short-slender rice yield trial, the genotype BRH13-1-9-7B (avg. 5.61 t/ha) produced significantly higher grain than the checks (BRRI dhan49 (avg. 5.38 t/ha) and BRRI dhan87 (avg. 5.23 t/ha)) with 109 days growth duration at three locations and in the extra-long-slender rice yield trial, three genotypes BRH11-2-4-7B, IR12A177 and BR238-5-1-4-2 produced higher yield (4.73-5.32 t/ha) than the checks BRRI dhan70 and Zirasail (3.91-4.37 t/ha).

Observation yield trial (OYT#1, 2 & 3), development of drought tolerant rice (DTR) program under TRB project, T. Aman 2021.

Three OYT consists of 729 genotypes along with standard checks were evaluated at Alimjong, Paba site where, **OYT#1** consisted of 30 genotypes along with checks BRRI dhan56 and BRRI dhan71, among them nine entries (5.26-6.76 t/ha, GD 103-108 days) produced higher yield with 5-10 days shorter GD than the check variety BRRI dhan71 (5.16 t/ha, GD 113 days). Among them, two entries produced more than 6.5 t/ha grain, these were- BR12022-6R-48 (6.76 t/ha) and BR12023-6R-111 (6.71 t/ha) with the same GD 107 days.

OYT#2 consisted of 479 genotypes along with checks BRRI dhan56 and BRRI dhan71 among them 55 entries (4.86-7.39 t/ha, GD 108-129 days) showed higher yield with mentioned GD than the check variety BRRI dhan71 (4.82 t/ha, GD 111 days). Entry no. BR11254-6R-47 produced 7.39 t/ha grain with two days longer GD 9,113 days) than the check BRRI dhan71.

OYT#3 consisted of 214 genotypes along with checks BRRI dhan49 and BRRI dhan71, among them 5 entries (4.61-5.81 t/ha, GD 111-112 days) performed better than the check variety BRRI dhan71 (4.55 t/ha, GD 111 days). GD showed more or less similar. Two entries- BR12022-6R-26 (5.81 t/ha) and BR10744-6R-36 (5.46 t/ha) produced more than five t/ha yield with the same GD 111 days. Some entries of three OYT were lodged at maturity stage because continued rainfall.

Observational yield trial (OYT), development of disease resistance (DDR) programme_under TRB project, T. Aman 2021.

In total 60 fixed breeding lines along with three checks BRRI dhan49, BRRI dhan87 and IRBB60 were established at BRRI RS, Rajshahi farm, six entries produced more than 6.5 t/ha yield (6.56-7.03

t/ha) with GD 106-116 days than the check variety BRRI dhan87 (6.03 t/ha and 121 days). Entry no BR11987-4R-161-1 produced higher yield 7.03 t/ha with 5 days shorter GD (116 days) than BRRI dhan87.

Preliminary yield Trial (PYT), development of disease resistance (DDR) programme under TRB project, T. Aman 2021.

The 41 genotypes along with check varieties BRRI dhan49, BRRI dhan87 and IRBB60 were evaluated at BRRI RS, Rajshahi farm. None of the tested entries performed higher grain than the check variety BRRI dhan87 (5.89 t/ha). The genotype BR11869-5R-276 produced similar grain (5.85 t/ha) but 17 days shorter GD than the check BRRI dhan87 (123 days). Overall experimental field infested by stem borer at active tillering stage. Some entries were lodged after strom on 27 September 2021 and 5-7 days continuous rainfall at crop maturity stage

Multi-Location yield trial (MLT), T. Aman 2021.

In total, three genotypes were evaluated against the checks BRRI dhan49, BRRI dhan87 and IRBB60 at farmers' field of Alimganj, Paba under the supervision of BRRI RS, Rajshahi. Overall experimental plots were infested by BPH at flowering stage. None of the tested entries produced higher grain yield than the check variety BRRI dhan49 (5.08 t/ha).

Establishment of AGGRi network trial (short duration) under IRRI-DSR rice breeding programme, T. Aman 2021.

This trial was conducted with 172 breeding lines including eight global and national checks at BRRI RS, Rajshahi farm. Among them eight entries produced higher yield (ranges from 7.03 to 8.14 t/ha, 108-116 day) compared with check varieties- Vandana, SAHBHAGI dhan, IRR154, IRR163, IRR176, IR87707-445-B-B-B and BRRI dhan71, BRRI dhan75 yield and GD rages from (Yield 3.63-6.01 t/ha, 107-122 days). Entry no- IR18R1088 (8.14 t/ha, 116 days) performed better on grain production but eight days longer GD compared to BRRI dhan71 (6.01 t/ha, 108 days) followed by all the tested entries and checks.

Establishment of AGGRi network trial (irrigated medium duration) under IRRI: Irrigated rice breeding programme, T. Aman 2021.

This trial was evaluated under the supervision of BRRI RS, Rajshahi with 95 advanced breeding lines including five national check varieties BRRI dhan49, BRRI dhan57, BRRI dhan75 BRRI dhan87 and BRRI dhan93. Among all the tested entries and checks two entries produced higher yield these were- IR14T156 (6.96 t/ha, 115 days) and IR19A7068 (6.53 t/ha, 108 days) with 15-22 days shorter GD compared to BRRI dhan93 (6.42 t/ha, 130 days). Yield and GD of the checks ranged from 2.07 to 6.42 t/ha, 101-133 days. Grain yield production of BRRI dhan49 (2.07 t/ha) lower because of rat damaged.

Advanced yield Trial (AYT#1), development of AGGRi (favourable) materials, T. Aman_2021.

Yield trial of some selected entries under AGGRI (favourable) programme, AYT#1 were evaluated at Alimganj, Paba site of BRRI RS, Rajshahi farm with 19 breeding lines including two checks- BRRI dhan56 and BRRI dhan71 at the drought prone environment Alimganj, Paba, Rajshahi. Two tested entries- IR15L1720 (4.60 t/ha, 102 days) and IR15L1718 (4.74 t/ha, 102 days) performed better yield and 5-9 days earlier GD compared to the two checks that ranged from (3.34 to 4.36 t/ha with 107-111 days).

Advanced Yield Trial (AYT#2), Development of AGGRi (drought) and STRASA_materials, T. Aman 2021.

Yield trial of some selected entries under AYT#2 (AGGRi drought and STRASA materials) were conducted at Alimganj, Paba site of BRRI RS, Rajshahi with 11 advanced breeding lines including check BRRI dhan71 at the drought prone environment Alimganj, Paba, Rajshahi Two tested entries- IR17L1368 (5.05 t/ha, 111 days) and IR17L1360 (5.10 t/ha, 111 days) shows more or less similar result on grain production and two days earlier GD compared to that of BRRI dhan71 (5.18 t/ha, 113 days).

Hybridization, Boro 2021-22.

A total of 261 F1 seeds were produced from 19 crosses using fourteen parents in Boro 2021-22 season.

Rapid generation advance of segregating nurseries, Boro 2021-22.

In total 17,141 individual progenies from 20 crosses were harvested from F4-F6 generations through FRGA method.

Regional Yield Trial (RYT), Boro 2021-22.

Twenty YTs viz. one FBR-SD, one FBR-MD, one FBR-LD, two CTR, one FBR-AGGRiNet , two STR, one FBR-Barishal , one ZER, one PQR, one Zira Type, one SS, one LS, one Blast, two BB, one BPH and one MLT were conducted against 18 different standard checks (BRRI dhan81, BRRI dhan96, BRRI dhan89, BRRI dhan92, BRRI dhan28, BRRI dhan67, BRRI dhan63, BRRI dhan97, BRRI dhan58, BRRI dhan29, BRRI dhan74, BRRI dhan84, Zirashail, BRRI dhan50, BRRI dhan63, BRRI dhan88, IRBB60 and T27A) in Boro season in which a total of 139 breeding lines were evaluated.

In the RYT(FBR-SD), out of 3, only the genotype IR17A1694 performed higher grain yield (7.56 t/ha) than the check varieties BRRI dhan81 and BRRI dhan96 (6.10-6.45 t/ha) with 153 days growth duration. Four tested entries (viz. IR17A2433, BR11318-5R-21, BR11318-5R-63 and BR11337-5R-72) produced significantly higher grain yield (7.38-7.99 t/ha) than the check varieties (BRRI dhan81 (6.0 t/h) and BRRI dhan96 (6.44 t/ha)) with similar growth duration in the RYT(FBR-MD). Out of nine, three entries (BR10301-5R-89, BR10604-5R-10 and BR11318-5R-84) produced higher grain yield (7.80-8.44 t/ha) than the check BRRI dhan89 (8.0 t/ha) with similar growth duration in the RYT(FBR-LD). Among the six tested entries in the RYT (CTR#1), only BR11894-R-R-R-R-230 (6.77 t/ha) showed higher grain yield than the check varieties BRR dhan28 (6.01 t/ha) and BRR dhan67 (5.16 t/ha). In the RYT (STR#1) the genotype BR10182-5-4-2 (6.59 t/ha) produced significantly higher grain yield with short growth duration (144 days) compare to BRRI dhan67 (5.45 t/ha). Out of ten, two genotypes (NGR 467-2 and NGR 1255-1) showed similar grain yield and growth duration (7.98-8.0 t/ha and 166 days) with the check variety BRRI dhan89 (**8.17** t/ha). Another, two genotypes (NGR 750-1 and NGR 796-2) produced significantly higher grain yield (7.0 t/ha) than the check BRRI dhan58 (6.26 t/ha) with the same growth duration (160 days) in the RYT (FBR-Barishal). In the RYT (ZER), the genotype BR9674-1-1-5-1-P3 produced highest grain yield (7.57 t/ha) with growth duration of 157 days same as the check BRRI dhan29 (7.33 t/ha). The genotype BR10247-14-18-4 (6.33 t/ha) and BR10247-4-7-4B (6.52 t/ha) showed almost similar grain yield with the check BRRI dhan28 (6.16 t/ha), but 8 days longer growth duration in RYT (LS). Five tested entries performed higher grain yield (6.50-7.37t/ha) than the check varieties BRRI dhan28 and BRRI dhan81 (5.90 and 6.12 t/ha) with the same growth duration. The genotype BRH13-1-9-7B produced highest grain yield (7.37 t/ha) with 151 days growth duration in RYT (SS). In both the places (BRRI RS, Rajshahi farm and Niamatpur), none of the genotype produced higher grain yield than the check variety BRRI dhan81 (6.02 t/ha). On average, the genotype BRH15-24-7B showed similar yield and growth duration like as Zirashail (5.36 t/ha, 152 days). In RYT (PQR), BR10322-23-1-2-4 and BR10322-23-6-3-7-B2 showed higher yield than the checks BRRI dhan63 and BRRI dhan81 (5.04-6.35 t/ha) with growth duration 142 days. BR (Path)12454-BC2-69-97-39-5-44 (7.50 t/ha) and BR (Path) 12454-BC2-71-91-6-23-26 (7.66 t/ha) showed almost similar yield and growth duration as the checks BRRI dhan29 (7.60 t/ha) and BRRI dhan89 (7.66 t/ha) in RYT(Blast). Twelve tested entries, BR11600-4R-105 produced highest grain yield (6.78 t/ha) with 156 days growth duration, although it was similar to the check BRRI dhan88 (6.87 t/ha) in RYT(BB#1). In RYT(BB#2), among the 14 entries, BR11604-4R-110 (8.01 t/ha) and BR11607-4R-153 (8.01 t/ha) shown highest yield with 166-169 days growth duration. Another three entries BR11604-4R-122, BR11604-4R-129, BR11604-4R-24 and BR11604-4R-52 produced significantly higher grain yield (7.50-7.86 t/ha) than the check BRRI dhan58 (7.08 t/ha), but similar to the check BRRI dhan89 (7.76 t/ha) with 166 days growth duration. The genotypes BR11593-5R-55 (7.79 t/ha) and BR11593-5R-79 (7.61 t/ha) showed the highest yield with 160 days growth duration and significantly higher than the check BRRI dhan88 (7.11 t/ha) in RYT(BPH). Out of seven entries, BR(Path)12454-BC2-69-97-39-5-44 (7.20 t/ha) and BR(Path)12454-BC2-71-91-6-23-26 (7.10 t/ha) showed almost similar yield and growth duration as the checks BRRI dhan29 (7.20 t/ha) and BRRI dhan89 (7.23 t/ha) in MLT(Blast). Sixty hills were selected from ten Zira type landraces based on grain type, plant height, panicle/hill character and growth duration for further head-to-head purification.

Observation yield trial (OYT), development of disease resistance (DDR) programme_under TRB project, Boro 2021-22.

This non-replicated trial established with checks IRBB60, BRRI dhan58, BRRI dhan88 and BRRI dhan89 at BRRI RS, Rajshahi farm**.** Out of 640 advanced breeding lines, data of 122 lines were retained. Rest of the lines, some were non-germinated and some were damaged by cold injury at seed bed. A total of 24 tested lines produced significantly higher grain yield (7.82—9.80 t/ha) with wide range of GD (145-164 days) compared to the check BRRI dhan89 (7.80 t/ha, 156 days). Ten entries produced more than 9 t/ha yield, where entry no- BR12116-5R-48 (9.80 t/ha, 155 days) produced the highest result on grain production among the ten tested entries and all the checks.

Advanced yield trial (AYT#1, 2 and 3), development of disease resistance (DDR) programme under TRB project, Boro 2021-22.

In total 97 genotypes were evaluated at BRRI RS, Rajshahi farm along with checks under the three AYTs, where: **AYT#1** consisted of 50 entries along with checks IRBB60 and BRRI dhan88. Among them 27 entries produced significantly higher grain ranged from 7.47 to 911 t/ha with the GD 149-165 days compared to the check BRRI dhan58 (6.87 t/ha and GD 146 days). Three entries- BR11867-5R-87 (9.11 t/ha, 164 days), BR11867-5R-179 (9.05 t/ha, 163 days) and BR11867-5R-296 (9.00 t/ha, 163 days) shows higher yield production, more than 9 t/ha with 18-19 days late GD compared with BRRI dhan58 (146 days).

AYT#2 consisted of 37 entries and three checks IRBB60, BRRI dhan58 and BRRI dhan89, 9 entries out of 37 entries produced significantly higher grain yield (8.41-9.16 t/ha, 160-165 day) with 2-7 days longer GD compared with check BRRI dhan89 (7.86 t/ha, 158 days). Two tested entries, BR11866-5R-223 (9.05 t/ha, 165 days) and BR11867-5R-421 (9.16 t/ha, 164 days) showed the highest performance on yield, more than 9 t/ha against all entries and checks.

AYT#3 Coasted of 10 genotypes and five checks-IRBB60, IRBB65, BRRI dhan58, BRRI dhan88 and BRRI dhan89. One entry-BR12096-4R-124-1 (9.59 t/ha, 164 days) produced significantly high yield with two days longer GD compared to the highest yield producing check-BRRI dhan89 (8.42 t/ha, 161 days).

Observation yield trial (OYT#1, 2 and 3), development of premium quality rice (PQR) programme under TRB project Boro 2021-22.

In total 198 genotypes were evaluated at BRRI RS, Rajshahi along with checks under the three OYT, where: **OYT#1** consisted of 33 genotypes along with checks BRRI dhan50, BRRI dhan63 and BRRI dhan81. Among them six entries (6.73-8.78 t/ha, GD 143-155 days) produced higher yield compared with three checks (5.84-6.60 t/ha, GD 144-154 days). Entry BR11359-4R-236 produced the higher grain yield (8.78 t/ha, 155 days) with the 1-11 days longer GD than the checks.

OYT#2 consisted of 119 genotypes along with checks BRRI dhan50, BRRI dhan63 and BRRI dhan58. Among them 22 entries (7.10-8.27 t/ha, GD 143-158 days) showed higher yield with mentioned GD compared than all checks (5.88-7.08 t/ha, 144-153 days). Entry no. BR11359-4R-409 produced 8.27 t/ha grain with seven days longer GD (155 days) to the check BRRI dhan58 (7.08 t/ha, 148 days)

OYT#3 consisted of 46 fixed lines along with checks BRRI dhan50, BRRI dhan63 and BRRI dhan92. Among them none of entries showed better performance against the check variety BRRI dhan92 (7.70 t/ha, GD 158 days). But compared to

BRRI dhan63 (6.48 t/ha, 144 days), 4 entries- BR11362-4R-140, BR11371-4R-185, BR11363-4R-3 and BR11363-4R-20 produced higher yield (6.72-7.09 t/ha) with 3-14 days longer GD.

Establishment of AGGRi network trial (dry season) under IRRI-Irrigated rice breeding programme, Boro 2021-22.

This trial was evaluated at BRRI RS, Rajshahi farm with 255 advanced breeding lines with 10 global and five national check varieties during Boro 2021-22. The tested entries showed a wide range of variations on grain yield starting from 4.02 t/ha to 9.87 t/ha with a mean value of 8.01 t/ha. Growth duration also varied among the selected lines. The entries varied in growth duration from 140 days to 165 days with a mean value of 145 days. Wide variations in plant height were also observed among this breeding lines. The entries showed 83.5 to 212.3 cm for plant height with a mean value 110.16 cm. Out of 259 entries tested, 79 entries showed more than 8.64-9.87 t/ha grain, which was higher with 136 days to 162 days growth duration compared with five national check varieties- BRRI dhan28, BRRI dhan29, BRRI dhan89, BRRI dhan100 and Fatema dhan yielded starting from 6.97 to 8.18 t/ha, respectively with 144-152 days growth duration. Fatema dhan was completely not germinated or damaged due to cold effect at seed bed.

Advanced yield trial (AYT), evaluation of breeding lines under AGGRiNet trial, Boro 2021-22.

BRRI RS, Rajshahi conducted a trial composed of 17 advanced breeding lines along with checks BRRI dhan81, BRRI dhan89, BRRI dhan92 and BRRI dhan96. Out of all the tested entries and checks (checks yields ranges from 5.51 to 7.04 t/ha, 143-158 days) three entries produced 7 t/ha yield (7.10-8.62 t/ha, 146-153 days) in which one entry-IR18A1907 produced high grain 8.62. t/ha among all the enters hanging days earlier GD (153 days) compared to the check variety BRRI dhan92 (7.04 t/ha, 158 days). BRRI dhan96 was not germinated at seed bed due to cold effect.

Advanced line adaptive research trial (ALART), Boro 2021-22.

In Boro season, five ALART trial were conducted, in ALART- FBR-Barishal, three lines and two check varietes were evaluated where two advanced lines BRBa 1-4-9 (7.70 t/ha) and BRBa 2-5-3 (7.53 t/ha) produced higher yield than the check BRRI dhan89 (7.02 t/ha). In ALART, three genotypes and two check varieties were evaluated and it was found that the two genotypes BRHII-9-11-4-5B (7.62 t/ha) and BRHI3-2-4-6-4B (7.85 t/ha) produced significantly higher yield than the check BRRI dhan63 (6.12 t/ha). Two ALART-PQR trials consisted of two genotypes and three checks were conducted at Paba and Godagari of Rajshahi where none of the genotypes produced higher yield than the checks. Four advanced lines were evaluated against BRRI dhan28 and BRRI dhan81 under ALART-BRR programme where none of the lines produced higher yield than the checks.

PEST MANAGEMENT

Effect of selected insecticide for stem borer management.

The present investigation was conducted at the BRRI RS, Rajshahi farm during Aman 2021 to study the efficacy of certain chemical insecticides. Four single-molecule insecticides along with control were used in this experiment and two rounds of applications were given; one at the maximum tillering stage and another before the flowering stage. The performance of different insecticides against stem borer were significantly affacted at seven days after spraying (DAS). The lowest dead heart infestation was found from Fipronil 50SC treated plot (4.05%) and it was not significantly different with Cartap 50SC treated plot (4.26%). The highest dead heart damage of 15.04% was found in the control plot. At 15 DAS on first spray, a similar trend in insecticide efficacy against stem borer was found with significant findings. There was no significant difference among the Fipronil 50SC and Cartap 50SP treated plot, dead heart infestation 5.93 and 6.50%

respectively and the highest dead heart infestation (13.19%) was found in the control plot.

The per cent white head infestation due to stem borer revealed significant results and Fipronil 50SC (3.65% white head) found superior among all insecticides but at per with Cartap 50SC (4.35% white head). The highest white head infestation (13.26%) was found in the control plot and it was significantly different with other treatments. At 15 DAS significantly lowest infestation was found in Fipronil 50SC treated plot (2.96% white head) and the significantly the highest infestation was found in the control plot (11.06% white head). Significantly the highest yield (6.12 t/ha) was found in Fipronil 50SC treated plot and the lowest yield was found in the control plot (3.92 t/ha).

Survey and monitoring of rice diseases in T. Aman and Boro 2021-22.

A survey was conducted to know the present situation of different rice diseases in three upazilas Paba, Tanore and Godagari in Rajshahi district during T. Aman 2021 and two upazillas (Paba and Godagari) in Boro 2021-22. Nine spots replicated three of each location were selected for conducting the survey and the disease data were recorded by following SES scale (1-9) and GPS data using ODK apps. A total of four rice diseases namely, bacterial blight, sheath blight, bacterial leaf streak and brown spot were found in all the surveyed areas in both the seasons. In T. Aman season, BRRI dhan34, BRRI dhan49, BRRI dhan51, BRRI dhan52 and Swarna were dominant varieties across the locations. On the other hand, BRRI dhan28 and Jira were cultivated in great extent of Rajshahi district in Boro season. Surveyed also done in BRRI RS, Rajshahi farm in both Boro and Aman season.

Survey was conducted in three upazillas of Rajshahi district in T. Aman 2021. In Paba Upazilla, incidence of bacterial blight, bacterial leaf streak, sheath blight and brown spot on average 54%, 12%, 17% and 28% with the severity of 5, 3, 3 and 3 respectively during this season. In Godagari, the incidence of bacterial blight and bacterial leaf streak were 81% and 40% with severity scale of 7 and 3 respectively. Neck blast and false smut disease also found in Chini Atap at Proshadpara and BRRI dhan51 at Habibnagar, Godagari respectively. Incidence of false smut (14%) and neck blast (4%) were also observed in Tanore upazila. Bacterial blight disease incidence was higher in this area as like as other areas about 58% of severity scale 9. Prevalence of bacterial blight disease was higher on Swarna, Chini Atap and BRRI dhan51 across the Rajshahi region in T. Aman season. False smut and neck blast were found comparatively higher in Paba than the other areas. These two diseases were mostly found on BRRI dhan49 (false smut) and BRRI dhan51 (neck blast) varieties. Across all the surveyed spots of Rajshahi region, incidence of bacterial blight, bacterial leaf streak, sheath blight and brown spot were higher (above 50%) whereas neck blast and false smut were comparatively lower (below 25%).

In Boro season, survey of major diseases was conducted in two upazilas Paba and Godagari. BRRI dhan28, BRRI dhan81, Lomba Jira and Khato Jira were predominant varieties across the region. In Paba upazila, incidence of bacterial leaf streak (5-25%) was higher than bacterial leaf blight (1-5%) disease. Prevalence of bacterial blight was higher and disease incidence was 3-60% in Godagari upazila. Incidence and severity of other diseases like sheath blight, bacterial leaf streak was lower (1-17%) in both the upazilas. Overall, most of the crop was soft dough to dough stage, crop condition was comparatively good and less disease infected than previous season. It may be noted here that prolonged temperature prevailed towards the end of Boro season in Rajshahi region.

In BRRI RS, Rajshahi farm, brown spot and bacterial blight disease were in medium to lower incidence (not above 15%) with less severity scale during T. Aman season. On the other hand, medium incidence of sheath blight disease was observed in this season. During Boro 2021-22, all diseases including brown spot and bacterial blight were found in few plots. Prevalence of major diseases was lower across the field of BRRI RS, Rajshahi farm due to good management.

Evaluation of effective chemical against sheath blight disease of rice, T. Aman 2021.

The experiment was conducted at BRRI Rajshahi farm under artificial inoculation condition. New fungicides with disease control and standard check (Nativo) treatment were also tested. Thirty-day-old seedlings of BR11 were transplanted with the spacing 20 cm X 15 cm having 2-3 seedlings/hill during T. Aman 2021. Plot size was 1m X 1m with three replications. The plants were inoculated with local *Rhizoctonia solani* culture grown on PDA medium at PI stage. Eight hills were inoculated from central area at random. New fungicides were sprayed at their recommended dose twice the first at five days after inoculation and the second at seven days after first spray. Data on relative lesion height (RLH) was taken at dough stage.

Among 20, none of fungicides/chemicals-controlled sheath blight disease successfully (equal or above 80%) in Rajshahi farm at T. Aman 2022.

Efficacy of new chemicals in controlling grain spot, brown spot and narrow brown spot of BRRI dhan52.

An investigation was carried out to identify promising new fungicides in controlling minor diseases such as grain spot, brown spot and narrow brown spot. Four new chemicals and one control (no chemical) were selected for this experiment. BRRI dhan52 as susceptible variety was used and grown in T. Aman season. Fungicides were sprayed at tillering stage and screening was done natural condition. Plot size was 1 m 2 with 3 replications followed randomized complete block design. New fungicides were sprayed at their recommended doses twice during tillering to maximum tillering stage. Data were taken at dough stage using SES scale.

In this experiment, less disease symptoms appeared on leaves due to artificial inoculation was not done and weather was not favouruable to induce those diseases naturally. All treatments/chemicals showed more or less same reaction against diseases. So, further trial is needed to know the appropriate result and find out appropriate chemical(s)/ fungicide(s).

Integrated approaches in reducing sheath blight diseases in T. Aman 2021.

An experiment was conducted to minimize the use of fungicides to control sheath blight disease. Four treatments and one control were selected for this experiment. BR11 as susceptible variety was used and grown in T. Aman season. Ash, MOP (11gm/3m^2), Japanese sol^n (4ml/0.5 lit), fungicide (Amistar top 325 SC) were used for treated plants two times at tillering stage. Plot size was three m^2 with three replications following randomized complete block design. Data was collected at dough stage using SES Scale. Results suggests that less disease incidence and severity was observed in MOP and Amistar Top treated plot. On the other hand, Japanese solution and MOP showed better yield than the others. The investigation will be repeated in next season for more confirmation.

RICE FARMING SYSTEMS

Evaluation of crop productivity and soil health under four crops cropping patterns

The trial consisted with six cropping patterns (CP) viz. CP_1. Potato/pumpkin (relay)-T Aus-T. Aman (BRRI dhan75), CP_2. Potato-mungbean-T. Aus-T. Aman (BRRI dhan75), CP_3. Field Pea-Onion-T. Aus-T. Aman (BRRI dhan75). CP_4. Mustard-Onion-T. Aus-T. Aman (BRRI dhan75), CP_5. Mustard-Onion/Maize (relay)-T. Aman (BRRI dhan75), CP_6. Potato-Maize-T. Aman (BRRI dhan95) were evaluated in BRRI RS, Rajshahi farm.

Among the cropping patterns, the rice equivalent yield (REY) yield of 1st of crop (Rabi season) remained higher 14.12 t/ha in CP_1 (Potato) followed by CP_2 (13.66 t/ha) (Potato) and CP_6 (13.44 t/ha) (Potato) and that was found lower (5.03 t/ha) in CP_3 (field pea**)**. In 2nd crop, REY (11.12 t/ha) was found higher in CP_3 (Onion) and that was remained lower (3.15 t/ha) in CP_2 (Mungbean). The REY in 3rd crop was found higher in CP_1 (BRRI dhan82) followed by CP_5 (Maize). T. Aman (Kharif II season) was the 4th crop in all the cropping patterns and the higher yield in T. Aman season was found in CP_2 (5.65 t/ha) followed by CP_4 (5.54

t/ha). The lower yield (5.38 t/ha) in Aman season was found in CP_4. Considering system yield, the higher REY (27.78 t/ha) was found in CP_4 followed by CP_5 (27.01 t/ha). The lower system yield was found in CP_5 (25.9 t/ha)

Evaluation of crop productivity under four crops cropping patterns in farmers field.

The trial consisted with five cropping patterns were evaluated in farmer's field. The cropping patterns were: CP_1. Two row potato/Two row Maize-T. Aus (BRRI dhan82)-T. Aman (BRRI dhan75), CP_2. Potato/Pumpkin-T Aus (BRRI dhan82)-T. Aman (BRRI dhan75), CP_3. Potato-Mungbean-T. Aus (BRRI dhan82)-T. Aman (BRRI dhan75), CP_4. Potato-Maize-T. Aman (BRRI dhan75), CP_5. Maize-Mungbean-T. Aman (BRRI dhan75).

The rice equivalent yield (REY) yield of 1st crop among the cropping patterns remained higher in potato of CP_4 (REY 14.56 t/ha) followed by CP_3 (14.40 t/ha) and CP_2 (14.30 t/ha) and that was found lower in 11.20 t/ha in CP_5 (Maize)**.** In potato-based patterns (4 patterns), the REY in 1st crop was found significantly lower in CP_1 of 11.72 t/ha. In contrast, the REY in 2nd crop was found significantly higher in CP_1 (maize) (9.72 t/ha) followed by CP_4 (Maize) (7.16 t/ha). The lower REY in 2nd crop was found in CP_3 (Pumpkin) (2.76 t/ha) and CP_3 (Mungbean) (3.24 t/ha). Among the cropping patterns, CP1, CP2 and CP3 were four crop-based patterns and BRRI dhan82 was grown those patterns and CP_4 and CP_4 remained fallow in 3rd crop. The REY in 3rd crop was found higher in CP_1 (BRRI dhan82) (4.80 t/ha) followed by CP_2 (4.70 t/ha) that was remained lower in CP_3 (4.60 t/ha). T. Aman (BRRI dhan75) was the 4th crop in all the cropping patterns and the higher yield in T. Aman season was found in CP_5 (5.46 t/ha) closely followed by CP_3 (5.54 t/ha). The lower yield (5.25 t/ha) in Aman season was found CP_2. Considering system yield of four crop-based patterns, the higher REY (31.57 t/ha) was found in CP_1 followed by CP_3 (27.69 t/ha) and that was remained lower in CP_2 (27.02 t/ha). Among the five cropping patterns, the lower system yield was found in three crop-based cropping patterns of CP_5 (20.11 t/ha).

Evaluation of crop productivity and soil health under strip tillage system in maize-mungbean-rice cropping pattern.

The trial was conducted at BRRI RS, Rajshahi to evaluate the productivity and profitability of strip tillage system. The tillage and crop establishment methods were T_1: Strip tillage dry seeded rice followed by strip tillage maize and mungbean, T_2: Strip tillage un-puddled rice through rice transplanted followed by strip tillage maize and mungben, T_3: Conventional tillage transplanted rice followed by strip tillage maize and mungben, T_4: Conventional transplanted rice followed by conventional maize and mungben.

The higher grain yield of Aman rice was found in T_3 (5.22 t/ha) which was statistically similar with all other treatments except T_1 (4.80 t/ha). In contrast, the highest grain yield of maize was found in T_1 (11.56 t/ha) followed by T_2 (11.20 t/ha) while the lowest yield was recorded in T_4 (10.35 t/ha). In case of mungbean, there was no statistical difference in yield among the treatment ranging from 1.07 t/ha in T_3 to 1.16 t/ha in T_4. Considering cropping system yield, the rice equivalent yield (REY) remained higher in T_1 (19.75 t/ha) closely followed by T_2 (19.56 t/ha) treatment and that was found lower in T_1 (18.98 t/ha) treatment. The gross return (Tk 5,19,500) as well as gross margin (Tk2,58,980) remained higher in T1 while those were remained lower in T_4 treatment (Gross return Tk4,99,480 and gross margin Tk 2,30,940).

Effect of planting time on rice varieties in Boro season.

The trial was conducted at BRRI RS, Rajshahi to identify the suitable planting time of different rice varieties in Boro season. This was two factor experiment and the treatments under factor A were V_1: BRRI dhan28,V_2: BRRI dhan58, V_3: BRRI dhan81, V_4: BRRI dhan89 and the treatments under factor B were S_1: 15 November seeding with 40-day-old seedling, S_2: 15 November seeding with 50-day-old seedling, S_3: 30 November seeding with 40 d old seedling, S_4: 30 November seeding with 50-day-old seeding, S_5: 15 December seeding with

40-day-old seedling, S_6: 15 December seeding with 50-day-old seedling, S_7: 30 December seeding with 35-day-old seedling, S_8: 15 January seeding with 30-day-old seedling, S_9: 30 January seeding with 30-day-old seedling. The interaction of variety and time of plating affected significantly and the highest yield was found in the combination $V_4 \times S_4$ (8.09 t/ha) followed by $V_4 \times S_1$ (7.91 t/ha) and $V_4 x S_2$ (7.77 t/ha). After that, the other high yielding combinations were $V_2 \times S_3$ (7.35 t/ha), $V_2 \times S_1$ (7.24 t/ha). The yield performance of BRRI dhan89 was remained higher in early seeding (upto 30 November) while the yield performance of BRRI dhan89 remained higher in late planting situation (upto 30 January). Irrespective of planting time, the highest yield was found in BRRI dhan89 (6.56 t/ha) followed by BRRI dhan58 (6.37 t/ha) and the lowest yield was found in BRRI dhan81 (5.03 t/ha).

SOCIOECONOMICS AND POLICY

Stability analysis of BRRI developed Aus varieties.

Twelve rice varieties were evaluated at BRRI RS, Rajshahi farm in Aus 2021-22 season. Among the 12 varieties, BRRI dhan82 (4.95 t/ha) were top ranked followed by BRRI dhan65 (4.88 t/ha). After BRRI dhan65, the next two high yielding varieties were BRRI hybrid dhan7 (4.64 t/ha) and BRRI dhan83 (4.19 t/ha). The grain yield remained lower in BRRI dhan24 (3.35 t/ha) decreasingly followed by BR26 (3.37 t/ha).

Stability analysis of BRRI developed T. Aman rice varieties.

Forty-seven Aman rice varieties were evaluated at BRRI RS, Rajshahi farm in T.Aman 2021-22. Among them, BRRI dhan93 were top ranked in terms of yield (5.81 t/ha) followed by BRRI hybrid dhan4 (5.61 t/ ha). Next to BRRI hybrid dhan4, the rice yields in Aman season remained higher in BRRI dhan66 (5.60 t/ha), BRRI dhan94 (5.55 t/ha) and BRRI dhan95 (5.49 t/ha). BR5, BRRI dhan38, BRRI dhan37, BRRI dhan34 and BR3 were found low yielding varieties and the yield ranged from 2.58 to 3.60 t/ ha).

Stability Analysis of BRRI developed Boro rice varieties.

Forty-six varieties were evaluated at BRRI RS, Rajshahi farm during Boro 2021-22 season. Considering the yield performance, top five varieties were hybrid dhan5 (9.50 t/ha), BRRI hybrid dhan2 (8.24 t/ha), BRRI dhan69 (7.77 t/ha), BRRI dhan99 (7.71), BRRI bybrid dhan3 (7.69 t/ha) and BRRI dhan29 (7.47 t/ha). BR17 (5.50 t/ha), BR1 (5.94 t/ha) and BRRI dhan68 (5.97 t/ha) were the low yielding among the Boro varieties.

TECHNOLOGY TRANSFER

Farmers training and seed distribution.

Farmers' training is an important tool to train up farmers on updated information for rice cultivation. BRRI RS, Rajshahi arranged 43 training programmes on modern rice cultivation, farm mechanization, cropping pattern etc at different upazilas of of Rajshahj region. In total of 1,150 participants were participated in the training programmes. Seeds of modern rice varieties were distributed to the farmers for variety demonstration.

Demonstration of BRRI released varieties

Field demonstrations were carried out at different locations of Rajshahi region during T. Aus, T. Aman and Boro seasons in the reporting year. Around 80 crop cut was done in Aus season from the demonstration's plots and the highest yield (5.12 t/ha) found in BRRI dhan48 closely followed by BRRI dhn82 (4.80). BINA Dhan-19 produced the yield of 4.60 t/ha while the local Pariza recorded the lowest grain yield of rice. Local 76 also produced remarkable yield of 4.75 t/ha. A total of 850 demonstrations were established in Aman season and 100 crop cut were done where the highest yield was found in BRRI dhan94 (6.12 t/ha) followed by BRRI dhan93 (5.89) and BRRI dhan95 (5.77 t/ha). BRRI dhan87 produced the yield of 5.42 t/ha while the lowest yield was recorded in BRRI dhan 4.20 t/ha in BRRI dhan90. In Boro season, around 900 demonstrations were established in farmer's field done where the highest yield was found in BRRI dhan89 (8.20 t/ha) followed by 7.70 t/ha in BRRI dhan92. After that BRRI dhan58 produced the yield of 7.55 t/ha while Zira dhan recorded the yield of 6.30 t/ha. The lowest yield was found in BRRI dhan81 (6.12 t/ha).

Head-to-head adaptive trial, Boro 2021-22.

Head-to-Head adaptive trial was conducted in six locations with five short duration (BRRI dhan28, BRRI dhan67, BRRI dhan81, BRRI dhan84 and BRRI dhan88) and four long duration varieties (BRRI dhan29, BRRI dhan58, BRRI dhan89, BRRI dhan92). In case of short duration varieties. The highest grain yield was found in BRRI dhan28 (6.64 t/ha) closely followed by BRRI dhan67 (6.62 t/ha) and the lowest yield was recorded in BRRI dhan81 (5.86 t/ha). In case of long duration varieties, the grain yield remained higher in BRRI dhan89 (7.50 t/ha) followed by BRRI dhn92 (7.38 t/ha) and the grain yield remained lower in BRRI dhan20 (6.99 t/ha). In Aman season of short duration varieties, the highest grain yield was found in BRRI dhan71 and BRRI dhan75 (5.59 t/ha) and the lowest yield was recorded in BINA Dhan-17 (5.11 t/ha). In case of long duration of Aman rice varieties, the grain yield remained higher in BRRI dhan94 (6.35 t/ha) followed by BRRI dhn93 (6.29 t/ha) and the grain yield remained lower in BRRI dhan80 (5.03 t/ha).

Truthfully leveled and breeders seed production

Nucleus seed stock was collected from GRS Division of BRRI. Single seedling was transplanted per hill. For breeder seed production, all official formalities with SCA and BRRI authority were performed through proper channel. Breeder seed was produced in T. Aman and Boro seasons of the reporting year but TLS seed was produced in Aus and T. Aman and Boro seasons. Considering three seasons (Aus, T. Aman and Boro), breeder and TLS seeds were produced 23 and 16 tons, respectively.

Advisory services

Any serious problem related to rice production at farmers' field was addressed duly in co-operation with the Department of agricultural Extension (DAE), Bangladesh Agricultural Development Corporation (BADC), Barind Multipurpose Development Authority (BMDA), Seed Certification Agency (SCA) and different NGO's. Field visits were done mainly to address different problems on insect and disease attack, seed sterility at flowering time etc.

BRRI RS, Rangpur

SUMMARY

To develop suitable modern rice varieties for Rangpur-Dinapur region, 20 germplasm were collected from different sources for maintenance breeding, eight single crosses were made and five F_1s were confirmed. 1000 progenies from six F_4, four F_5 and four F_7 generations were selected through field RGA nurseries. A total of 120 plants and three genotypes were selected from observational yield trial (OYT). In total 183 testcross F_1 s were found from source nursery through testcross during Boro season 2021-22.

Under TRB platform, in T. Aus, BR12096-4R-156-1 produced 4.68 t/ha grain yield with in 90 days. Whereas best performing standard check BRRI dhan98 produced 4.76 t/ha grain yield with 110 days. In T. Aman season, for the development of submergence and stagnant flood tolerant rice varieties 44 genotypes from OYT, 20 genotypes from PYT, seven genotypes from AYT, one genotype from ALART (Short duration) and one genotype from ALART (Long duration) were selected.

Under cold tolerant rice variety development, 62 genotypes were selected during Boro season. 23 genotypes were selected from AYT. BR11941-4 R-122 and BR11957-4 R-121 showed highest grain yield 9.1 t/ha. In insect resistant rice breeding program, BR11941-4 R-122 and BR 11957-4 R-121 were selected for high yield potential compared to the standard checks.

In planting time experiment, early seeding of all the tested cultivars accumulated the highest GDD and it decreased with the increase of seeding date. Appreciable better yield was achieved in Rangpur region when BRRI dhan75 was transplanted on 20 July and BRRI dhan87 as well as BRRI dhan93 on 10^{th} of August.

In long-term nutrient omission trial has been running in the BRRI RS, farm, Rangpur since 2014-15 in Boro-Fallow-T. Aman cropping pattern. After seventh cropping year, it is found that N is the most limiting nutrient for rice growth and yield followed by phosphorus, potassium and sulphur irrespective of season.

In determining minimum irrigation water requirement of rice, the control treatment (i.e., continuous standing water in the field) received the highest amount among the treatments while CROPWAT treatments required comparatively less irrigation. Yields were similar in AWD and CROPWAT treatments and yield of control treatment was different than the other two treatments. The AWD treatment received comparatively lower irrigation than continuous standing water treatment. AWD treatment had the highest yield among the treatments, but irrigation application and yields of AWD and CROPWAT treatments did not have any major difference.

A total of 1,535 varietal demonstrations were conducted in Rangpur-Dinajpur region during this reporting period. Under TRB programmes, nine head to head adaptive trials were conducted during the reporting period. Fifteen field days were arranged at different demonstration sites. Under training programme, 834 farmers, 106 SAAOs and 30 seed dealers were trained on modern rice production technology. A total of 1,095 kg, 6,684 kg and 8,434 kg TLS were produced in three seasons. In total of 7,700 kg of breeder seed was sent to GRS Division, BRRI HQ Gazipur. In this reporting period, 9,972 kg TLS was distributed among the farmers for dissemination and popularization of latest BRRI varieties in Rangpur-Dinajpur region.

VARIETAL DEVELOPMENT PROGRAMME (VDP)

Development of rice varieties suitable for T. Aman and Boro season in Rangpur region

In total 20 germplasm were collected from farmers' field and the genebank of Genetic Resources and Seed Division for maintenance of breeding. Eight single crosses were made using ten parents **(Table 1)**. Five F_1s were confirmed **(Table 2)**. Six F_4, four F_5 and four F_7 generations were advanced through field RGA. In total 1000 individual plants were selected from Field RGA **(Table 3)**.

Table 1. List of crosses made, under breeding for standard rice varieties for Rangpur region, 2021-22.

Cross conmibation	F_1 seed	Characteristics
T. Aman, 2021		
BRRI dhan93/Kalijira (Slender)	52	Premium quality
BRRI dhan93/ Kalijira (Short)	35	Premium quality
BRRI dhan93/ Gainja (Red)	84	Premium quality
BRRI dhan93/ Gainja (White)	32	Premium quality
BRRI dhan93/ Kataribhog (Dinajpur)	29	Premium quality
Boro, 2021-2022		
Pusa Basmati-1/BRRI dhan28	17	Premium quality
BR8415-5-4-Rang5-8-1-1-1/ Pusa Basmati-1	19	Premium quality
BR8415-5-4-Rang5-8-1-1-1/ Basmati (Acc. No. 4905)	24	Premium quality

Table 2. List of F_1 confirmed, under breeding for standard rice varieties for Rangpur region, T. Aman, 2021.

BR no.	Crosse	Objective
BRrang38	Swarna5/Malshira	Premium quality
BRrang39	Swarna5/Kalijira (Slender)	Premium quality
BRrang40	Swarna5/Kalijira (Short)	Premium quality
BRrang41	IR4630/Gainza (Red endosperm)	Premium quality
BRrang42	IR4630/Gainza (White endosperm)	Premium quality

Table 3. List of segregating generation in field RGA under breeding for standard rice varieties for Rangpur region, T. Aman 2021.

BR no.	Cross	Objective
F_4 Generation		
BRrang32	BR8470-3-4-Rang2-4-2-2/BRRI dhan34	Premium quality
BRrang33	BR8415-2-2-Rang1-4-1-1-1/BRRI dhan34	Premium quality
BRrang34	BR8415-5-4-Rang5-8-1-1-1/Black rice	Premium quality
BRrang35	BRRI dhan90/BRRI dhan70	Premium quality
BRrang36	BRRI dhan87/Miniket (Dinajpur)	Premium quality
BRrang37	BR8412-5-4-Rang5-8-1-1-1/Black rice	Premium quality
F_5 Generation		
BRrang28	BRRI dhan87/Shompa katari	Premium quality
BRrang29	BRRI dhan87/Swarna5	High yield potential
BRrang30	BRRI dhan87/Black rice (GRSD)	Premium quality
BRrang31	BR8470-3-4-Rang2-4-2-2/BRRI dhan87	High yield potential
F_7 Generation		
BRrang13	Nania/Swarna5	Earliness, PQR and High yield
BRrang14	Nania/Lal Swarna	Earliness, PQR and High yield
BRrang15	Swarna5/Minikit	Earliness, PQR and High yield
BRrang21	BRRI dhan75/ Minikit	Earliness, PQR and High yield

Observational yield trial (OYT)

A total of 150 genotypes were evaluated along with three standard checks viz BRRI dhan52, BRRI dhan75 and BRRI dhan87. In total 120 P/S were selected based on phenotypic acceptance and homogeneity and three fixed genotypes were selected (Table 4).

Table 4. Agronomic parameters of the selected materials from observational yield trial (OYT), T. Aman 2021.

Designation	PHt. (cm)	Mat. (days)	Yield (t/ha)
BRrang13-RGA-5-1-5	100	118	6.0
BRrang13-RGA-5-2-6	102	115	6.3
BRrang13-RGA-5-3-7	110	110	6.5
BRRI dhan52 (ck)	115	142	5.1
BRRI dhan75 (ck)	104	112	4.5
BRRI dhan87 (ck)	121	128	5.4

DS: 12 Jul, 2021; DT: 03Aug, 2021 and Spacing: 20 cm x 20 cm

Constituting of source nursery for evaluation of pyramided restorer lines and resistant elite lines by testcross

Sixteen pyramided lines and 72 elite lines with five CMS lines were estallished in source nursery. In total 183 testcross F_1s were found from source nursery through testcross during Boro season 2021-22. The testcross F_1s along with corresponding male parents and standard checks will be evaluated in testcross nursery during next T. Aman season, 2022.

Regional yield trial (RYT), T. Aman 2021

A total of 15 RYTs were conducted in T. Aman season: three short slender, three long slender, three extra slender, two rainfed lowland rice (RLR), two salinity tolerance rice (STR), one zinc enriched rice (ZER) and one drought tolerance rice (DTR) were tested against standard check varieties.

RYT#1 (Short Slender; BRRI Rangpur). Four genotypes along with three checks; BRRI dhan49, BRRI dhan87 and Zirasail were evaluated. None of the tested genotypes were found higher yielder over the check varieties.

RYT#1 (Short slender; Parbortipur, Dinajpur). Four genotypes along with three checks; BRRI dhan49, BRRI dhan87 and Zirasail were evaluated. BRH10-1-14-2-6B produced the highest yield (5.06t/ha) over the checks.

RYT#3 (Short Slender. Chirirbondor, Dinajpur): Four genotypes along with three checks; BRRI dhan49, BRRI dhan87 and Zirasail were evaluated. BRH13-1-9-7B produced highest yield (5.03t/ha) over the checks.

RYT#4 (Long Slender; BRRI RS, Rangpur). Five genotypes along with two checks; BRRI dhan49 and BRRI dhan87 were evaluated. BR10247-14-18-4 produced the highest yield (5.05 t/ha) over the checks.

RYT#5 (Long slender; Parbortipur, Dinajpur). Five genotypes along with two checks BRRI dhan49 and BRRI dhan87 were evaluated. BR9392-1-9-7-5B produced the highest yield (4.92 t/ha) over the checks.

RYT#6 (Long slender; Chirirbondor, Dinajpur). Five genotypes along with two checks; BRRI dhan49 and BRRI dhan87 were evaluated. BR9392-10-20-1B produced the highest yield (4.83 t/ha) over the checks.

RYT#7 (Extra long slender; BRRI RS, Rangpur). Three genotypes along with two checks BRRI dhan70 and Zirasail were evaluated. BRH11-2-4-7B produced the highest yield (5.72 t/ha) followed by IR12A177 (5.66 t/ha) over the checks.

RYT#8 (Extra long slender; Parbortipur, Dinajpur). Three genotypes along with two checks BRRI dhan70 and Zirasail were evaluated. BRH11-2-4-7B produced the highest yield (5.4t/ha) followed by BR238-5-1-4-2 (4.8 t/ha).

RYT#9 (Extra long slender; Chirirbondor, Dinajpur). Three genotypes along with two checks BRRI dhan70 and Zirasail were evaluated. BRH11-2-4-7B produced the highest yield (4.4t/ha) followed by IR12A177 (3.61 t/ha).

RYT#10 (RLR-1). Five genotypes along with standard checks BRRI dhan49 and BRRI dhan71 were evaluated. SVIN209 produced the highest yield (6.16t/ha) with 131 days among the tested entries.

RYT#11 (RLR-2). Two genotypes along with three standard checks BRRI dhan49, BRRI dhan71 and BRRI dhan87 were evaluated. None of the tested genotypes were found highes yielder over the check variety.

RYT#12 (STR-1). Eight genotypes along with two standard checks BRRI dhan73 and BRRI dhan87 were evaluated. BR11716-4R-120 produced the highest yield (4.76t/ha) with 121 days among the tested entries.

RYT#13 (STR-2). Eight genotypes along with two standard checks BRRI dhan73 and BRRI dhan87 were evaluated. BR11716-4R-129 produced the highest yield (5.33t/ha) followed by BR11723-4R-172 (4.87 t/ha) among the tested entries.

RYT#14 (ZER). Two genotypes along with two standard checks BRRI dhan72 and BRRI dhan87 were evaluated. BR10005-25-8-4-7-20 produced the highest yield (4.41 t/ha) with 117 days.

RYT#15 (DTR). Four genotypes were tested along with two checks BRRI dhan56 and BRRI dhan71. BR10538-2-1-2-3-2 produced the highest yield (4.23 t/ha) ovar all tested entries having similar growth duration with BRRI dhan56 (110 days).

Regional yield trial (RYT), Boro 2021-22

a total of 20 ryts were conducted during boro season: two cold tolerant rice (CTR), three favorable boro rice (FBR), one aggrinet, three disease resistant rice (DRR), one zinc enriched rice (ZER), one premium quality rice (PQR), one insect resistant rice (IRR), one zira type (ZIRA), one short slender (SS), one long slender (LS), one favourable boro rice (Biotechnology), one favourable boro rice (fbr-barishal), and five late boro against standard check varieties.

RYT# 1 (CTR-1). Six genotypes along with thee checks BRRI dhan28, BRRI dhan69 and BRRI dhan96 were evaluated. BR11894-R-R-R-R-230 (5.87 t/ha) performed better over the checks.

RYT# 2 (CTR-2). Six genotypes along with thee checks BRRI dhan67, BRRI dhan89 and BRRI dhan92 were evaluated. BR11894-R-R-R-R-80 (617 t/ha) performed better but none of the entries were selected.

RYT# 3 (FBR-1; SD). Four genotypes along with two checks BRRI dhan81 and BRRI dhan96 were evaluated. IR17A1694 (6.46 t/ha) produced the highest grain yield among the all tested entries.

RYT# 4 (FBR-1; MD). Thirteen genotypes along with two checks BRRI dhan81 and BRRI dhan96 were evaluated. BR11318-5R-63 were produced the highest grain yield (7.27 t/ha) followed by BR9945-5R-21 (7.10 t/ha).

RYT# 5 (FBR-1; LD). Nine genotypes along with two checks BRRI dhan89 and BRRI dhan92 were evaluated. None of the entries produced higher grain over the standard check varieties.

RYT# 6 (AGGRINET). Seven advanced genotypes along with four standard checks BRRI dhan63, BRRI dhan81, BRRI dhan89 and BRRI dhan92 were evaluated. IR17A2593 produced the highest grain yield (6.91 t/ha) followed by IR16A3667 (6.90 t/ha).

RYT#7 (DRR#1). Twelve genotypes along with BRRI dhan88 and IRBB60 were evaluated. BR11607-4R-6 (5.43 t/ha) and BR11607-4R-111(5.30 t/ha) performed better than the standard check varieties.

RYT#8 (DRR#2). Fourteen genotypes along three checks; BRRI dhan58, BRRI dhan89 and IRBB60 (Resistant check) were evaluated. BR11607-4R-2 (6.05 t/ha) and BR11607-4R-20 (5.82 t/ha) performed better than the standard check varieties.

RYT#9 (DRR#3). Twelve genotypes along two checks BRRI dhan88 and IRBB60 (Resistant check) were evaluated. BR11607-4R-6 (5.43 t/ha) and BR11607-4R-111 (5.40 t/ha) performed better than the standard check varieties.

RYT#10 (ZER). Two genotypes were evaluated along with the two checks BRRI dhan29, BRRI dhan74 and BRRI dhan84. BR9674-4-2-10-5-P9 produced the highest grain yield (7.32 t/ha and within 170 days) perfomed better over the check varieties.

RYT#11 (PQR). Two genotypes were evaluated along with the checks BRRI dhan50, BRRI dhan63 and BRRI dhan81. BR10322-23-1-2-4 (6.44 t/ha; 159 days) performed better than the standard checks.

RYT#12 (IRR). Seven genotypes were evaluated along with three checks BRRI dhan58, BRRI dhan88 and T27A (Resistant check). BR11593-5R-73 produced the highest grain yield (6.06 t/ha; 163 days) among the tested entries.

RYT#13 (Zira type). Three genotypes were evaluated along with two checks BRRI dhan81 and Zirashail. BRH13-9-5-3B produced the highest grain yield (7.13 t/ha within 160 days) followed by BRH11-7-17-10B (6.47 t/ha within 162 days). Zirashail produced 4.35 t/ha grain yield within 162 days.

RYT#14 (Short slender). Five genotypes were evaluated along with two checks BRRI dhan28 and BRRI dhan81. BRH13-2-4-7-2B produced highest grain yield (8.02 t/ha; 153 days) followed by BRH10-1-14-2-6B (7.37 t/ha; 154 days). On the contrary, BRRI dhan81 produced 5.55 t/ha grain yield with 150 days.

RYT#15 (Long slender). Three genotypes were evaluated along with one check BRRI dhan28. BRH11-2-4-7B produced the highest grain yield (7.86t/ha; 154 days) followed by BR10247-4-7-4B

(6.29 t/ha; 154 days). On the otherhand, BRRI dhan28 produced 5.78 t/ha grain yield with 149 days.

RYT#16 (Biotechnology). Two genotypes were evaluated along with two checks BRRI dhan88 and BRRI dhan96. None of the tested genotypes performed better than the standard checks.

RYT#17 (FBR; Barishal). Nine genotypes were evaluated against BRRI dhan58 and BRRI dhan89. NGR1308-2 (7.90 t/ha with 160 days) was perfomed better over BRRI dhan58 (7.87 t/ha with 159 days).

RYT#18 (BRAUS-1; Parbortipur, Dinajpur). Five genotypes were evaluated against four checks BRRI dhan28, BRRI dhan58, BRRI dhan74 and BINA dhan14. HHZ5-DT20-DT20-DT1 perfomed better than the test entries. It produced 4.54 t/ha with only 110 days.

RYT#19 (BRAUS-2; Saidpur, Nilphamari). Five genotypes were evaluated against four checks BRRI dhan28, BRRI dhan58, BRRI dhan74 and BINA dhan14. None of the entries performed better than the standard checks.

RYT#20 (BRAUS-3; Dorshona, Rangpur). Five genotypes were evaluated against four checks; BRRI dhan28, BRRI dhan58, BRRI dhan74 and BINA dhan14. None of the entries performed better than the standard checks.

Multilocation Trail (MLT)

T. Aman 2021

MLT#1 (Disease resistant rice; DRR). Three advanced genotypes along with the check varieties BRRI dhan49, BRRI dhan87 and IRBB60 were evaluated. None of the entries performed better than the check varieties.

Boro 2021-2022

MLT#1: Blast resistant advanced lines (Mithapukur-Rangpur)

Ten advanced genotypes along with four check varieties BRRI dhan28, BRRI dhan29, BRRI dhan63, and BRRI dhan64 were evaluated. AL75 produced the highest grain yield (8.69 t/ha) followed by HGG205 (8.21 t/ha). Neck blast infection score was below 10% in those selected genotypes.

MLT#2: Blast resistant advanced lines (Mithapukur-Rangpur)

Eight advanced genotypes along with two check varieties BRRI dhan29 and BRRI dhan58 were evaluated. BR (Path) 13800-BC3-134-96 produced the highest grain yield (8.28 t/ha) followed by BR (Path) 13800-BC3-134-252 (8.06 t/ha). Neck blast infection score was below 10% in the selected genotypes.

MLT#3: Blast resistant advanced lines (BRRI Rangpur)

Seven advanced genotypes along with three check varieties BRRI dhan29, BRRI dhan89 and BRRI dhan92 were evaluated. BR (Path) 12454-BC2-87-24-32-1-29 produced similar grain yield (7.9t/ha) with BRRI dhan89 (7.9 t/ha). Neck blast infection score was below 10% in this selected genotype.

MLT#4: Blast resistant advanced lines (Mithapukur-Rangpur)

Seven advanced genotypes along with three check varieties BRRI dhan29, BRRI dhan89 and BRRI dhan92 were evaluated. BR (Path) 12454-BC2-56-81-27-3-30 produced highest grain yield (8.77t/ha) folloed by BRRI dhan92 (8.37 t/ha). Neck blast infection score was below 10% in the selected genotype.

Advanced Line Adaptive Research Trial (ALART)

A total of 29 ALARTs were conducted under T. Aman 2021 and Boro 2021-22 seasons. In T. Aman 2021, IR16F1148 performed better than the standard checks (BRRI dhan71 and BINA dhan11). One genotype (BRBa 2-5-3) from FBR_Barishal and one genotupe (BRH13-2-4-6-4B) from (SHR) performed better than the standard checks during Boro 2021-22 season.

Proposed variety trial (PVT)

In total five PVTs were conducted under T. Aus 2021 T. Aman 2021 and Boro 2021-22 seasons. In T. Aus 2021 season, two PVTs (I-029 to I-032); one PVTs in T. Aman 2021 season (I-033 to I-035) and Three PVTs in Boro 21-22 Season (I-036 to I-041) were conducted to develop rice varieties.

TRB project

T. Aus 2021

DEVELOPMENT OF SHORT DURATION T. AUS RICE VARIETIES

In OYT, 384 fixed lines with three standard checks BRRI dhan48, BRRI dhan82 and BRRI dhan98 were tested by following non-replicated Augmented RCB design. Among the tested genotypes we have selected 57 genotypes based on phenotypic acceptance and grain yield (≥3.50 t/ha) for next generation yield trial. Plant height ranged from 88 to 142 cm and growth duration ranged from 98 to 116. In this trial, the genotype BR12096-4R-127-1 with 111 days growth duration produced the highest grain yield (5.51 t/ha). Also genotype BR12096-4R-156-1 produced 4.68 t/ha grain yield with 90 days growth duration. Whereas best performing standard check BRRI dhan98 produced 4.76 t/ha grain yield with 110 days growth duration. Among the tested genotypes the yield range of six genotypes were 5.18 t/ha to 5.1 t/ha.

It also mentioned that we have found acceptable heritability likely 78%, 85%, 76% and 41%, which ensure the precision of the trial.

In PYT, 37 advanced lines with three were tested standard checks BRRI dhan48, BRRI dhan82 and BRRI dhan98 were tested by following augmented row-column design. Among the tested genotypes we have selected 10 genotypes based on phenotypic acceptance and grain yield for next generation yield trial. Plant height ranged from 119 to 124 cm and growth duration ranged from 99 to 118 days**.** The highest yield was found in BR11863-5R-256 (4.35 t/ha) with 99 days growth durations. Whereas standard check BRRI dhan98 produced 3.55 t/ha grain yield with 107 days growth durations. It also mentioned that we have found acceptable heritability likely 54%, 92%, 64% and 74%, which ensure the precision of the trial.

In AYT, 48 genotypes with two checks BRRI dhan48 and BRRI dhan98 were evaluated using raw-column design. Among the tested genotypes we have selected 13 genotypes based on phenotypic acceptance and grain yield (≥3.00 t/ha) for next generation yield trial. Plant height ranged from 98 to 114 cm and growth duration ranged from 98 to 117 days**.** The highest yield was found in BR11578-4R-69-1 (4.22 t/ha) with 116 days growth durations. Whereas best performing check variety BRRI dhan98 produced 3.57 t/ha grain yield with 100 days growth duration. We have found acceptable heritability likely 82%, 91%, 64%, 88% and 87 % which ensure the precision of the trial.

Investigators: Anisar Rahman, M M Rana, M R Hassan, Sanjoy Debsharma and M Khatun

T. Aman 2021

DEVELOPMENT OF SUBMERGENCE AND STAGNANT FLOOD TOLERANT RICE VARIETIES

In different yield trial, 999 genotypes were tested in five locations (stress: Bhogdanga, Kurigram; Kodalkhata, Lalmonirhat; Aditmari, Lalmonirhatout; Control stress: Submergence Tank, BRRI RS, Rangpur; Non-stress: Darshana, Rangpur) of northern region of Bangladesh. Among the tested genotypes 140 genotypes were selected based on phenotypic acceptance, growth duration, survivability and higher yield performance.

From OYT#1 fifteen genotypes out of 98 genotypes, from OYT#2, 10 genotypes out of 50, from OYT#3, nineteen genotypes out of 42, from PYT-Early eleven genotypes out of 21 from PYT-Late, nine genotypes out of 18, from SYT-Early, 16 genotypes out of 28, from SYT-Late, nine genotypes out of 16, from SYT-Tall, five genotypes out of 12, from AYT, seven genotype out of 12, from ALART (Short duration), one genotypes out of two, from ALART (Long duration), one genotype out of three were selected.

In OYT#1, the genotype BR11694-5R-202 and BR10212-10-4-1 with83% and 95% survivability produced the highest yield of 7.23 t/ha under stress condition.

In OYT#2 the genotype BR12154-5R-159 produced higher yield (7.3 t/ha) under stress with 88.3% survivability.

In OYT#3, the genotype BR11690-5R-56 produced the highest yield (6.85 t/ha) followed by the genotype BR12162-5R-319 (6.84 t/ha) having a survivability of 63.3% and 95 % survivability respectively.

In PYT-Early, produced the highest yield 6.43 t/ha given by the genotype BR11694-5R-125 with survivability of 90%.

In PYT-Late, the genotype BR11686-5R-179 produced the highest yield (7.88 t/ha) with 95% survivability and 153 days growth duration.

In SYT-Early, the genotype IR16F1033 produced the highest yield (7.74 t/ha) with 88.8% survivability and 144 days growth duration.

In SYT-Late, the genotype IR19L1016 produced the highest yield of 6.53 t/ha with 80.0% survivability and 152 days growth duration.

In SYT-Tall, the genotype IR15F1764 produced the highest yield of 6.93 t/ha with 80% survivability and 163 days growth duration under stress.

From AYT, three genotypes viz IR13F652-1-PS2, IR16F1063and IR16F1081 produced higher yield under stress (6.59 t/ha, 6.63 t/ha and 6.24 respectively) with survivability of 78%, 93% and 74 % respectively. Yield and survivability were significantly higher than the check varieties BRRI dhan79 (5.10 t/ha) with 66% survivability. These three genotypes were also promoted to PVS.

From ALART-Short duration, advanced lines IR16F1148-LS produced the highest average grain yield (5.83 t/ha) with 92% survivability which is significantly higher than check variety BINA dhan11 (5.31 t/ha grain yield with 86% survivability). This genotype was promoted to PVT.

In ALART-Long duration, Advanced line IR13F441 produced the highest 6.01 t/ha grain yield with 88.01 % survivability. These genotypes will be RE-ALART for Barishal region in the next season.

The heritability obtained for grain yield under stress of all trials conducted was ranging from 51 % to 98%, while that for non-stress trials was ranging from 54 % to 89%, indicating acceptable level of precision in this experiment.

Investigators: Anisar Rahman, M R Hassan, M A Badshah, Sharmistha Ghosal, Z A Riyad, **and** K M Iftekharuddaula

AGGRI MEDIUM DURATION 2021 WET SEASON TRIAL (SUBMERGENCE)

The main objective of this trial was selection of best performing parental materials with better phenotypic acceptability and higher survivability under controlled submerged condition. Under submergence tolerance breeding programme, 265 breeding lines along with 10 national and five international check varieties were evaluated under rainfed and stress condition at BRRI regional station Rangpur. The experiments were conducted following Alpha Lattice design with two replications. Data were analyzed separately under each ecosystem and genotypes were selected based on phenotypic acceptance, uniformity, survivability, growth duration, yield for the submergence screening and rainfed condition trials. A wide range of variation was observed among the genotypes. The survivability was ranged from 0 to 100%. Based on the phenotypic acceptability, higher survivability, and grain yield, 37 genotypes were selected for yield trials. These lines will be used for further screening and evaluated in Advanced Yield Trial.

Investigators: Anisar Rahman, MR Hasan, Sharmistha Ghosal, Z A Riyadh **&** KM Iftekharuddaula

DEVELOPMENT OF DROUGHT TOLERANT RICE VARIETIES

A total of 729 fixed lines from previous LST trial with three the standard checks BRRI dhan49, BRRI dhan56 and BRRI dhan71 were tested by following non-replicated Augmented RCB design in three OYTs. During panicle initiation (PI) to hard dough stage there was no rainfall and supplementary irrigation. As a result the underground water table was below 100 cm which is ideal condition for evaluating drought stress tolerant material.

In OYT-1 (Growth duration: 90-110 days), 10 advanced lines were selected among 30 fixed lines based on phenotypic acceptance, plant height, response to drought stress, growth duration and grain yield. Advanced line BR12022-6R-71 produced 4.68 t/ha grain yield whereas BRRI dhan71 produced 4.24 t/ha grain yield.

In OYT-2 (Growth duration: 111-120 days), 70 advanced lines were selected among 480 fixed lines based on phenotypic acceptance, plant height, response to drought stress, growth duration and grain yield. Advanced breeding lines BR11250-6R-28, BR11729-6R-130 and BR11246-6R-67 respectively produced 5.98 t/ha, 5.33 t/ha and 5.15 t/ha grain yield. Whereas the best performing check BRRI dhan71 produced 5.46 t/ha grain yield.

In OYT-3 (Growth duration: 121-130 days), 15 advanced lines were selected among 230 fixed lines based on phenotypic acceptance, plant height, response to drought stress, growth duration and grain yield. Advanced line BR11742-6R-26, BR12019-6R-155 and BR11742-6R-30 respectively produced 5.18 t/ha, 4.36 t/ha and 4.22 t/ha grain yield whereas BRRI dhan71 produced 4.18 t/ha grain yield.

Investigators: Anisar Rahman, M M Rana, M R Hassan, R R Mazumdar and MA Kader.

DEVELOPMENT OF DISEASE RESISTANCE (BLB, RTV, NB) RICE VARIETIES FOR TRANSPLANTED AMAN

A total of 101 fixed lines from previous LST and OYT trial with standard checks BRRI dhan49 and BRRI dhan87 as well as the resistance check IRBB60 were tested by following non-replicated Augmented RCB design for OYT and Row-column design for PYT trial. In total 23 genotypes were selected based on disease infestation, phenotypic acceptance, growth duration and higher yield performance.

In OYT, the yield range was 2.33-7.25 t/ha where, growth duration range was 120-145 days. Among eight selected genotypes, BR11993-4R-2-1, BR11987-4R-156-1 and BR12098-4R-185-1 produced 7.25 t/ha, 6.74 t/ha and 5.95 t/ha grain yield respcetuively. On the other hand, best performing check variety BRRI dhan87 produced 5.35 t/ha grain yield.

In PYT trial, the yield was range from 3.03 to 7.23 t/ha and growth duration was ranged from 120 to 145 days. Among fifteen selected genotypes, BR11869-5R-73, BR11871-5R-127 and BR11869-5R-276 produced 7.23 t/ha, 6.68 t/ha and 6.39 t/ha grain yield. Whereas the best performing check variety BRRI dhan87 produced 4.97 t/ha grain yield.

Investigators: Anisar Rahman, M M Rana, M R Hassan, Sanjoy Debsharma and M Khatun.

DEVELOPMENT OF INSECT RESISTANCE RICE (BPH) FOR T. AMAN SEASON

A total of 527 fixed lines from the previous LST and PYTs with four standard checks BRRI dhan33, BRRI dhan49, BRRI dhan52 & BRRI dhan87 were tested by following non-replicated Augmented RCB design for OYT and Row-column design for PYT trial. In total 77 genotypes were selected based on Insect SES score, phenotypic acceptance, growth duration and higher yield performance.

In OYT, 62 genotypes were selected out of 432. The yield range was 1.46-8.11 t/ha where, Growth duration range was 97-156 days. Advanced breeding lines BR12180-5R-51, BR12208-5R-345, BR12208-5R-80, BR12211-5R-176 and BR12186-5R-42 produced 8.11 t/ha, 7.72 t/ha, 7.05 t/ha, 7.01 t/ha and 6.53 t/ha grain yield. On the other hand, best performing check variety BRRI dhan49 produced 5.27 t/ha grain yield.

In AYT trial, the yield was ranged from 1.51 to 5.81 t/ha and growth duration was range from 117-147 days. Among fifteen selected genotypes, BR11295-4R-435, BR11295-4R-197, IRBPHN-SVIN013-18 and BR11052-4R-46 produced 5.81 t/ha, 5.71 t/ha, 5.65 t/ha and 5.57 t/ha grain yield. Whereas best performing check variety BRRI dhan49 produced 4.87 t/ha grain yield.

- **Investigators:** Anisar Rahman, M M Rana, M R Hassan and M R A Sarkar.

DEVELOPMENT OF RAINFED LOWLAND RICE (RLR) FOR T. AMAN SEASON

The aim of the project is to develop Favourable rice variety for T. Aman season with shorter growth duration ('≤ 130 days) and high yielding potential (≥ 6.5 t/ha), better phenotypic acceptance and grain quality. A total of 699 fixed lines from previous LST trial with six standard checks BRRI dhan49, BRRI dhan57 and BRRI dhan62, BRRI dhan71, BRRI dhan75 and BRRI dhan87 were tested by following non-replicated Augmented RCB design in four OYTs.

In OYT-1, 21 advanced lines were selected among 104 fixed lines based on phenotypic acceptance, plant height, response to drought stress, growth duration and grain yield. The yield and growth duration range of this trial were 2.28-7.60 t/ha and 110-153 days respectively. Advanced lines BR12000-6R-172 and BR10796-6R-133 produced 7.60 t/ha and 7.00 t/ha grain yield respectively.

In OYT-2 trial, 35 advanced lines were selected among 192 fixed lines based on phenotypic acceptance, plant height, response to drought stress, growth duration and grain yield. The yield and growth duration range of this trial were 1.76-7.17 t/ha and 102-153 days respectively. Advanced breeding lines BR12007-6R-92 produced 7.17 t/ha grain yield. Whereas the best performing check BRRI dhan71 produced 6.56 t/ha grain yield.

In OYT-3 trial, 23 advanced lines were selected among 289 fixed lines based on phenotypic acceptance, plant height, response to drought stress, growth duration and grain yield. The yield and growth duration range of this trial were 1.33-7.53 t/ha and 109-152 days respectively. Advanced lines BR11338-6R-192 and BR11333-6R-73 respectively produced 7.53 t/ha 6.99 t/ha grain yield.

OYT-4 was a photosensitive trial, here, 12 advanced lines were selected among 114 fixed lines based on phenotypic acceptance, plant height, response to drought stress, photosensitivity and grain yield. The yield and growth duration range of this trial were 1.04-7.06 t/ha and 126-151 days respectively. Advanced line BR10802-6R-242 produced 7.06 t/ha grain yield.

- **Investigators:** Anisar Rahman, M M Rana, M R Hassan, R R Mazumdar and M A Kader.

EVALUATION OF ELITE BREEDING POOL OF TRANSPLANTED AMAN FOR BREEDING VALUE ESTIMATION

The main objective of this trial is to identify superior parents with ≥5.0 t/ha grain yield with superior plant type, disease and insect resistance and fine grain quality. This trial is composed of 180 advanced breeding lines and five standard checks of T. Aman season which is implemented by following augmented RCB design.

In this trial 46 parental genotypes were selected with different trait panel where 16 genotypes produced ≥5.00 t/ha grain yield

- **Investigators:** Anisar Rahman, M R Hasan, M M Emam Ahmed, Dr Ruhul Amin Sarker and Partha Sarathi Piswas.

BORO 2021-2022

DEVELOPMENT OF FAVOURABLE BORO AND COLD TOLERANT RICE VARIETIES.

The project aims are to develop favourable Boro and seedling and reproductive stage cold tolerant rice verities for stress prone environment. In different yield trials, 321 genotypes were tested out of which 62 were selected based on cold tolerant (SES), phenotypic acceptance, growth duration, and yield performance.

From OYT (FBC) 54 genotypes out of 300, from AYT (cold)-AGGRi Network eight genotypes out of 21 were selected.

In OYT (FBC), the genotypes BR12510-5R-42 produced the highest grain yield (8.72 t/ha) with 166 days growth duration and 1 cold (SES) score at seedling stage. Among the tested genotypes, 14 genotypes produced yield from 7.02 t/ha to 7.91 t/ha and 12 genotypes produced 6.00 t/ha to 6.96 t/ha grain yield.

In AYT (Cold), the genotypes IR17A1275 produced 8.97 t/ha grain yield with 149 days growth duration and 1 Cold (SES) score. Among the tested genotypes eight genotypes produced yield from 7.00 t/ha to 8.68 t/ha.

In estimation of breeding value (EBV) trial, 65 genotypes were selected as parents for future breeding programme based on phenotypic acceptance, plant and grain type, disease and insect response, and grain yield.

Investigators: Anisar Rahman, M R Hasan, M M Emam Ahmed, Dr Ruhul Amin Sarker and Partha Sarathi Piswas.

DEVELOPMENT OF INSECT RESISTANCE (BPH) RICE VARIETIES:

The project aims are to development of major insect (BPH) resistance rice varieties for insect affected target region of Bangladesh. In OYT experiment, a total of 71 genotypes were selected out of 292 genotypes based on phenotypic acceptance, growth duration, and yield performance. Fifteen genotypes did not show any BPH symptom. Ten genotypes showed BPH score 1, 15 genotypes showed BPH score 3 and the remaining genotypes showed BPH score 5 to 9. The highest grain yield (9.49 t/ha) were found in both genotypes BR12671-4R-89 and BR12671-4R-77 with 166 days growth durations. Twelve genotypes produced more than 8.00 ton/ha grain yield.

In PYT, total 87 genotypes were evaluated with standard checks BRRI dhan88, BRRI dhan89, BR3 (S. ck) and T27A (R. ck) during Boro 2021-2022. 25 genotypes were selected based on phenotypic acceptance, insect resistance score and grain yield. Advanced genotypes BR12180-5R-73 showed highest grain yield 8.76 t/ha. Twenty-five genotypes produced more than 6.5 t/ha grain yield.

In AYT, in total 60 genotypes were evaluated with the standard checks BRRI dhan88, BRRI dhan89 and BRRI dhan92 during Boro 2021-2022. 23 genotypes were selected based on phenotypic acceptance, insect resistance score and grain yield. Advanced genotypes BR 11941-4 R-122 and BR 11957-4 R-121 showed highest grain yield 9.1 t/ha. It also mention that 20 genotypes produced 6.5 to 8.75 t/ha grain yield.

- **Investigators:** M A Rahman, M R Hassan M R A Sarker, M A Rahman **&** H Khatun.

DEVELOPMENT OF DISEASE RESISTANCE (BB, RTV AND BLAST) RICE VARIETIES

In different yield trial7s, 377 genotypes were tested out of which 111 genotypes were selected based on Disease infestation, phenotypic acceptance at maturity stage, growth duration and yield performance.

From OYT 72 genotypes out of 282, from AYT#1, 22 genotypes out of 50, from AYT#2, 10 genotypes out of 40 and from AYT#3 7 genotypes out of 15 genotypes were selected for further yield conformation.

In OYT (BB), the genotype BR12116-5R-147 produced the highest yield of 9.26 t/ha with 165 days growth duration. Three genotypes produced more than 8 t/ha yield, 13 genotypes produced more than 7 t/ha grain yield. Where the best performing check variety BRRI dhan58 produced 7.19 t/ha grain yield with 157 days growth duration.

In AYT#1 (BB), the best performing genotype BR11868-5R-124 produced 9.715 t/ha grain yield with 162 days growth duration, better phenotypic acceptance (PAcp=3) and no visible BLB and blast infestation. Among the tested genotypes, 11 genotypes produced grain yield 7.00 t/ha to 8.9 t/ha with no BLB and blast disease symptom. On the other hand best performing standard check variety BRRI dhan88 produced 6.06 t/ha grain yield with 150 days growth duration.

In AYT#2 (BB), the highest grain yield (8.68 t/ha) was found in genotype BR11560-4R-19 with 157 days growth duration, 3 PAcp score and with no BLB, Blast & other disease symptom. Where standard check BRRI dhan58 produced 7.30 t/ha grain yield with 157 days growth duration. . Among the tested genotypes, 10 genotypes produced grain yield 7 t/ha to 8.81 t/ha with no BLB and blast disease symptom.

In AYT#3 (BB), the highest grain yield (6.87 t/ha) was found in genotype BR12096-4R-124-1with 161 days growth duration. Among the tested genotypes, four genotypes produced grain yield 6.5

t/ha to 6.83 t/ha with no BLB and blast disease symptom.

- **Investigators:** Anisar Rahman, M R Hassan, Sanjoy Debsharma and M Khatun.

DEVELOPMENT OF PREMIUM QUALITY RICE (PQR)

The main objective of this programme is to develop fine grain with aroma or without aroma consisting rice variety with more than 6.5 t/ha grain yield. A total of 200 fixed lines with four checks BRRI dhan50, BRRI dhan63, BRRI dhan81 and BRRI dhan92 were evaluated by following augmented RCB design. Among three OYT trial, OYT-2 trial was completely damaged by GTCL gass line construction work.

In OYT-1, four genotypes were selected out of 34. The best performing genotype BR11359-4R-230 and BR11359-4R-263 produced 6.81 t/ha and 6.79 t/ha grain yield with 154 days growth duration respectively. Where best performing check variety BRRI dhan63 produced 5.60 t/ha grain yield with 151 days growth durations.

In OYT-2 trial, 10 genotypes were selected out of 46 genotypes. The best performing genotype BR11371-4R-511 produced 6.04 t/ha grain yield with 155 days growth duration. Where best performing check variety BRRI dhan50 produced 5.54 t/ha grain yield with 156 days growth durations.

- **Investigators:** Anisar Rahman, M R Hassan, R R Mazumdar and MA Kader.

INTERNATIONAL NETWORK FOR GENETIC EVALUATION OF RICE (INGER)

One trial (2021 IRLON_SET21) was conducted in BRRI Rangpur during T. Aman 2021 season. In IRLON, 72 entries including checks were tested following augmented design and three genotypes were selected for using in crossing programme.

CROP-SOIL-WATER MANAGEMENT

PROGRAM 1: INFLUENCE OF DATES OF TRANSPLANTING ON THE YIELDS OF RICE

Planting time may play the deciding role in performance of rice, hence choosing the right timing for transplanting under specific agro-climatic conditions is the key to successful rice cultivation under changing climatic scenarios. The experiment was conducted at BRRI RS farm, Rangpur aimed to identify a suitable planting window of short (BRRI dhan75), medium (BRRI dhan87) and long (BRRI dhan93) duration cultivars to maximize grain yield. The selected cultivars were planted five different dates at 10 days interval from July 10th to August 20th. Twenty-five-day-old seedlings were transplanted following randomized complete block design with three replications. All agronomic practices were performed uniformly for all the treatments. Data of agronomic parameters i.e. panicle number/hill, grains/panicle and yield were collected at harvest. Results showed that there was a significant effect of date of transplanting on the yield of potential of the tested varieties in T. aman season (Table 5). Early seeding of all the tested cultivars accumulated the highest GDD and it decreased with the increase of seeding date (Table 6). Early transplanting of BRRI dhan75 (10 to 20 July) produced greater number of panicles/hill, grains/panicle and grain yield than the delayed transplanting. BRRI dhan87 and BRRI dhan93 transplanted on 10 August produced higher number of panicles/hill, grains/panicle and grain yield (Table 5 and 6). The tested varieties transplanted on 30 July were found to have less number of grains/panicle and yield. This happened due to the continuous rainfall at flowering stage in the 1st week of October that hampered pollination and seed setting. In conclusion, to achieve appreciable better yield in the Rangpur region, BRRI dhan75 should preferably be transplanted on 20 July and BRRI dhan87 as well as BRRI dhan93 on 10 of August.

M M Rana, T K Roy and M R Hasan

Table 5. Effect of planting time on the panicles/hill and number of grains/panicle of rice in T. Aman, 2021 season at BRRI RS, Rangpur.

Variety	Date of transplanting									
	10 July		20 July		30 July		10 August		20 August	
	Panicle no./Hill	Grains/ panicle	Panicle no./Hill	Grains/ panicle	Panicle no./Hill	Grains/ panicle	Panicle no./Hill	Grains/ panicle	Panicle no./Hill	Grains/ panicle
BRRI dhan75	11.60	114.33	10.736	111.66	9.93	77.66	10.46	86.66	9.86	86.66
BRRI dhan87	10.40	82.66	8.73	102.33	9.70	79.00	8.80	130.00	9.53	125.33
BRRI dhan93	9.00	93.00	10.00	122.33	9.46	110.00	10.46	129.33	8.60	120.33
Lsd (0.05)	1.82	26.00	2.66	26.74	2.11	30.73	3.10	34.41	1.62	17.44
CV	7.8	12.1	12.1	10.5	9.7	15.3	13.7	13.2	7.80	7.00

Table 6. Effect of planting time on the GDD accumulation and yield of rice in T. Aman 2021 season at BRRI RS, Rangpur.

Variety	Date of transplanting									
	10 July		20 July		30 July		10 August		20 August	
	Yield (t/ha)	GDD (ºC)	Yield (t/ha)	GDD (ºC)	Yield (t/ha)	GDD (ºC)	Yield (t/ha)	GDD (ºC)	Yield (t/ha)	GDD (ºC)
BRRI dhan75	5.30	2051.00	5.46	2090.37	3.76	2115.60	4.90	2174.10	4.84	1961.50
BRRI dhan87	3.68	2284.37	5.19	2280.83	4.01	2198.93	5.92	2098.37	5.71	2027.93
BRRI dhan93	4.48	2510.40	6.17	2440.50	5.43	2323.53	7.05	2231.73	6.76	2119.27
Lsd (0.05)	0.81	51.93	1.13	16.55	1.23	54.42	1.43	139.29	0.81	44.77
CV	8.1	1.00	8.9	0.30	12.3	1.10	10.4	2.80	5.9	1.00

LONG-TERM MISSING ELEMENT TRIAL AT BRRI RS, RANGPUR

Long-term nutrient omission trial is an effective tool for identifying the contribution of nutrients in crop production. In order to find out the role of major macro and micronutrients, a long- term field experiment has been running in the BRRI RS farm, Rangpur since 2014-15 in Rice-Fallow–Rice cropping pattern. The experiment includes seven treatments [T_1=Fertilizer control, T_2= NPKSZn, T_3= PKSZn (-N), T_4= NKSZn (-P), T_5= NPSZn (-K), T_6= NPKZn (-S), T_7=NPKS (-Zn)] which were designed in RCB with three replications. HYV rice has been growing in Boro-Fallow-T. Aman cropping pattern. Omission of major nutrients significantly reduced the grain yield. After seventh cropping year we found that N is the most limiting nutrient for rice growth and yield followed by phosphorus, potassium and sulphur irrespective of season at BRRI RS farm Rangpur (Table 7 and 8).

A T M Sakhawat Hossain, M I U Sarkar, Md Rokebul Hasan and Aminul Islam

Table 7. Effect of long-term missing element on the tiller, panicle, grain and straw yield of BRRI dhan87 at BRRI farm, Rangpur in T. Aman 2021.

Treatment	Tiller/m^2	Panicle/m^2	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	(%) Grain yield decreased due to nutrient omission
T_1	159 b	150 b	3.56 c	3.71 c	-
T_2	274 a	265 a	5.54 a	5.73 a	-
T_3	160 b	146 b	3.76 c	3.86 c	32
T_4	237 a	228 a	5.04 b	5.25 b	13
T_5	256 a	244 a	5.33 ab	5.48 ab	4
T_6	261 a	251 a	5.43 ab	5.63 a	2
T_7	252 a	241 a	5.27 ab	5.43 ab	5
LSD (0.05)	*38*	*37*	*0.39*	*0.37*	
CV (%)	*5.87*	*5.88*	*2.81*	*2.61*	

N.B. T_1= Control, T_2= NPKSZn, T_3= PKSZn (-N), T_4= NKSZn (-P), T_5= NPSZn (-K), T_6= NPKZn (-S), T_7=NPKS (-Zn)

Table 8. Effect of long-term missing element on the tiller, panicle, grain and straw yield of BRRI dhan89 at BRRI farm, Rangpur in Boro 2021-22.

Treatment	Tiller/m^2	Panicle/m^2	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	(%) Grain yield decreased due to nutrient omission
T_1	151 c	142 c	3.06 d	3.18 d	-
T_2	265 a	255 a	7.24 a	7.34 a	-
T_3	156 c	144 c	3.35 d	3.44 d	54
T_4	222 b	209 b	6.38 c	6.53 c	26
T_5	235 ab	225 ab	6.50 bc	6.64 bc	12
T_6	240 ab	229 ab	6.62 bc	6.76 bc	9
T_7	247 ab	239 ab	6.85 ab	6.99 ab	6
LSD (0.05)	*37*	*33*	*0.45*	*0.42*	
CV (%)	*5.99*	*5.57*	*2.73*	*2.52*	

N.B. T_1= Control, T_2= NPKSZn, T_3= PKSZn (-N), T_4= NKSZn (-P), T_5= NPSZn (-K), T_6= NPKZn (-S), T_7=NPKS (-Zn)

DETERMINING MINIMUM IRRIGATION WATER REQUIREMENT OF RICE AT DIFFERENT REGIONS OF BANGLADESH THROUGH WATER BALANCE FROM ON-FARM DEMAND AND MODEL SIMULATION

The experiment was conducted for two seasons (T. Aman and Boro) in 2021-2022 at the research field of BRRI RS, Rangpur. BRRI dhan87 and BRRI dhan58 were transplanted in T. Aman 2021 and Boro 2021-22 seasons, respectively. In Rangpur, during T. Aman season, drought occurred at the later part of the season as rain ceased. The control treatment (i.e., continuous standing water in the field) received the highest amount while CROPWAT treatments required comparatively less irrigation. Both AWD and CROPWAT treatment saved irrigation compared to continuous standing water treatment. Yields were similar in AWD and CROPWAT treatments and yield of control treatment was different than other two treatments (Table 9). During Boro 2021-22 season, the total growth span of BRRI dhan58 was 150 days, however, 105 days after transplanting (vegetative, reproductive, and ripening stage) was taken into consideration in this study. The actual water requirement was calculated using the total measured evapotranspiration (ET) during this time (105 days). Predicted water requirement was simulated by CROPWAT model. Presumably, treatment T1 received highest amount of irrigation water in response to total irrigation requirement (Table 9), because the field was kept almost saturated all the time during the experiment. The AWD treatment (T2) received comparatively lower irrigation than continuous standing water treatment. Generally, received amounts of irrigation in T2 and T3 were closer. In Rangpur, AWD treatment had the highest yield among the treatments, but irrigation application and yields of AWD and CROPWAT treatments did not have any major difference in Rangpur. Irrigation scheduling by CROPWAT model might be a potential approach to save irrigation water, but still needed in depth evaluation in terms of irrigation demand, irrigation received and yields.

D Roy, M B Hossain, M N H Mahmud, P LC Paul, S Yesmin, P K Kundu, M Maniruzzaman and M R Hasan

Table 9. Treatment wise irrigation applied and average yield in T. Aman 2021 and Boro 2021-2022 Rangpur.

Treatment	Irrigation (mm)		Yield (t/ha)	
	T. Aman	Boro	T. Aman	Boro
Control (T1)	260	1150	4.45	6.76
AWD (T2)	232	963	5.20	7.71
CROPWAT (T3)	145	790	5.43	7.50

SOCIO-ECONOMIC

STABILITY ANALYSIS OF BRRI VARIETIES AT BRRI RS RANGPUR IN T. AUS, T. AMAN AND BORO SEASON DURING 2021-2022

One hundred seven of BRRI developed varieties were evaluated during T. Aus (13), T. Aman (47) and Boro (47) season at BRRI RS, Rangpur following RCBD with three replications. BRRI dhan83 produced highest yield (3.69 t/ha) followed by BRRI dhan65 (3.67 t/ha), BRRI dhan48 (3.62 t/ha) and BRRI dhan98 (3.62 t/ha) during T. Aus season. In T. Aman, BRRI dhan87 (5.7 t/ha) produced the highest yield followed by BRRI dhan95 (5.27 t/ha) and BRRI dhan71 (5.07 t/ha) in short duration; BRRI dhan94 (6.65 t/ha) produced the highest yield followed by BRRI dhan93 (6.53 t/ha) and BR11 (6.52 t/ha) in medium duration. In long duration, BR22 (5.12 t/ha) produced highest yield followed by BR23 (5.08 t/ha). During Boro season, BRRI dhan74 showed the highest yield (7.8 t/ha) followed by BRRI hybrid dhan2 (7.55 t/ha) and BRRI hybrid dhan5 (7.22 t/ha) in short duration group. In long duration group, BRRI dhan92 produced the highest yield (7.48 t/ha) followed by BRRI dhan29 (7.39 t/ha) and BRRI dhan89 (6.98 t/ha).

TECHNOLOGY TRANSFER
DEMONSTRATION

BRRI RS Rangpur (GOB). A total of 1,535 (1,535 bigha) varietal demonstrations were conducted at different locations of Rangpur-Dinajpur region. In T. Aus season BRRI dhan48, BRRI dhan82, BRRI dhan98, BRRI hybrid dhan7 were used and maximum yield was observed 5.99 t/ha in BRRI dhan48 at Dhormopur, Fulbari, Kurigram and minimum yield was observed 2.25 in case of BRRI dhan48 at Durgapur, Mithapukur, Rangpur. In T. Aman sesson, BRRI dhan49, BRRI dhan52, BRRI dhan70, BRRI dhan75, BRRI dhan79, BRRI dhan87, BRRI dhan90, BRRI dhan93, BRRI dhan94, BRRI dhan95, BRRI hybrid dhan4 and BRRI hybrid dhan6 were used. Maximum yield 6.54t/ha was observed in BRRI hybrid dhan6 at Kasu Kazitari, Kaunia, Rangpur and minimum was 3.26 in BRRI dhan87 at Pakhatipara, Sadar, Nilphamari. In Boro season BRRI dhan58, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan88, BRRI dhan89, BRRI dhan92, BRRI dhan96, Bangabandhu dhan100, BRRI hybrid dhan3 as well as BRRI hybrid dhan5 were used. Yield range was 9.5 to 4.2 t/ha. Maximum yield was observed 9.5t/ha in BRRI dhan92 at Votmari, Kaliganj, Lalmonirhat and minimum was 4.20 in BRRI dhan89 in Rajarhat, Kurigram.

TRB Project. Nine Head to Head Adaptive trials were conducted in eight upazilas under four districts in Rangpur-Dinajpur region during the reporting period. Five varieties viz. BRRI dhan51, BRRI dhan52, BRRI dhan79, Guti swarna and IR13F440 were used in T. Aman season. Eleven varieties viz. BINA dhan24, BRRI dhan28, BRRI dhan29, BRRI dhan58, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan88, BRRI dhan89, BRRI dhan92 and Bangabandhu dhan100 were used in Boro season. In T. Aman season, BRRI dhan51, BRRI dhan52 and BRRI dhan79 (Table 10); and in Boro season the farmers chose BRRI dhan74, BRRI dhan89, BRRI dhan92 and Bangabandhu dhan100 due to grain appearance, high yield and less disease incidence (Table 11).

Table 10. Grain yield of head to head adaptive trials under TRB project in Rangpur region, T. Aman 2021.

Location	Yield (t/ha)				
	BRRI dhann51	BRRI dhan52	BRRI dhann79	Guti swarna	IR13F440
Rajarhat, Kurigram	4.51	4.01	4.90	5.03	4.37
Sadar, Kurigram	3.62	4.20	2.87	3.93	4.16
Mithapukur, Rangpur	5.22	6.43	5.45	5.63	5.77
Rowmari, Kurigram	4.42	3.60	6.51	5.90	5.24

Table 11. Grain yield of head to head trials under TRB project in Rangpur-Dinajpur region, Boro 2021-22.

Location	Yield (t/ha)										
	Bina dhan24	BRRI dhan29	BRRI dhan58	BRRI dhan89	BRRI dhan92	BRRI dhan28	BRRI dhan74	BRRI dhan81	BRRI dhan84	BRRI dhan88	Bangabandhu dhan100
Sadar, Nilphamari	7.41	7.29	7.36	7.69	8.16	-	-	-	-	-	-
Mithapukur, Rangpur	6.70	5.87	5.97	6.77	7.14	-	-	-	-	-	-
Sadar, Rangpur	-	-	-	-	-	7.32	7.70	7.00	5.43	5.69	5.61
Kaunia, Rangpur	-		-	-	-	5.80	6.93	5.91	6.47	5.62	5.59
Parbatipur, Dinajpur	-		-	-	-	4.82	8.19	7.20	7.78	6.10	6.84

Training and field day. Thirty-two farmers, SAAO and seed dealer training on modern rice production technology was conducted at different upazilas of Rangpur-Dinajpur region in collaboration with DAE. A toal of 834 farmers and 106 SAAO and 30 dealers were trained through this programme. A total of 55 womens were present in the farmers training programme. It was very much helpful to minimize knowledge gap on modern Rice production technologies. Twelve in-house trainings were arranged at the programmes at BRRI RS, Rangpur to improve the capability in office management of the office staff. Fifteen field days were arranged at different demonstration sites in collaboration with DAE during this reporting period. A total of 750 farmers, local leaders and DAE personnel attended those field day programmes.

Seeds and seedling distribution among the flood affected farmers: BRRI RS, Rangpur arranged special programs for the flood affected farmers. Different photosensitive varieties viz. BR22, BRRI dhan34, Nizarsail and Gainja were distributed among the flood affected farmers in Sadar-Gaibandha, Rajarhat-Kurigram, Sadar-Rangpur, Payrabannd-Mithapukur-Rangpur and Dharmadas- Metro-Rangpur.

Promotional activities for the former enclave's farmer. BRRI RS, Rangpur conducted 31 demonstration programmes for the dissemination of BRRI developed latest varieties in Dashiarchora, Fulbari, Kurigram (Former enclave), Dohogram, Patgram, Lalmonirhat (Former enclave) and Garati, Sadar, Panchagarh (Former enclave).

Seed production and dissemination in July 2021-June 2022

A total of 1,095 kg, 6,684 kg and 8,434 kg TLS were produced in T. Aus, T. Aman and Boro season respectively. A total of 3,450 kg Breeder seed (BRRI dhan52, BRRI dhan83 and BRRI dhan87) was produced in T. Aman season and 4,250 kg breeder seed (BRRI dhan74 and BRRI dhan89) was also produced in Boro season. Moreover, a total of 7,700 kg breeder seed was sent to the GRS Division, BRRI Gazipur. In three seasons, 9972 kg TLS was distributed among the farmers for dissemination in Rangpur-Dinajpur region (Table 12).

Table 12. Variety-wise seed production and distribution during T. Aus 2021, T. Aman, 2021 and Boro 2021-2022 BRRI RS, Rangpur.

Variety	Amount (kg)		Send to GRS (Breeder-kg)	Sold (TLS-kg)	Distribution of TLS(kg)
	TLS	Breeder seed			
T. Aus, 2021					
BRRI dhan48	203	-	-	105	98
BRRI dhan82	354	-	-	155	199
BRRI dhan83	78	560	560	-	78
BRRI dhan98	460	-	-	127	333
BRRI hybrid dhan7	-	-	-	-	100
Total	1095	560	560	387	808

Variety	Amount (kg)		Send to GRS (Breeder-kg)	Sold (TLS-kg)	Distribution of TLS(kg)
	TLS	Breeder seed			
T. Aman, 2021					
BR22	335	-	-	-	335
BRRI dhan34	367	-	-	367	-
BRRI dhan49	53	-	-	35	18
BRRI dhan52	47	1000	1000	47	-
BRRI dhan70	103	-	-	17	86
BRRI dhan71	225	-	-	213	12
BRRI dhan75	218	-	-	218	-
BRRI dhan79	82	-	-	53	29
BRRI dhan87	2358	1890	1890	776	1582
BRRI dhan90	143	-	-	143	-
BRRI dhan91	48	-	-	10	38
BRRI dhan93	1869	-	-	709	1160
BRRI dhan94	427	-	-	12	415
BRRI dhan95	282	-	-	72	210
Naizarsail	51	-	-	-	51
Gainja	76	-	-	-	76
BRRI hybrid dhan4	-	-	-	-	100
BRRI hybrid dhan6	-	-	-	-	400
Total	6684	2890	2890	2672	4512
Boro 2021-22					
BR16	150	-	-	40	110
BRRI dhan28	216	-	-	194	22
BRRI dhan29	157			80	77
BRRI dhan50	123	-	-	37	86
BRRI dhan58	259	-	-	172	87
BRRI dhan67	28	-	-	-	28
BRRI dhan74	1754	2000	2000	715	1039
BRRI dhan81	250	-	-	172	78
BRRI dhan84	196	-	-	157	39
BRRI dhan86	528	-	-	239	289
BRRI dhan88	767	-	-	527	240
BRRI dhan89	1750	2250	2250	577	1173
BRRI dhan92	1181	-	-	803	378
BRRI dhan96	775			279	496
Bangabandhu dhan100	300			300	-
BRRI hybrid dhan3	-	-	-	-	200
BRRI hybrid dhan5	-	-	-	-	300
Total	8434	4250	4250	4292	4652
Grand Total	16213	7700	7700	7351	9972

BRRI RS, Satkhira

SUMMARY

From 6348 tested populations at Debnagar, Satkhira, 658 entries from 33 crosses were selected for T. Aman 2021 based on phenotype and salt tolerance. In Boro 2020-21, 5170 entries from 22 crosses were tested at BRRI Farm, Satkhira and 313 were chosen.

One hundred twenty-five entries were chosen from 728 tested at BRRI Farm and Assasuni for T. Aman 2021. 422 OYT (STR), 28 OYT (IRR), and 11 OYT (IRSSTN) were tested in a non-replicated trial in BRRI farm and Debhata during Boro 2021-22.

In PYT-1 at Debnagar, no entry yielded more than BRRI dhan73 (3.60 t/ha) and dhan87 (4.14 t/ha). In Assasuni, BR11388-4R-292 (2.89 t/ha) yielded more than BRRIdhan87 (1.94 t/ha). BR11920-4R-624 (3.09 t/ha) and BR11940-4R-191 (2.99 t/ha) yielded more than BRRI dhan87 at Koyra (1.56 t/ha). In PYT-2 at Debnagar, BR11921-4R-103 (4.91 t/ha) yielded statistically higher over BRRI dhan73 (3.35 t/ha). At Koyra, BR11905-4R-201 (5.52 t/ha) and BR11905-4R-66 (5.28 t/ha) gave the highest yield over the check varieties, BRRI dhan73 (2.16 t/ha) and BRRI dhan87 (2.99 t/ha). At Kaliganj, BR11921-4R-81 (6.63 t/ha) with 134 growth duration statistically yielded more than BRRI dhan73 (2.56 t/ha) and BRRI dhan87 (2.56 t/ha). Both BR11905-4R-270(4.56 t/ha) and BR11905-4R-56(4.54 t/ha) performed better over the checks. At Assasuni, BR11921-4R-323 (3.9 t/ha), BR11920-4R-326 (3.8 t/ha), and BR11940-4R-115 (3.4 t/ha) performed better than the check BRRI dhan87 (2.2 t/ha). In PYT-3, the entries BR11920-4R-226 (5.84 t/ha) and BR11388-4R-125 (5.82 t/ha) gave a significantly higher yield than the checks BRRI dhan73 (2.27 t/ha) and BRRI dhan87 (3.23 t/ha) and at Kaliganj site.

At BRRI-farm Sathkira, BR11727-4R-6 (8.01t/ha), BR11712-4R-60 (7.47t/ha) and BR11715-4R-34(7.17 t/ha) entries gave statistically significant higher yield than BRRI dhan97(6.12 t/ha) and BRRI dhan89 (4.34 t/ha) in AYT-1, BR11722-4R-360 (6.32 t/ha), BR11712-4R-333(6.03 t/ha) and BR11713-4R-70 (6.02 t/ha) entries gave statistically significant higher yield than BRRI dhan67(5.38 t/ha) and BRRI dhan97(5.82t/ha) in AYT-2 in BRRI-farm Sathkira.

In RYT for STR#2, BR11723-4R-172 gave statistically higher yield over BRRI dhan73 and similar with BRRI dhan87 during T. Aman, 2021 at BRRI farm, Satkhira. BR11391-4R-144 (2.46 t/ha) statistically yielded higher than BRRI dhan73 (1.81 t/ha) and BRRI dhan87 (1.88 t/ha). BR11394-4R-147 (2.19 t/ha) gave high yield than BRRI dhan73 (1.81 t/ha) only in Assasuni. BR9674-4-2-10-5-P9 and BR9674-1-1-5-1-P3 performed better over BRRI dhan74 & BRRI dhan84 but statistically similar with BRRI dhan29 in RYT(ZER) during Boro 2021-22. RYT for bacterial blight-resistant rice, RYT(BB-1), BR11607-4R-111, BR11600-4R-105, BR11600-4R-140, BR11600-4R-82, BR11607-4R-42, BR11607-4R-46 and BR11607-4R-6 performed statistically better over BRRI dhan88 and IRBB60. BR9901-1-3-10 (7.03 t/ha) and BR9918-10-4-5(6.97 t/ha) both the entries gave statistically higher yield than BRRI dhan89 (6.15 t/ha) and BRRI dhan97 (6.33 t/ha) in RYT-1 at BRRI farm.

A total of 15 genotypes were selected based on salt injury score (SIS) at the vegetative stage, grain type, and grain yield from 144 genotypes. However, two genotypes such as IR19X10031(4.81 t/ha), and IR19X1008 (4.52 t/ha) produced higher grain yield than all checks but were statistically similar.

In ALART for ZER, the entry BR9674-1-1-5-2-P4 gave higher yield than the checks BRRI dhan49 during T. Aman 2021. The entries, BR(Path)12452-BC3-42-22-11-4 & BR(Path)13784-BC3-61-1-6-HR3 performed statistically better over BRRI dhan28 & BRRI dhan88 during Boro 2021-22.

The yield reduction due to N omission from complete fertilizer was 27% and 70% in T. Aman 2021 and Boro 2021-22 seasons, respectively. Nitrogen is the most critical yield-limiting nutrient and balanced fertilizer application needed for getting maximum yield as well as maintaining soil health.

During Aus 2021, among the 12 varieties, BRRI dhan48 showed the highest yield (4.56 t/ha) followed by BRRI dhan82 (3.96 t/ha), BRRI dhan83 (3.92 t/ha), BR26 (3.90 t/ha). BRRI dhan87 (6.10 t/ha) had the best performance during Aman 2021. BRRI hybrid dhan5 produced the highest yield (7.87 t/ha) and BRRI hybrid dhan2 yielded 7.39 t/ha during Boro 2021-22.

BRRI dhan87 give the highest yield (6.25 t/ha) with the lowest growth duration (124 Days) in the head-to-head trial. BR10 (5.61 t/ha) perform better in the coastal ecosystem and BRRI dhan52 (5.33 t/ha) gave higher yield in FFS ecosystem. BRRI dhan67 (6.76 t/ha) gave the highest yield followed by BRRI dhan97 (6.49 t/ha), BRRI dhan28 (5.43 t/ha), BRRI dhan99 (5.35 t/ha) during boro 2021-22 in salt-affected area. Bangabandhu dhan100 (6.27 t/ha) gave the highest yield for short duration in the non-saline environment in head-to-head adaptive trial.

At the seedling stage, maximum seedling height and seedling strength were observed when seedlings were covered with polythene sheets keeping a round-shaped opening.

At Assasuni, Kaliganj and Debhata highest yield was observed by BRRI hybrid dhan5 (7.40 t/ha), BRRI hybrid dhan3 (6.90 t/ha) and IT (6.83 t/ha), respectively during the assessment of suitable hybrid rice genotypes under saline-prone areas for Boro season.

A total of 26.71 tons of breeder seed of different Aman and Boro rice varieties were produced and sent to GRS division. In addition, 34.96 tons of truthfully labelled seeds of different Aus, Aman and Boro rice varieties were produced, stored, sold and distributed to the farmers, NGOs and DAE. Twenty-two farmer's trainings on rice production technology, quality seed production & preservation were conducted to train 638 farmers of Satkhira, Khulna and Jashore districts.

VARIETAL DEVELOPMENT

Line Stage Trial (LST)

In T. Aman 2021, a total of 658 entries from 33 crosses were selected from 6348 tested populations at Debnagar, Satkhira based on their phenotypic appearance and salt tolerance ability. In Boro 2020-21, a total of 5170 entries from 22 crosses were evaluated in the field of BRRI-Farm, Satkhira to select suitable genotypes having salt tolerance ability and out of them, 313 entries were selected.

Observational Yield Trial (OYT)

In T. Aman 2021, a total of 125 entries were selected from 728 tested entries under OYT conducted at BRRI Farm and Assasuni. But at Assasuni, the entries didn't flower at all due to soil problems. In Boro 2021-22, 422 entries of OYT (STR), 28 entries of OYT (IRR) and 11 entries of OYT (IRSSTN) were evaluated in a non-replicated trial against standard checks in BRRI farm and Debhata.

Preliminary Yield Trial (PYT) in T. Aman 2021

A total of 30, 104, and 103 genotypes were evaluated in PYT-1, PYT-2 and PYT-3, respectively at Debnagar, Assasuni, Kaliganj and Koyra against four checks of BRRI dhan73, BRRI dhan87, BRRI dhan23 and BRRI dhan30 during T. Aman 2021.

PYT-1: At Debnagar site, no entry gave higher yield over the checks BRRI dhan73 (3.60 t ha^{-1}) and BRRI dhan87 (4.14 t $ha^{-1)}$. At Assasuni site, BR11388-4R-292 (2.89 t ha^{-1}) yielded higher than the check BRRIdhan87 (1.94t ha^{-1}). At Koyra site, BR11920-4R-624 (3.09 t ha^{-1}) and BR11940-4R-191(2.99 t ha^{-1}) yielded higher than the check BRRI dhan87(1.56 t ha^{-1}). At Kaliganj, no entry gave statistically higher yield over BRRI dhna73 (2.68 t ha^{-1}) but BR11921-4R-35 (3.40 t ha^{-1}), BR11910-4R-12 (3.33 t ha^{-1}) and BR11920-4R-478 (3.16 t ha^{-1}) entries gave statistically higher yield than BRRI dhan87 (1.04 t ha^{-1}).

PYT-2: At Debnagar site, BR11921-4R-103 (4.91 t ha^{-1}) statistically yielded higher than check BRRI dhan73 (3.35 t $ha^{-1)}$. At Koyra site, BR11905-4R-201 (5.52t ha^{-1}) and BR11905-4R-66 (5.28t ha^{-1}), statistically gave the highest yield than the check varieties BRRI BRRI dhan73 (2.16 t ha^{-1}) and BRRI dhan87 (2.99 t ha^{-1}). At Kaliganj site, BR11921-4R-81 (6.63t ha^{-1}) entry with 134 growth duration statistically yielded higher than the check varieties BRRI dhan73 (2.56 t ha^{-1}) and BRRI dhan87 (1.32 t ha^{-1}). BR11905-4R-270(4.56 t ha$^{-1)}$ and BR11905-4R-56(4.54 t ha^{-1}) both entries yielded statistically better than the checks. At Assasuni site, BR11921-4R-323(3.9 t ha^{-1}), BR11920-4R-326 (3.8 t ha^{-1}) and BR11940-4R-115 (3.4 t ha^{-1}) entries were performed statistically better than the check BRRI dhan87 (2.2 t ha^{-1}).

PYT-3: In PYT-3, the entries BR11920-4R-226 (5.84 t ha^{-1}) and BR11388-4R-125 (5.82 t ha^{-1}), gave significantly highest yield than the checks BRRI dhan73 (2.27 t ha^{-1}), BRRI dhan87 (3.23 t ha^{-1}) and at Kaliganj site. No entries gave a high yield at Debnagar, Assasuni and Koyra.

Preliminary Yield Trial (PYT) in Boro 2021-22

A total of 60 genotypes were evaluated in PYT-1 and 60 genotypes were evaluated PYT-2, respectively at different sites in Satkhira and Khulna districts. BRRI dhan67 and BRRI dhan89, BRRI 97 were used as checks.

PYT-1: At BRRI farm, BR11276-4R-152(7.56 t ha^{-1}) entry gave the statistically highest yield than the checks BRRI dhan89 (6.41 t ha^{-1}) and BRRI dhan97 (6.74 t ha^{-1}). No entry gave higher yield than BRRI dhan67 (8.30 t ha^{-1}) here. At Debhata site, BR12274-4R-379 (7.29 t ha^{-1}), BR12274-4R-160 (7.13 t ha^{-1}), BR12275-4R-350 (6.33 t ha^{-1}) and BR11276-4R-200 (6.23 t ha^{-1}) entries gave statistically highest yield than the checks BRRI dhan67 (5.77 t ha^{-1}), BRRI dhan89 (4.63 t ha^{-1}) and BRRI dhan97 (5.45 t ha^{-1}). At the Kaliganj site, BR12274-4R-151 (5.1 t ha^{-1}) gave statistically highest yield than the checks BRRI dhan67 (4.5 t ha^{-1}), and BRRI dhan97 (4.3 t ha^{-1}).

PYT-2: At the BRRI farm, no entry gave higher yield over BRRI dhan67 (6.25 t ha^{-1}) but BR22276-4R-296 (6.44 t ha^{-1}) gave the statistically higher yield than the checks BRRI dhan89 (6.17 t ha^{-1}) and BRRI dhan97 (5.26 t ha^{-1}). At Debhata site, BR11718-4R-176 (6.26 t ha^{-1}) and BR12273-4R-90 (6.02 t ha^{-1}), both the entries gave significantly higher yield than the checks BRRI dhan67 (5.69 t ha^{-1}), BRRI dhan89 (5.04 t ha^{-1}) and BRRI dhan97 (4.90 t ha^{-1}). At the Kaliganj site, no entries gave higher yield over BRRI dhan97 (4.60 t ha^{-1}) but BR22274-4R-227 (4.4 t ha^{-1}), BR22728-4R-46 (4.3 t ha^{-1}) both gave the statistically higher yield than the checks BRRI dhan67 (3.5 t ha^{-1}), and BRRI dhan89 (2.4 t ha^{-1}).

Advanced yield trial (AYT) during T. Aman, 2021

In AYT, 46 genotypes were evaluated against BRRI dhan73 as tolerant checks and BRRI dhan87 as a sensitive check at different sites in Satkhira and Khulna districts.

AYT-1: At the Kaliganj site, BR11388-4R-5 (4.47t ha^{-1}) and BR11388-4R-6 (4.22t ha^{-1}) yielded statistically higher than the checks BRRI dhan73 (3.48 t ha^{-1}), BRRI dhan87 (3.76 t ha^{-1}), respectively. No entry yielded better than check varieties in Debnagar, Assasuni and Koyra.

AYT-2: At the Assasuni site, BR11391-4R-144 (2.46 t ha^{-1}) statistically yielded higher over BRRI dhan 73 (1.81 t ha^{-1}) and BRRI dhan87 (1.88 t ha^{-1}). At Kaliganj site, BR11394-4R-139 (4.64 t ha^{-1}) statistically yielded higher than BRRI dhan87 (1.08 t ha^{-1}). At the Koyra site, BR11392-4R-132 (5.73 t ha^{-1}) statistically yielded higher than BRRI dhan73 (3.84 t ha^{-1}) and BRRI dhan87(2.13 t ha^{-1}). No entry gave higher yield than the checks at Debnagar.

Advanced Yield Trial (AYT) in Boro 2020-21

A total of 25 genotypes were evaluated in AYT -1, 19 genotypes were evaluated in AYT -2 and 25 genotypes were evaluated in AYT -3 against BRRI dhan67, BRRI dhan89 and BRRI dhan97 checks.

AYT-1: At BRRI-farm Sathkira, BR11727-4R-6 (8.01 t ha^{-1}), BR11712-4R-60 (7.47 t ha^{-1}) and BR11715-4R-34 (7.17 t ha^{-1}) entries gave statistically significant higher yield than BRRI dhan97 (6.12 t ha^{-1}) and BRRI dhan89 (4.34 t ha^{-1}). At Debhata site, BR11727-4R-6 (4.41 t ha^{-1}), BR11723-4R-107 (4.23 t ha^{-1}) and BR11712-4R-44 (3.94 t ha^{-1}) entries gave statistically higher yield than BRRI dhan67 (2.55 t ha^{-1}) and BRRI dhan97 (2.85 t ha^{-1}). At Kaliganj site, BR11712-4R-44 (5.21 t ha^{-1}) gave statistically higher yield than BRRI dhan67 (4.05 t ha^{-1}) and BRRI dhan89 (3.16 t ha^{-1}).

AYT-2: At BRRI-farm Sathkira, BR11722-4R-360 (6.32 t ha^{-1}), BR11712-4R-333 (6.03 t ha^{-1}) and BR11713-4R-70 (6.02 t ha^{-1}) entries gave statistically significant higher yield than BRRI dhan67 (5.38 t ha^{-1}) and BRRI dhan97 (5.82t ha^{-1}). At Debhata site, no entry gave higher yield than the checks. At Kaliganj site, no entries gave higher yield over BRRI dhan67 (5.40 t ha^{-1}) but BR11712-4R-121 (4.9 t ha^{-1}) gave statistically higher yield over BRRI dhan89 (2.8 t ha^{-1}) and BRRI dhan97 (3.7 t ha^{-1}).

AYT-3: At BRRI-farm Sathkira, BR11716-4R-55 (7.79 t ha^{-1}) and BR11718-4R-2 (7.13 t ha^{-1}) entries gave statistically significant higher yield than BRRI dhan67 (6.30 t ha^{-1}), BRRI dhan89 (6.85 t ha^{-1}) and BRRI dhan97(5.87t ha^{-1}). At Debhata site, BR11714-4R-322 (4.94 t ha^{-1}) and BR11714-4R-148 (4.91 t ha^{-1}) had statistically higher yield than BRRI dhan67 (4.0 t ha^{-1}), and BRRI dhan97 (4.13 t ha^{-1}). At Kaliganj site, BR11716-4R-55(4.88 t ha^{-1}), BR11714-4R-148 (4.67 t ha^{-1}) and BR11714-4R-322 (4.67 t ha^{-1}) statistically higher yield than BRRI dhan67 (3.79 t ha^{-1}), BRRI dhan89 (3.23 t ha^{-1}) and BRRI dhan97 (3.92t ha^{-1}).

Regional yield trial (RYT) during T. Aman, 2021 at BRRI farm, Satkhira

In T. Aman 2021 season, two regional yield trials (RYTs) were conducted for salt tolerance rice (STR), one trial each for zinc enriched rice (ZER) and rainfed lowland rice (RLR) following RCB design at BRRI, Satkhira. No entries performed better over the check, BRRI dhan87 but entries, BR11716-4R-120, BR11723-4R-48, BR11716-4R-123, BR11716-4R-114, BR11716-4R-147 and BR10672-1-3-7-12 performed better over BRRI dhan73 in RYT(STR#1) in Table 1. In RYT for STR#2, BR11723-4R-172 gave statistically higher yield over BRRI dhan73 and like BRRI dhan87 in Table 2. No entries were selected in RYT for zinc-enriched rice (ZER) and rainfed lowland rice (RLR) in Tables 3 & 4.

Regional yield trial (RYT) for saline tolerant rice in T. Aman 2021 (TRB)

A total of 14 genotypes in RYT-1, 8 genotypes in RYT-2 and 18 genotypes in RYT-3 were evaluated against BRRI dhan73 and BRRI dhan87 at different locations of Satkhira and Khulna. In RYT-1, at Assasuni site, BR11391-4R-144 (2.46 t ha-1) statistically yielded higher than BRRI dhan73 (1.81 t ha-1) and BRRI dhan87 (1.88 t ha-1). BR11394-4R-147 (2.19 t ha-1) gave high yield than BRRI dhan73 (1.81 t ha^{-1}) only. At Debnagar no entry gave high yield than the checks. BR11394-4R-139 (4.64 t ha^{-1}), BR11391-4R-100 (3.39 t ha^{-1}) entries gave higher yield than the check BRRI dhan87 (1.08 t ha^{-1}). BR11392-4R-123 (5.73 t ha^{-1}) statistically yielded higher than BRRI dhan73 (3.84 t ha^{-1}) and BRRI dhan87 (2.13 t ha^{-1}) at the Koyra site. In RYT-2, at Debnagar site, no entries gave higher yield than BRRI dhan87 (6.46 t ha^{-1}) but BR11723-4R-12 (6.29 t ha^{-1}), BR11723-4R-48 (5.76 t ha^{-1}) and BR11716-4R-147 (5.37 t ha^{-1}) entries gave statistically higher yield than BRRI dhan73 (4.48 t ha^{-1}). At Koyra site, BR11723-4R-12 (3.37 t ha^{-1}), BR11716-4R-114 (3.35 t ha^{-1}) & BR11723-4R-48 (2.87 t ha^{-1}), entries gave statistically higher yield than BRRI dhan73 (1.62 t ha^{-1}) and BRRI dhan87 (1.36 t ha^{-1}). In RYT-3, at Assasuni site, no entries gave higher yield than BRRI dhan73 (4.04 t ha^{-1}) and BRRI dhan87 (3.82 t ha^{-1}). At Debnagar site, BR10429-4-1-2(4.81 t ha^{-1}) and BR10426-9-5-3B1(4.51 t ha^{-1}) entries gave statistically higher yield than BRRI dhan73 (3.94 t ha^{-1}) and BRRI dhan87 (3.16 t ha^{-1}). At Koyra site, no entries gave higher yield than BRRI dhan73 (4.37 t ha^{-1}) but BR10441-17-1-5(4.57 t ha^{-1}) and BR10441-10-15-4 (4.01 t ha^{-1}) entries gave statistically higher yield than BRRI dhan87 (3.18 t ha^{-1}).

Regional yield trial (RYT) during Boro, 2021-22

In Boro 2020-21, different entries of zinc enriched rice (ZER), premium quality rice (PQR), salt tolerance rice (STR), blast resistant rice (BRR), favourable boro rice (FBR#Barishal and FBR#bio), bacterial blight resistant rice (BB#1 and BB#2) and entries of long slender grain (LS) were assessed in regional yield trials (RYTs). The field trials were conducted at BRRI, Satkhira following RCB design. Among the different entries of RYT(ZER), BR9674-4-2-10-5-P9 and BR9674-1-1-5-1-P3 performed better over BRRI dhan74 & BRRI dhan84 but statistically similar with BRRI dhan29 in Table 5. No entries gave higher yield in RTY(PQR) in Table 6. In case of RYT(STR#1) & RY(STR#2), no entry performed better over the tolerant checks, BRRI dhan67& BRRI dhan97 in Tables 7 & 8.

All the blast resistant lines produced 7.5-8.8 t/ha yield with a range of growth duration 145-148 days (Table 9). All the check varieties produced 8.1-8.4 t/ha with growth duration 146-149 days. The entry, BR12454-BC2-13-81-88-87-HR gave statistically higher yield 8.83 t/ha with 4 days early maturity than the check BRRI dhan92. None of the entries/check varieties were infected with leaf/neck blast although the adjacent plots of BRRI dhan28 was much infected with leaf (score 5) and neck blast disease (10% panicle).

No entries were selected in RYT (FBR#Barishal and FBR#bio) in Tables 10 & 11. In RYT for bacterial blight-resistant rice, RYT(BB-1), BR11607-4R-111, BR11600-4R-105, BR11600-4R-140, BR11600-4R-82, BR11607-4R-42, BR11607-4R-46 and BR11607-4R-6 performed statistically better over BRRI dhan88 and IRBB60 in Table 12. The entry, BR11604-4R-122 gave higher yield over BRRI dhan58 and BRRI dhan89 and tolerant check, IRBB60 in RYT(BB#2) in Table 13. In RYT(LS), the entry, BR10247-4-7-4B performed better over the check, BRRI dhan28 (Table 14).

Regional Yield Trial (RYT) for saline tolerant rice in Boro 2020-21 (TRB)

A total of 8 genotypes in RYT-1 and 9 genotypes in RYT-2 were evaluated against BRRI dhan67, BRRI dhan89, BRRI dhan97at different locations of Satkhira and Khulna. In RYT-1**,** at BRRI farm BR9901-1-3-10 (7.03t ha^{-1}) and BR9918-10-4-5(6.97 t ha^{-1}), both the entries gave statistically higher yield than BRRI dhan89 (6.15 t ha^{-1}) and BRRI dhan97 (6.33 t ha^{-1}). At Kaliganj site BR9901-1-3-10(4.7 t ha^{-1}) and BR9918-10-4-5 (4.4 t ha^{-1}) gave statistically higher yield than BRRI dhan89 (3.08 t ha^{-1}). No entries gave higher yield than BRRI dhan97 (4.31 t ha^{-1}) here. In RYT-2**,** at BRRI farm, in the RYT-2 trial, IR 108175-B-22-AJY 3-B-1 (6.95 t ha^{-1}) entry gave statistically higher yield than BRRI dhan67 (6.2 t ha^{-1}), BRRI dhan89 (5.93 t ha^{-1}) and BRRI dhan97 (6.39 t ha^{-1}). At Kaliganj site, no entries gave better yield than BRRI dhan67 (6.16 t ha^{-1}) but TP21654 (5.80 t ha^{-1}) gave statistically higher yield over BRRI dhan89 (3.70 t ha^{-1}) and BRRI dhan97 (5.09 t ha^{-1}).

AGGRi Network Trial

A total of 144 elite genotypes were tested in AGGRi Network trial along with IRRI 147, Pokkali, IRRI 230 and BRRI dhan67, BRRIdhan97. BRRIdhan99 as tolerant checks and BRRI dhan28, BRRIdhan89, BRRI dhan92, and IRRI 154 as sensitive at Debhata in Satkhira during Boro 2021-22 to select superior genotypes for including directly in the variety release system or use as parents in the breeding program. Wide variations were observed for grain yield ranging from 1.01 t/ha to 4.81 t/ha and growth duration 136 days to 153 days respectively. A total of 15 genotypes were selected based on salt injury score (SIS) at the vegetative stage, grain type, and grain yield from 144 genotypes. However, two genotypes such as IR19X10031(4.81 t/ha), and IR19X1008 (4.52 t/ha) produced higher grain yield than all checks but it was statistically insignificant. These lines may be used in the advanced yield trials and used as parents in the breeding program.

Advanced Line Adaptive Research Trial (ALART) during T. Aman 2021

In T. Aman 2021, six ALARTs were conducted totally at farmer's fields in Satkhira and Khulna, one each for Insect Resistance Rice (IRR) & Zinc Enriched Rice (ZER) and four trials for STR (Saline Tolerant Rice) in Tables 15-17. None of the tested entries performed better over their respective check varieties in ALARTs for IRR and STR. In ALART for ZER, the entry BR9674-1-1-5-2-P4 gave higher yield than the checks BRRI dhan49 (Table 16).

Advanced Line Adaptive Research Trial (ALART) during Boro 2021-22

One ALART each for blast resistant rice (BRR) and super high yielding rice (SHR) and four each for salt-tolerant rice, STR#1& STR#2 were conducted during Boro 2021-22 following RCBD in Tables 18-21. In ALART (BRR), the entries, BR(Path)12452-BC3-42-22-11-4 & BR(Path)13784-BC3-61-1-6-HR3 performed statistically better over BRRI dhan28 & BRRI dhan88 (Table 18). However, no entries performed better over the checks in ALART for SHR, STR#1 and STR#2.

Selection of suitable hybrid rice genotypes in saline-prone areas during Boro season

Eight BRRI developed hybrid rice varieties along with promising hybrid lines (BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5, BRRI hybrid dhan6, BRRI hybrid dhan7, BRRI99A/BRRI31R and BRRI99A/EL254R) were evaluated over five company released hybrid varieties (Gold, Janokraj, Heera, Tejgold and SL-8) and three salinity tolerant inbreed rice varieties (BRRI dhan67, IT and Binadhan-10) at farmers field in three salt affected locations of Satkhira district during Boro 2021-22 season. The objective was to find out suitable hybrid rice genotypes suitable for saline-prone areas in Boro season. At Assasuni, Kaliganj and Debhata highest yield was observed by BRRI hybrid dhan5 (7.40 t/ha), BRRI hybrid dhan3 (6.90 t/ha) and IT (6.83 t/ha), respectively. The mean results showed that BRRI hybrid dhan5 followed by BRRI hybrid dhan4 performed better over the company hybrid varieties (Table 22). Soil-water salinity of the experimental plots is presented in Fig. 1.

CROP-SOIL-WATER MANAGEMENT

Missing element trial

The experiment was carried out at BRRI farm, Satkhira using BRRI dhan87 and BRRI dhan67 during T. Aman 2021 and Boro 2021-22, respectively to study the effect of nutrient omission on rice growth and yield. The treatment consisted of omission of different nutrients (N, P, K, S and Zn) from the complete fertilizer. The omission of N from complete fertilizer (NPKSZn) appeared as the most yield-limiting nutrient, while the complete fertilizer produced the highest yield of rice in both T. Aman 2021 and Boro 2021-22 seasons (Table 23). The yield reduction due to N omission from complete fertilizer was 27% and 70% in T. Aman 2021 and Boro 2021-22 seasons, respectively.

Effect of zinc fertilization for zinc fortification in rice in the saline environment

The study was conducted in BRRI regional station Satkhira, during Boro 2021-22, to find out the effects of Zn fertilization on Zn accumulation and uptake by Zn enriched rice variety (Bangabandhu dhan100) in saline soil. Seven variations of Zn application along with control were used as treatments. Due to the high salinity effects and adverse climatic conditions, the yield was not as expected, the highest yield (4.75 t/ha) was found from the control plot of Bangabandhu dhan100 and there is no significant difference in plant height, while the amount of zinc content in rice grain and straw yet to be analyzed.

Raising Boro seedlings for energy-efficient land use

The experiment was conducted to understand effective way of healthy seedling raising technique for reduction of field duration of Boro rice (BRRI dhan81) cultivation by early transplanting. The experiment consisted of different techniques of polythene covering following the RCB design with three replications at BRRI farm, Satkhira during the Boro 2021-2022 season. At 30 and 40 DAS, maximum seedling strength (19.96 and 20.43) and at 10 DAT, minimum seedling mortality (0.52) were observed when seedlings were covered with polyethene keeping round shape opening (Table 24). From the field trial, no significant difference was found in case of plant height, growth duration and grain yield.

SOCIO-ECONOMIC AND POLICY

Stability Analysis of BRRI Varieties during 2020-21

A total of 106 varieties were evaluated to determine yield and yield contributing traits during T. Aus (13), T. Aman (46) and Boro (47) seasons. The experiments were laid out in RCB design with three replications. During Aus 2021, among the 12 varieties, BRRI dhan48 showed the highest yield (4.56 t ha^{-1}) followed by BRRI dhan82 (3.96 t ha^{-1}), BRRI dhan83 (3.92 t ha^{-1}), BR26 (3.90 t ha^{-1}) (Table 25). The growth duration of those varieties ranged from 104-112 days. During T. Aman 2021, among short-duration varieties, BRRI dhan87 (6.10 t ha^{-1}) had the best performance based on yield compared to others (Table 26). In medium-duration Aman varieties (21) based on yield, BRRI dhan52 produced the highest grain yield (5.71 t ha^{-1}), which was identical to BRRI dhan11 (5.46 t ha^{-1}), BRRI dhan94 (5.18 t ha^{-1}) and BRRI dhan93 (5.18 t ha^{-1}) (Table 27). The growth duration of those varieties ranged from 130-138 days. In long-duration T. Aman varieties (11), BR10 (4.93 t ha^{-1}) produced the highest yield (Table 28). During Boro 2021-22, among the long-duration varieties (25), BR16 gave the highest yield (7.21 t ha^{-1}) followed by BRRI dhan97 (6.99 t ha^{-1}), BRRI dhan29 (6.97 t ha^{-1}), BRRI dhan14 (6.93 t ha^{-1}) (Table 29). The growth duration of those varieties ranged from 145-165 days. Among the short-duration varieties (22), particularly among hybrid varieties, BRRI hybrid dhan5 produced the highest yield (7.87 t ha^{-1}) compared to BRRI hybrid dhan2 (7.39 t ha^{-1}). And, particularly among inbred varieties, Bangabandhu dhan100 showed better performance considering yield compared to others. The growth duration of those varieties ranged from 140-144 days. Among the long-duration varieties, BRRI dhan97 gave higher yield followed by BRRI dhan99 (Table 30).

TECHNOLOGY TRANSFER

Production of BRRI released rice varieties in the southern coastal gher-ecosystem

In Boro 2020-21, the performance of three BRRI released saline tolerant varieties viz., BRRI dhan67, BRRI dhan97 and BRRI dhan99 were tested against BRRI dhan28 in saline gher system at Kaliganj, Satkhira. BRRI dhan67 (6.31 t/ha) was the highest yielder followed by BRRI dhan97 (6.11 t/ha), BRRI dhan99 (5.95 t/ha) and BRRI dhan28 (5.82 t/ha), respectively.

Head-to-Head Adaptive Trial

T. Aman 2021: In T. Aman, two HHATs were conducted for coastal ecosystem and two HHATs for rainfed lowland rice (RLR) long duration at farmers' fields of Keshabpur, Jashore districts. The cultivated variety was BRRI dhan80, BRRI dhan87, BRRI dhan93, BRRI dhan94, BRRI dhan95. Among them, BRRI dhan87 give the highest yield (6.25 t/ha) with the lowest growth duration (124 DAS). In HHATs for the coastal ecosystem, conducted at Koyra, Khulna district, BR10 (5.61 t/ha) perform better than BRRI dhan73 (4.99 t ha^{-1}) and BRRI dhan78 (4.56 t ha^{-1}), BRRI dhan79 (4.87 t ha^{-1}). In HHATs for FFS, conducted at Keshabpur, Jashore, BRRI dhan52 (5.33 t ha^{-1}) performed better than IR13F441 (4.81t ha^{-1}) and BRRI dhan51 (4.74 t ha^{-1}) and BRRI dhan79 (4.51 t ha^{-1}).

Boro 2021-22: In Boro, four HHATs for the coastal ecosystem, two HHATs for RLR long duration and two HHATs for sort duration were conducted at farmers' fields of Satkhira and Jashore districts. In HHATs for the coastal ecosystem, conducted at Jugrajpur and Assasuni of Satkhira districts, BRRI dhan67 (6.76 t ha^{-1}) gave the highest yield followed by BRRI dhan97 (6.49 t ha^{-1}), BRRI dhan28 (5.43 tha^{-1}), BRRI dhan99 (5.35 tha^{-1}). In Kaliganj BRRI dhan97 (6.49 t ha^{-1}) gave the highest yield followed by BRRI dhan67 (6.23 t ha^{-1}). In HHATs for short duration conducted at Keshabpur, Jashore, Bangabandhu dhan100 (6.27 t ha^{-1}) gave the highest yield followed by BRRI dhan28 (5.81 t ha^{-1}), BRRI dhan81 (5.8 t ha^{-1}) and BRRI dhan84 (5.64 t ha^{-1}).

Seed production and dissemination

A total of 26.71 tons of breeder seed of different Aman and Boro rice varieties were produced and sent to GRS division. In addition, 34.96 tons of truthfully labelled seeds of different Aus, Aman and Boro rice varieties were produced, stored, sold, and distributed to the farmers, NGOs and DAE.

Training, Field Day and Workshop

Twenty-two farmer's trainings on rice production technology, quality seed production & preservation were conducted to train 638 farmers of Satkhira, Khulna and Jashore districts. A total of fifteen field days were arranged during the reporting period. BRRI, Satkhira participated in various workshops, seminars, regional and district agricultural coordination committee meetings, district coordination committee meetings, discussion meetings, and farmers' field visits with advisory activities on field level and online basis.

Tables and Graphs

Table 1. Performance of different entries under RYT(STR#1) at BRRI, Satkhira during T. Aman 2021

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR11716-4R-108	106	128	4.66
BR11716-4R-120	109	121	5.18
BR11723-4R-48	103	118	5.76
BR11723-4R-12	107	115	6.29
BR11716-4R-123	110	117	5.34
BR11716-4R-114	103	124	5.09
BR11716-4R-147	112	116	5.37
BR10672-1-3-7-12	115	108	5.03
BRRI dhan73(Tol. ck)	127	117	4.48
BRRI dhan87(Sus. ck)	129	124	6.46
LSD(0.05)	2.59	0.96	0.32
CV (%)	2.83	1.01	7.45

Table 2. Performance of different entries under RYT(STR#2) at BRRI, Satkhira during T. Aman 2021

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR11723-4R-172	104	117	5.06
BR11716-4R-102	109	116	6.70
BR11715-4R-186	104	118	5.88
BR11712-4R-218	108	118	6.09
BR11712-4R-227	105	122	5.14
BR11723-4R-27	104	118	5.68
BR11716-4R-129	106	124	5.77
BR11716-4R-105	127	112	5.71
BRRI dhan73(Tol. ck)	130	117	4.61
BRRI dhan87(Sus. ck)	126	123	6.18
LSD(0.05)	1.89	1.01	0.41
CV (%)	2.07	1.04	8.74

Table 3. Performance of different entries under RYT(ZER) at BRRI, Satkhira during T. Aman 2021

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR10005-25-8-4-7-20	121	117	4.98
BR10022-2-8-9-5-22	125	124	5.92
BRRI dhan72	115	121	5.62
BRRI dhan87	125	124	6.06
LSD (0.05)	1.75	0.68	0.25
CV (%)	1.77	0.69	5.52

Table 4. Performance of different entries under RYT(RLR) at BRRI, Satkhira during T. Aman 2021

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
SVIN209	109	125	5.19
SVIN172	112	119	5.36
IR98377-B-B-B-B-24	110	121	5.60
BR9840-52-1-2-1	121	119	5.84
BRRI dhan49	107	132	4.96
BRRI dhan71	112	115	4.90
BRRI dhan87	126	123	5.82
LSD(0.05)	1.77	0.92	0.26
CV (%)	1.91	0.93	6.02

Table 5. Performance of different entries under RYT(ZER) at BRRI, Satkhira during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR9674-4-2-10-5-P9	114	149	6.99
BR9674-1-1-5-1-P3	109	148	7.22
BRRI dhan29 (Ck)	96	149	7.76
BRRI dhan74 (Ck)	98	139	5.83
BRRI dhan84 (Ck)	99	137	6.51
LSD(0.05)	2	0.92	0.35
CV (%)	2.38	0.78	6.31

Table 6. Performance of different entries under RYT(PQR)) at BRRI, Satkhira during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR10322-23-1-2-4	102	137	5.15
BR10322-23-6-3-7-B2	98	135	4.87
BRRI dhan50	85	147	5.18
BRRI dhan63	85	144	5.87
BRRI dhan81	96	140	5.79
LSD(0.05)	1.1	1.07	0.24
CV (%)	1.46	0.94	5.36

Table 7. Performance of different entries under RYT(STR#1) at BRRI, Satkhira during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR10182-5-4-2	102	145	4.28
BR10187-1-4-12	108	144	4.80
BR10187-1-5-11	97	148	4.36
BR10188-10-1-18	108	152	4.18
BR9901-1-3-10	104	146	4.63
BR9904-1-3-3	121	151	4.87
BR9918-10-4-5	94	147	4.48
BR9926-7-7-6	107	142	4.89
BRRI dhan89	115	152	3.95
BRRI dhan67	117	143	4.98
BRRI dhan97	108	150	4.89
LSD(0.05)	2.27	0.89	0.29
CV (%)	2.59	0.75	7.73

Table 8. Performance of different entries under RYT(STR#2) at BRRI, Satkhira during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
IR 108175-B-22-AJY 3-B-1	131	147	4.03
IR 108604-2-1-AJY 3-B-1	99	148	4.07
IR 108604-2-3-AJY 3-B-1	122	147	4.21
IR15T1399	96	142	4.49
TP20532	98	143	4.03
TP21654	106	146	4.65
TP24493	90	146	4.27
TP30629	103	141	4.10
TP30642	104	141	4.47
BRRI dhan89	112	150	3.81
BRRI dhan67	112	142	4.64
BRRI dhan97	112	147	4.88
LSD(0.05)	2.24	0.67	0.29
CV (%)	2.57	0.57	8.21

Table 9. Performance of blast resistance entries under RYT (BRR-Dum) at BRRI, Satkhira during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR12454-BC2-87-24-32-1-29	118	148	7.45
BR12454- BC2-56-81-27-3-30	124	147	7.47
BR12454- BC2-69-97-39-5-44	112	146	7.61
BR12454- BC2-71-91-6-23-26	120	146	7.74
BR12454- BC2-75-32-31-39-7	121	144	7.50
BR12454- BC2-48-10-88-81-32	114	146	8.04
BR12454-BC2-13-81-88-87-HR	119	145	8.83
BRRI dhan29 (S. Check)	106	149	8.39
BRRI dhan89 (S. Check)	118	146	8.12
BRRI dhan92 (S. Check)	122	149	8.31
LSD (0.05)	2.75	0.88	0.36
CV (%)	2.87	0.74	5.51

Table 10. Performance of different entries under RYT(FBR-Barishal) at BRRI, Satkhira during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
NGR414-1*	-	-	Damaged
NGR418-1	103	145	5.12
NGR467-2*	-	-	Damaged
NGR521-1*	-	-	Damaged
NGR522-1	96	146	4.69
NGR750-1*	-	-	Damaged

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
NGR796-2*	-	-	Damaged
NGR1161-3	98	144	4.60
NGR1255-1	111	150	4.31
NGR1308-2	99	140	4.22
BRRI dhan58	96	146	4.95
BRRI dhan89	113	149	5.23
LSD (0.05)	1.3	1.08	0.38
CV (%)	1.55	0.91	12.56

Table 11. Performance of different entries under RYT(FBR-Bio) at BRRI, Satkhira during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR(Bio)10381-AC32-3	116	142	5.01
BR(Bio)10381-AC1-2	94	139	4.35
BRRI dhan88	99	139	4.92
BRRI dhan96	91	143	5.30
LSD(0.05)	1.54	0.6	0.15
CV (%)	1.89	0.53	3.81

Table 12. Performance of different entries under RYT(BB-1) at BRRI, Satkhira during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR11604-4R-77	122	145	4.95
BR11607-4R-111	101	146	5.25
BR11607-4R-128	97	144	4.65
BR11600-4R-105	113	144	5.59
BR11600-4R-140	110	142	5.80
BR11600-4R-82	108	142	5.74
BR11607-4R-156	101	142	5.32
BR11607-4R-184	108	143	5.20
BR11607-4R-42	109	145	5.82
BR11607-4R-46	98	143	6.20
BR11607-4R-6	99	145	5.48
BR11607-4R-79	107	146	4.90
BRRI dhan88	99	139	5.04
IRBB60	93	151	4.62
LSD(0.05)	0.7	0.64	0.21
CV (%)	1.82	0.54	9.51

Table 13. Performance of different entries under RYT(BB-2) at BRRI, Satkhira during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR11604-4R-110	127	140	4.66
BR11604-4R-147	126	139	4.96
BR11604-4R-35	115	139	5.39
BR11604-4R-72	126	142	5.52
BR11607-4R-153	125	142	5.72
BR11607-4R-2	115	145	5.40
BR11607-4R-20	106	145	5.29
BR11600-4R-287	109	140	5.65
BR11604-4R-118	126	144	5.25
BR11604-4R-122	132	151	6.23
BR11604-4R-129	121	144	5.67
BR11604-4R-24	120	147	5.86
BR11604-4R-52	119	146	5.15
BR11607-4R-258	101	142	5.80
BRRI dhan58	103	149	5.89
BRRI dhan89	112	152	5.57
IRBB60	73	149	4.34
LSD(0.05)	3.04	0.81	0.22
CV (%)	3.25	0.69	9.5

Table 14. Performance of different entries under RYT(LS) at BRRI, Satkhira during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BRH11-2-4-7B*	-	-	Not germinated
BRH10247-14-18-4	104	143	5.38
BR10247-4-7-4B	105	140	6.36
BRRI dhan28	104	139	5.74
LSD(0.05)	NS	0.72	0.23
CV (%)	1.07	0.63	5

Table 15. Performance of different genotypes under ALART(IRR) during T. Aman 2021

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR9880-40-1-3-34	107	125	5.03
BR9880-27-4-1-18	115	119	5.52
BRRI dhan87 (CK)	123	120	6.02
BRRI dhan93 (CK)	121	129	5.57
LSD(0.05)	2.49	0.47	0.15
CV(%)	2.62	0.47	3.42

Table 16. Performance of different genotypes under ALART (ZER) during T. Aman 2021

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR9674-1-1-5-2-P4	120	116	5.67
BRRI dhan49 (CK)	102	129	5.05
BRRI dhan72 (Ck)	113	121	5.52
BRRI dhan87 (Ck)	124	122	5.72
LSD(0.05)	1.67	1.08	0.25
CV(%)	1.78	1.09	5.58

Table 17. Performance of different genotypes under ALART (STR) during T. Aman 2021

Entry/Variety	**PH (cm)**	**GD (days)**	**Grain Yield (t/ha)**				
			Sadar	**Dum**	**Kali**	**Bati**	**Mean**
IR108158-B-2-AJY1-1	122	120	4.98	4.82	4.77	5.08	4.91
IR15T1464	117	121	4.94	4.94	5.01	5.06	4.99
TP30649	118	119	5.23	5.27	5.47	5.58	5.39
BRRI dhan73 (Tol. Ck)	124	121	5.23	4.98	5.29	5.36	5.22
BRRI dhan87 (Sus. Ck)	124	123	5.83	5.94	5.67	6.24	5.92
LSD(0.05)	2.55	1.43	NS	0.27	0.17	0.35	0.19
CV(%)	0.94	0.93	0.86	0.81	0.85	0.83	2.36

Table 18. Performance of different genotypes under ALART(BRR) during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR(Path)12452-BC3-42-22-11-4	114	137	5.62
BR(Path)12452-BC6-53-21-11	117	137	5.25
BR(Path)13784-BC3-61-1-6-HR3	108	139	5.41
BR(Path)13784-BC3-63-6-4-HR6	101	139	5.23
BRRI dhan28 (Ck)	106	137	5.1
BRRI dhan88 (Ck)	99	139	5.04
LSD(0.05)	2.14	NS	0.31
CV(%)	1.09	-	3.2

Table 19. Performance of different genotypes under ALART(SHR) during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BRHII-9-11-4-5B	98	151	5.6
BRH13-2-4-6-4B	100	150	5.81
BRH13-7-9-3-2B	122	149	5.74
BRRI dhan63 (Ck)	88	142	5.54
Zirashail (Ck)	101	140	5.53
LSD(0.05)	1.67	1.08	0.25
CV(%)	1.78	1.09	5.58

Table 20. Performance of different genotypes under ALART(STR-1) during Boro 2021-22

Entry/Variety	PH (cm)	GD (days)	Grain Yield (t/ha)			
			Assa	Kali	Deb	Mean
BR11715-4R-186	103	158	4.78	4.81	5.32	4.97
BR11723-4R-27	101	159	4.61	4.66	5.1	4.79
BR11723-4R-12	101	160	4.74	4.81	5.02	4.86
BRRI dhan67 (Tol. Ck)	106	139	5.81	5.76	5.99	5.85
BRRI dhan92 (Sen.Ck)	117	155	5.69	5.56	5.83	5.69
LSD(0.05)	1.46	NS	0.14	0.36	0.37	0.19
CV(%)	0.73	-	1.43	3.73	3.56	1.87

Table 21. Performance of different genotypes under ALART(STR-2) during Boro 2021-22

Entry/Variety	PH (cm)	GD (days)	Grain Yield (t/ha)			
			Assa	Kali	Sadar	Mean
BR11712-4R-227	102	164	5.54	5.51	6.11	5.72
BR11716-4R-105	105	165	4.6	4.77	5.08	4.82
BR11716-4R-102	102	168	4.49	4.56	4.99	4.68
BRRI dhan67 (Tol.Ck)	108	139	5.53	5.7	5.97	5.73
BRRI dhan92 (Sen.Ck)	115	155	5.29	5.51	5.71	5.5
LSD(0.05)	1.42	NS	1.32	0.12	0.3	0.22
CV(%)	0.71	-	1.38	1.22	2.81	1.51

Table 22. Performance of different genotypes at Assasuni, Kaligonj, Debhata in Satkhira during Boro 2020-21

Genotype	PH (cm)	GD (days)	Yield (t ha^{-1})			
			Assasuni	Kaliganj	Debhata	Mean
Binadhan-10	89	142	5.93	5.84	5.80	5.86
BRRI dhan67	88	138	5.75	5.52	5.96	5.74
BRRI hybrid dhan2	110	138	6.39	5.34	5.52	5.75
BRRI hybrid dhan3	99	139	7.21	6.90	6.91	7.01
BRRI hybrid dhan4	104	139	7.06	6.79	6.80	6.88
BRRI hybrid dhan5	101	139	7.40	6.80	6.59	6.93
BRRI hybrid dhan6	104	138	6.38	6.48	6.25	6.37
BRRI hybrid dhan7	102	140	6.32	6.64	5.87	6.28
BRRI99A/BRRI31R	100	138	6.55	6.18	5.62	6.12
BRRI99A/EL254R	103	138	6.89	6.48	6.11	6.49
Gold (Lal teer)	94	139	5.51	5.55	5.30	5.45
Heera (Supreme)	109	138	5.47	5.34	5.22	5.34
IT	120	140	6.25	5.98	6.83	6.35
Janokraj	101	138	5.79	5.33	5.70	5.61
SL-8 (BADC)	110	140	5.59	5.42	5.40	5.47
$LSD_{0.05}$	2.57	0.62	0.36	0.35	0.41	0.45
CV (%)	1.50	0.27	3.40	3.51	4.10	4.41

Table 23. Effect of missing element on grain yield and panicle number of BRRI dhan87 during T. Aman 2021 and BRRI dhan67 in Boro 2021-22.

Treatments	T. Aman 2021			Boro 2021-22		
	Straw yield ($5m^2$)	Grain yield ($t\ ha^{-1}$)	Yield decrease (%) due to missing nutrient	Straw yield ($5m^2$)	Grain yield ($t\ ha^{-1}$)	Yield decrease (%) due to missing nutrient
PKSZn (-N)	2.24	4.39	22	1.69	2.71	60
NKSZn (-P)	3.64	5.04	11	4.03	5.78	14
NPSZn (-K)	3.25	5.21	7	3.71	6.05	9
NPKZn (-S)	3.10	5.27	6	3.54	5.75	14
NPKS (-Zn)	3.38	5.56	1	4.03	6.11	3
NPKSZn	3.33	5.61	-	4.18	6.70	-
Control	2.32	4.11	27	1.53	2.26	70
LSD(0.05)	0.37	0.51		5.78	0.21	
CV (%)	15.2	13.57		8.50	5.25	

Table 24. Effect of different healthy seedling raising techniques of rice during Boro 2020-2021 season

Polythene covering	Seedling height (cm)		Leaf number		Seedling strength		Seedling mortality (%)
	30 DAS	40 DAS	30 DAS	40 DAS	30 DAS	40 DAS	10 DAT
For all time	38.18	41.50	4.62	4.86	12.83	16.71	1.91
From 11.0 am to sunset	30.60	33.26	4.45	4.82	16.99	15.04	1.31
For whole night	31.12	34.94	4.61	5.64	13.02	16.81	1.37
For all time with round shaped opening	33.52	36.76	4.43	5.03	19.96	20.43	0.52
No polyethene covering/ Control	29.08	33.48	4.64	5.26	17.54	18.37	1.52
$LSD_{0.05}$	0.61	0.19	NS	NS	0.12	0.09	
CV(%)	3.95	4.22	-	-	1.31	1.23	

Table 25. Performance of different BRRI varieties under stability analysis during Aus 2021

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR21	105	105	3.61
BR24	104	105	3.25
BR26	118	112	3.9
BRRI dhan27	134	103	3.64
BRRI dhan42	98	107	3.83
BRRI dhan43	123	106	3.64
BRRI dhan48	103	107	4.56
BRRI dhan65	112	104	3.11
BRRI dhan82	106	104	3.96
BRRI dhan83	113	104	3.92

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BRRI dhan85	106	106	3.81
BRRI dhan98	105	107	3.75
BRRI hybrid dhan7	105	107	3.45
LSD(0.05)	7.2	1.55	0.32
CV (%)	8.01	1.79	10.43

Table 26. Performance of different short duration BRRI varieties under stability analysis during Aman 2021

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BRRI dhan33	100	111	3.86
BRRI dhan39	105	114	3.8
BRRI dhan53	103	116	3.95
BRRI dhan56	108	106	4.08
BRRI dhan57	111	100	3.58
BRRI dhan62	93	100	3.15
BRRI dhan66	114	109	3.76
BRRI dhan71	104	111	4.16
BRRI dhan73	115	117	3.58
BRRI dhan75	104	106	4.86
BRRI dhan87	118	120	6.1
BRRI dhan90	102	115	3.68
BRRI dhan95	119	118	3.92
BRRI Hybrid dhan4	104	112	5.21
BRRI Hybrid dhan6	107	114	5.68
LSD(0.05)	1.28	0.43	0.18
CV (%)	1.46	0.47	5.28

Table 27. Performance of different medium duration BRRI varieties under stability analysis during Aman 2021

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR3	87	130	3.86
BR4	118	137	4.91
BR11	108	138	5.46
BR25	123	132	4.62
BRRI dhan30	117	140	4.72
BRRI dhan31	111	135	4.6
BRRI dhan32	103	122	4.85
BRRI dhan40	112	137	4.76
BRRI dhan44	119	137	4.97
BRRI dhan49	97	128	4.92
BRRI dhan51	86	135	4.32

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BRRI dhan52	107	135	5.71
BRRI dhan54	107	130	4.46
BRRI dhan70	121	125	4.58
BRRI dhan72	111	125	4.65
BRRI dhan77	133	137	4.57
BRRI dhan78	110	130	5.1
BRRI dhan79	110	127	4.8
BRRI dhan80	117	127	4.33
BRRI dhan93	118	130	5.18
BRRI dhan94	113	134	5.19
LSD(0.05)	4.29	0.23	0.29
CV (%)	4.74	0.21	7.51

Table 28. Performance of different long duration BRRI varieties under stability analysis during Aman 2021

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR5	117	140	3.64
BR10	110	142	4.93
BR22	122	142	4.14
BR23	122	141	4.26
BRRI dhan34*	112	130	3.48
BRRI dhan37*	126	135	3.22
BRRI dhan38*	124	135	3.22
BRRI dhan41	108	143	4.16
BRRI dhan46	102	145	3.61
BRRI dhan76	136	147	2.86
BRRI dhan91	134	150	2.36
LSD(0.05)	1.84	0.14	0.29
CV (%)	1.89	0.12	9.65

Table 29. Performance of different short duration BRRI varieties under stability analysis during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR1	86	147	5.28
BR6	97	136	5.16
BRRI dhan26	107	135	5.11
BRRI dhan27			NG
BRRI dhan28	88	135	5.77
BRRI dhan36	89	136	5.39
BRRI dhan45	99	135	5.99
BRRI dhan55	98	139	5.59

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BRRI dhan61	87	139	5.72
BRRI dhan63	86	139	6.07
BRRI dhan67	98	136	5.9
BRRI dhan68	95	136	5.73
BRRI dhan74	94	139	5.24
BRRI dhan81	95	136	5.45
BRRI dhan84	91	136	5.43
BRRI dhan86	88	135	5.71
BRRI dhan88	87	136	4.99
BRRI dhan96	84	139	5.54
Bangabandhu dhan100	98	139	6.32
BRRI Hybrid dhan2	96	141	7.39
BRRI Hybrid dhan3	106	144	6.13
BRRI Hybrid dhan5	105	144	7.87
LSD(0.05)	1.51	0.23	0.34
CV (%)	1.97	0.21	7.19

Table 30. Performance of different long duration BRRI varieties under stability analysis during Boro 2021-22

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR2	121	144	5.61
BR3	123	167	6.07
BR7	118	145	5.66
BR8	123	146	6.12
BR9	131	147	5.16
BR12	91	146	6.2
BR14	120	145	6.93
BR15	99	146	5.44
BR16	91	165	7.21
BR17	152	144	4.29
BR18	115	145	5.4
BR19	114	146	5.1
BRRI dhan29	99	146	6.97
BRRI dhan35	114	146	5.71
BRRI dhan47	102	139	6.51
BRRI dhan50	90	144	5.71
BRRI dhan58	103	144	5.89
BRRI dhan59	89	144	6.03
BRRI dhan60	94	139	5.86
BRRI dhan64	104	144	4.95

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BRRI dhan69	107	144	6.4
BRRI dhan89	112	144	5.95
BRRI dhan92	120	146	5.98
BRRI dhan97	117	144	6.99
BRRI dhan99	115	146	6.55
LSD(0.05)	3.2	0.33	0.32
CV (%)	3.55	0.28	6.6

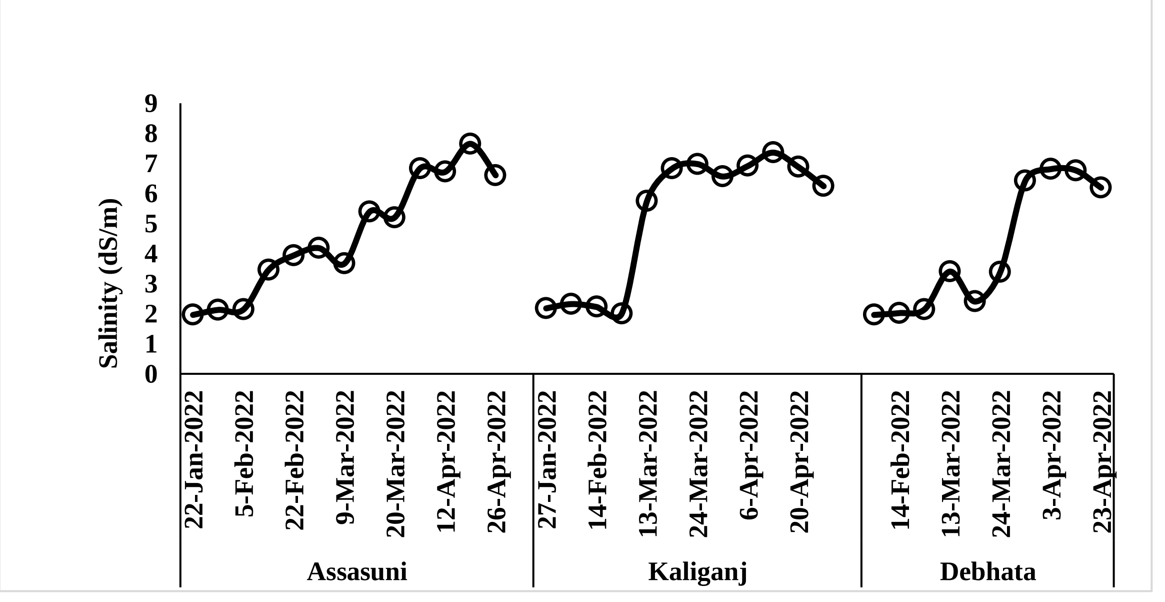


Fig. 1. Soil water salinity of the experimental plots at Assasuni, Kaliganj and Debhata, Satkhira during Boro 2021-22

BRRI RS, Sonagazi

SUMMARY

Regional yield trials (RYT) and advanced line adaptive research trial (ALART) were conducted at experimental field of BRRI RS, Sonagazi, Feni to test the yield performance and to evaluate the yield potential and adaptability of superior breeding lines, respectively. From RYT, 92 breeding lines were tested during the reporting period from which 16 lines were found better than the checks regarding grain yield and yield contributing characters. Breeding lines were supplied from Plant Breeding and Biotechnology Divisions. Seven lines along with standard checks BRRI dhan49, BRRI dhan71, BRRI dhan72 and BRRI dhan87 were tested during T. Aman 2021 from which, one Zinc Enriched Rice (ZER) and one rainfed lowland rice (RLR) were evaluated under on-station condition which were supplied from Plant Breeding Division of BRRI HQ. On the basis of growth duration, yield and yield contributing characters, no lines were selected for advanced trial during T. Aman 2021. Seventy-two lines along with standard checks BRRI dhan28, BRRI dhan29, BRRI dhan50, BRRI dhan58, BRRI dhan63, BRRI dhan67, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan89, BRRI dhan92, BRRI dhan96, BRRI dhan97 and local check Zirasail were tested during Boro 2021-22. Two lines from FBR-SD (IR17A1723 and BRRI dhan29-SC3-28-16-10-6-HR6 (Com)-HR1(Gaz)-P8 (Hbj)), one line from FBR-LD ((BR10604-5R-58), one line from STR-1 (BR9904-1-3-3), six lines from FBR-MD (BR11342-5R-23, BR113375R-72, BR10317-5R-57, BR11303-5R-53, SV1N109, IR17A2433), two lines from FBR-Barisal (NGR521-2 and NGR522-1), four lines from SS (BRH10-1-14-2-6B, BRH13-1-9-7B, BRH17-23-8-2-7B, BRH13-2-4-7-2B), one line from LS (BR10247-14-18-4) were recommended for advanced trial. From ALART, a total of 18 breeding lines were evaluated under this trial during the reporting period. Breeding lines were supplied from Plant Breeding and Biotechnology Divisions.

On-farm demonstrations were conducted under SPDP during Aus 2020, Aman 2020 and Boro 2020-21 seasons. Number of total demonstration was 164 (3 bigha/demo.) and direct beneficiary farmers were about 3,987 from which about 173 tons of quality seed produced and retained farmers about 17 of seed tons. During the reporting period, BRRI RS, Sonagazi produced 14.07 tons of breeder seed during Aman 2020 (3.57 tons) and Boro 2020-21 (10.5 tons) seasons. All the breeder seeds of different varieties were sent to Genetic Resources and Seed Division, BRRI, Gazipur. Total TLS production of BRRI released modern rice varieties during Aus, Aman and Boro were 1,500 kg, 11,500 kg and 5,300 kg respectively. A total of 35 farmers trainings were arranged with the participation of 1010 farmers (784 male and 226 female). Fourteen field days were arranged in selected demonstration sites at the crop maturity stage where nearly 2,250 progressive farmers, local leaders, DAE field stuff, public representatives and NGO workers participated.

VARIETY DEVELOPMENT

RYT zinc enriched rice (ZER) during T. Aman 2021

Two advanced lines BR10005-25-8-4-7-20 and BR10022-2-8-9-5-22 along with two standard check BRRI dhan72 and BRRI dhan87 were evaluated at BRRI RS, Sonagazi, Feni during T. Aman 2021. The advanced lines BR10005-25-8-4-7-20 and BR10022-2-8-9-5-22 produced 5.97 and 6.27 t/ha yields respectively (Table 1). None of the tested lines showed better performance than the standard checks.

Table 1. Results of RYT(ZER) during T. Aman 2021at BRRI RS, Sonagazi.

Designation	Grain yield (t/ha)	Growth duration (day)	Plant height (cm)
BR10005-25-8-4-7-20	5.97	128	122
BR10022-2-8-9-5-22	6.27	131	118
BRRI dhan72 (ck)	6.04	125	121
BRRI dhan87 (ck)	6.34	129	120

$LSD_{0.05}$	NS	1.63	NS
CV (%)	6.307	0.63	2.10

RYT rainfed lowland rice (RLR) during T. Aman 2021

Five advanced lines SVIN209, SVIN172, IR98377-B-B-B-B-24, BR9840-52-1-2-1and BR8492-9-5-3-2-HR1 along with three standard checks BRRI dhan49, BRRI dhan71 and BRRI dhan87 were evaluated at BRRI RS, Sonagazi, Feni during Aman 2021. The advanced lines SVIN209, SVIN172, IR98377-B-B-B-B-24, BR9840-52-1-2-1 and BR8492-9-5-3-2-HR1 produced 5.34, 5.39, 4.24, 4.61 and 5.19 t/ha yields respectively (Table 2). None of the tested lines showed better performance than standard checks.

Table 2. Results of RYT (RLR) during T. Aman 2021 at BRRI RS, Sonagazi.

Designation	Grain yield (t/ha)	Growth duration (day)	Plant height (cm)
SVIN209	5.34	131	121
SVIN172	5.39	122	127
IR98377-B-B-B-B-24	4.24	124	119
BR9840-52-1-2-1	4.61	121	124
BR8492-9-5-3-2-HR1	5.19	130	125
BRRI dhan49 (ck)	4.88	133	104
BRRI dhan71 (ck)	5.06	118	122
BRRI dhan87 (ck)	5.62	129	125
$LSD_{0.05}$	0.63	1.86	7.56
CV (%)	7.16	0.83	3.57

RYT favourable boro rice short duration (FBR SD) during Boro 2021- 22

In RYT (FBR SD), IR17A1723 and BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR1(Gaz)-P8(Hbj) showed higher yield than BRRI dhan81 and BRRI dhan96 (checks). IR17A1694 showed higher yield than BRRI dhan96 and lower yield than BRRI dhan81 (Table 3). So, these two lines (IR17A1723 and BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR1(Gaz)-P8 (Hbj)) can be tested for further varietal development activities.

Table 3. Results of RYT (FBR SD) during Boro 2021- 22 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield(t/ha)
IR17A1694	107	140	6.47
BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR2(Gaz)-P11(Hbj)	damaged	damaged	damaged
IR17A1723	100	142	6.78
BRRI dhan81	104	144	6.52
BRRI dhan96	92	142	6.26
BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR1(Gaz)-P8(Hbj)	99	148	7.08
LSD 0.05	4.9578	2.1468	0.5439
CV (%)	2.62	0.80	4.36

RYT Favourable boro rice long duration (FBR LD) Boro 2021-22

In RYT FBR LD, BR10604-5R-58 showed higher yield than BRRI dhan89 and BRRI dhan92 (checks), but the other lines showed lower yield than the checks (Table 4). So, this line (BR10604-5R-58) can be selected for further varietal development activities.

Table 4. Results of RYT (FBR LD) during Boro 2021- 22 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield(t/ha)
BRRI dhan89	108	156	8.31
BR10599-5R-375	105	150	7.56
BRRI dhan92	107	160	8.40
BR11318-5R-148	112	153	8.03
BR11318-5R-140	113	151	7.40
BR11318-5R-84	108	146	7.12
BR11318-5R-106	118	151	7.02
BR10604-5R-58	114	152	8.47
BR10301-5R-89	111	149	7.64
BR11318-5R-10	102	149	7.90
BR10604-5R-10	115	150	6.82
LSD 0.05	4.1210	2.9410	0.7544
CV (%)	2.19	1.14	5.75

RYT AGGRi NETBoro 2021-22

In RYT AGGRi NET, IR08N134, IR17A1694, IR12A173, IR17A2241, IR17A1650, IR17A2433, IR16A3667 (all the lines) showed lower yield than BRRI dhan89 and BRRI dhan92. IR08N134 and IR12A173 showed higher yield than BRRI dhan63 and BRRI dhan81; the other lines also showed higher yield than BRRI dhan63 and BRRI dhan81, but showed lower yield than these two lines (IR08N134 and IR12A173) (Table 5). So, none of the entries performed better than the checks.

Table 5. Results of RYT AGGRi NET during Boro 2021- 22 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
IR08N134	107	142	7.6
BRRI dhan89	108	155	8.18
IR17A1694	105	144	6.81
IR12A173	115	142	7.21
IR17A2241	108	142	6.95
BRRI dhan81	104	145	6.36
BRRI dhan92	109	161	8.50
IR17A1650	103	140	6.6
IR17A2433	116	142	6.51
IR16A3667	111	143	6.52
BRRI dhan63	95	145	6.26
LSD 0.05	4.7963	2.4753	0.5759
CV (%)	2.62	1.00	4.80

Development of salt tolerant rice (STR 1) Boro 2021-22

In RYT STR 1, BR9904-1-3-3 showed higher yield than BRRI dhan89 and BRRI dhan67 but similar yield as BRRI dhan97 (check). On the other hand, other lines showed lower yield than the checks (Table 6). So, this line (BR9904-1-3-3) may be selected for further varietal development activities.

Table 6. Results of RYT STR-1 during Boro 2021- 22 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield(t/ha)
BR10182-5-4-2	106	143	6.09
BR10187-1-4-12	103	143	5.74
BR10187-1-5-11	111	145	5.46
BR10188-10-1-18	106	145	6.28
BR9901-1-3-10	105	145	4.89
BR9904-1-3-3	105	146	6.59
BR9918-10-4-5	107	144	4.78
BR9926-7-7-6	106	144	5.89
BRRI dhan89	110	155	6.34
BRRI dhan67	103	147	5.48

BRRI dhan97	107	151	6.60
LSD 0.05	5.2937	1.8373	0.4049
CV (%)	2.93	0.74	4.08

Development of salt tolerant rice (STR 2) Boro 2021-2022

In RYT STR 2, TP21654 showed higher yield than BRRI dhan67 and BRRI dhan97 but lower yield than BRRI dhan89. Other lines showed almost the same yield performance or lower yield performance the checks (Table 7). So, none of the entries performed better than all the three checks.

Table 7. Results of RYT STR-2 during Boro 2021- 22 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield(t/ha)
IR108175-B-22-AJY3-B-1	112	144	6.27
IR108604-2-1-AJY3-B-1	110	145	6.66
IR108604-2-3-AJY3-B-1	109	144	6.60
IR15T1399TP20532	107	144	6.05
TP20532	98	145	6.33
TP21654	118	146	6.83
TP24493	101	141	6.30
TP30629	102	143	5.74
TP30642	108	144	5.76
BRRI dhan89	106	155	7.64
BRRI dhan67	100	146	6.24
BRRI dhan97	102	151	6.12
LSD 0.05	2.8388	1.6522	0.4985
CV (%)	1.58	0.67	4.61

RYT for favorable boro rice medium duration (FBR MD) Boro 2021-22

In RYT FBR MD tested lines BR9945-5R-25, BR9945-5R-21, BR10623-5R-15, BR10601-5R-74 , BR11318-5R-21, BR11318-5R-63 showed similar grain yield to the check varieties of BRRI dhan96 but lower yield than the check BRRI dhan81 and BR8899-14-4-1-2-2-1 showed similar grain yield with to check variety of BRRI dhan81 but higher than the check BRRI dhan96. BR11342-5R-23, BR11337-5R-72, BR10317-5R-57, BR11303-5R-53, SV1N109, IR17A2433 entries produced higher yield than the check varieties of BRRI dhan96 and BRRI dhan81(Table 8).

Six better yielder entries i. e.BR11342-5R-23, BR113375R-72, BR10317-5R-57, BR11303-5R-53, SV1N109, IR17A2433 could be selected for further varietal development activities

Table 8. Results of RYT (FBR MD) during Boro 2021- 22 at BRRI RS, Sonagazi.

Designation	Plant height(cm)	Growth duration (day)	Grain yield (t/ha)
BR11342-5R-23	111	138	6.78
BR11337-5R-72	100	137	6.79
BR10317-5R-57	102	142	6.66
BRRI dhan96	92	145	6.41
BR11318-5R-63	101	139	6.43
BR8899-14-4-1-2-2-1	93	140	6.49
BR11303-5R-53	102	142	7.16
SV1N109	104	136	6.65
BR9945-5R-25	105	144	6.12
BR10623-5R-15	113	144	6.15
BR9945-5R-21	103	141	6.43
BRRI dhan81	105	144	6.62
BR10601-5R-74	112	145	6.41
IR17A2433	112	140	6.94
BR11318-5R-21	101	141	6.17
LSD 0.05	4.1672	2.6462	0.5932
CV (%)	2.40	1.12	5.42

RYT (FBR ZER) Boro 2021-22

In RYT ZER tested linesBR9674-4-2-10-5-P9,BR9674-1-1-5-1-P3 showed similar grain yield with the check varieties of BRRI dhan29, BRRI dhan74 and BRRI dhan84 (Table 9). So, none of the entries performed better than the three checks.

Table 9. Results of RYT (FBR ZER) during Boro 2021- 22 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield(t/ha)
BR9674-4-2-10-5-P9	110	146	7.03
BR9674-1-1-5-1-P3	113	152	6.95
BRRI dhan29(ck)	102	161	7.45
BRRI dhan74(ck)	103	148	6.69
BRRI dhan84(ck)	100	140	6.32
LSD 0.05	6.2162	1.9140	0.9330
CV (%)	3.12	0.68	7.19

RYT Favourable Boro rice, Boro 2021-22

In RYT FBR, tested lines BR (Bio) 10381AC32-3, BR (Bio) 10381AC1-2 showed similar grain yield to the check varieties of BRRI dhan88 and BRRI dhan96 (Table 10). So, none of the entries performed better than the checks.

Table 10. Results of RYT FBR (Favourable Boro rice) during Boro 2021- 22 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield(t/ha)
BR(Bio)10381AC32-3	105	139	6.5
BR(Bio)10381AC1-2	86	137	6.72
BRRI dhan88(ck)	95	142	7.26
BRRI dhan96(ck)	87	145	6.6
LSD 0.05	2.2088	1.4891	0.1619
CV(%)	1.18	0.53	1.2

RYT (Barishal) for favourable Boro rice, Boro 2021-22

In RYT (Barishal) for favourable Boro rice, tested lines NGR111-1, NGR418-1, NGR467-2, NGR750-1, NGR796-2, NGR1161-3, NGR1255-1, NGR1308-2 showed lower yield than the check of BRRI dhan89 and BRRI dhan58. NGR521-2 and NGR522-1 entries produced higher yield than the check varieties BRRI dhan58 and BRRI dhan89 (Table 11).

Tow better yielder entries i. e. NGR521-2 and NGR522-1 could be selected for further varietal development activities

Table 11. Results of RYT (Barishal) for favourable Boro rice (FBR) during Boro 2021- 22 at BRRI Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
NGR111-1	92	145	5.88
NGR418-1	96	146	5.61
NGR467-2	97	147	6.35
NGR521-2	98	138	7.2
NGR522-1	103	140	7.42
NGR750-1	105	146	6.88
NGR796-2	95	140	6.51
NGR1161-3	92	141	6.12
NGR1255-1	105	146	5.75
NGR1308-2	98	141	5.59
BRRI dhan58(ck)	110	150	6.51
BRRI dhan89(ck)	111	154	7.31
LSD 0.05	4.8239	1.2419	0.3490
CV (%)	2.84	0.51	3.21

Regional yield trial-1 (SS-short slender)

In RYT (SS-short slender) tested lines BRH10-1-14-2-6B, BRH13-1-9-7B, BRH17-23-8-2-7B, BRH13-2-4-7-2B showed higher grain yield than the check varieties of BRRI dhan28 and BRRI dhan81 but BRH9-3-2B showed similar grain yield with the check varieties BRRI dhan81 and BRRI dhan28 (Table 12).

Four better yielder entries i.e. BRH10-1-14-2-6B, BRH13-1-9-7B, BRH17-23-8-2-7B, BRH13-2-4-7-2B could be selected for further varietal development activities

Table 12. Results of RYT (SS-short slender) for favourable Boro rice during Boro 2021- 22 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BRH10-1-14-2-6B	98	142	7.35
BRH9-3-2B	100	143	6.65
BRH13-1-9-7B	102	141	7.22
BRH17-23-8-2-7B	97	142	7.44
BRH13-2-4-7-2B	96	142	7.08
BRRI dhan28(ck)	100	141	6.29
BRRI dhan81(ck)	103	146	6.53
LSD 0.05	6.2957	1.9921	0.5667
CV (%)	3.57	0.79	4.59

Regional yield trial-3 (LS-long slender)

In (RYT 3- long slender) tested lines BR10247-4-7-4B, BRH11-2-4-7B showed similar grain yield with the check variety BRRI dhan28 but BR10247-14-18-4 higher yield than the check of BRRI dhan28 (Table 13). One better yielder entry i.e. BR10247-14-18-4 produced could be selected for further varietal development activities.

Table 13. Results of RYT regional yieldtrial-3 (long slender) for favourable Boro rice during Boro 2021- 22 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Groth duration (day)	Grain yield (t/ha)
BRH11-2-4-7B	108	144	6.91
BR10247-14-18-4	109	145	7.14
BR10247-4-7-4B	108	146	6.97
BRRI dhan28(ck)	101	141	6.45
LSD 0.05	6.71	2.61	0.7606
CV (%)	2.76	2.61	4.82

Advanced line adaptive research trial (ALART) during Boro 2021-22

Advanced line adaptive research trial (ALART) for premium quality rice (PQR)

The two lines BR9930-2-3-2-2 and BR9930-2-3-3-1 produced lower yield (5.36 and 5.25 t ha^{-1}) compared to three check varieties (5.84, 6.18 and 6.01 t ha^{-1}). Their plant heights were also higher (123 cm) than the check varieties (Table 14).

Table 14. Performance of different genotypes under ALART for PQR during Boro 2021-22.

Genotype	**Plant height (cm)**	**Growth duration (day)**	**Yield (t/ha)**
BR9930-2-3-2-2	123	144	5.36
BR9930-2-3-3-1	121	145	5.25
BRRI dhan50 (ck)	86	153	5.84
BRRI dhan63 (ck)	97	146	6.18
BRRI dhan81 (ck)	106	144	6.01
CV (%)	2.8	0.84	7.77
$LSD_{0.05}$	5.61	2.31	0.84

Advanced line adaptive research trial (ALART) for superior high yielding rice (SHR)

The line BRH13-7-9-3-2B produced the highest yield (6.46 t ha^{-1}) compared to the two check varieties (6.31 and 5.77 t ha^{-1}) but its plant height was very much longer (125 cm) which increased the chances of lodging. The line BRHII-9-11-4-5B also produced better yield (6.24 t ha^{-1}) compared to the check variety Zirashail (5.77 t ha^{-1}) (Table 15).

Table 15. Performance of different genotypes under ALART for SHR during Boro 2021-22.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BRHII-9-11-4-5B	106	154	6.24
BRH13-2-4-6-4B	104	155	6.11
BRH13-7-9-3-2B	125	155	6.46
BRRI dhan63 (ck)	95	148	6.31
Zirashail (ck)	106	147	5.77
CV (%)	1.68	0.37	4.91
$LSD_{0.05}$	3.39	1.06	0.57

Advanced line adaptive research trial (ALART) for favourable boro rice (FBR-Barishal)

The four lines BRBa 1-4-9, BRBa 2-5-3, BRBa 3-1-7 and BRBa 3-2-4 gave higher yield (7.42, 7.67, 7.52 and 7.64 t ha^{-1}) compared to the check variety BRRI dhan58 (7.04 t ha^{-1}) but also produced the lower yield compared to the check variety BRRI dhan89 (8.17 t ha^{-1}). The line BRBa 1-4-9 showed the highest plant height (128 cm) compared to the others (Table 16).

Table 16. Performance of different genotypes under ALART for FBR-Barishal during Boro 2021-22.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BRBa 1-4-9	128	153	7.42
BRBa 2-5-3	102	152	7.67
BRBa 3-1-7	105	154	7.52
BRBa 3-2-4	106	155	7.64
BRRI dhan58 (ck)	107	152	7.04
BRRI dhan89 (ck)	107	156	8.17
CV (%)	1.41	0.82	5.22
$LSD_{0.05}$	2.80	2.30	0.72

ALART for salt tolerant rice (STR-1)

The three lines BR11715-4R-186, BR11723-4R-27 and BR11723-4R-12 produced higher yield compared to the check variety BRRI dhan67 but also produced lower yield compared to the check variety BRRI dhan92 in both STR-1. The three lines showed the longer growth duration compared to the two check varieties in both STR-1 (Table 17.1 and 17.2).

Table17.1 Performance of different genotypes under ALART for STR-1 during Boro 2021-22, Char Elahi, Companiganj, Noakhali.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR11715-4R-186	117	168	7.67
BR11723-4R-27	115	167	7.48
BR11723-4R-12	114	165	7.14
BRRI dhan67 (Tol.ck)	107	143	6.54
BRRI dhan92 (Sen.ck)	112	160	8.05
CV (%)	1.82	0.6	5.53
$LSD_{0.05}$	3.89	1.82	0.77

Table 17.2. Performance of different genotypes under ALART for STR-1 during Boro 2021-2022, Londonipara, Sonagazi, Feni.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR11715-4R-186	115	169	7.13
BR11723-4R-27	113	168	7.22
BR11723-4R-12	112	164	6.77
BRRI dhan67 (Tol. ck)	108	144	6.18
BRRI dhan92 (Sen. ck)	108	159	7.54
CV (%)	1.63	0.39	5.05
$LSD_{0.05}$	3.40	1.19	0.66

(ALART for salt tolerant rice (STR-2)

The three lines BR11712-4R-227, BR11716-4R-105 and BR11716-4R-102 produced higher yield compared to the check variety BRRI dhan67 but also produced lower yield compared to the check variety BRRI dhan92 in both STR-2. The three lines showed longer growth duration compared to the two check varieties in both STR-2 (Table 18.1 and 18.2).

Table 18.1. Performance of different genotypes under ALART for STR-2 during Boro 2021-2022, Char Elahi, Companiganj, Noakhali.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR11712-4R-227	110	168	7.36
BR11716-4R-105	111	167	7.15
BR11716-4R-102	106	166	7.02
BRRI dhan67 (Tol.ck)	106	144	6.44
BRRI dhan92 (Sen.ck)	111	161	8.22
CV (%)	1.88	0.85	3.43
$LSD_{0.05}$	3.86	2.58	0.47

Table 18.2. Performance of different genotypes under ALART for STR-2 during Boro 2021-22, Londonipara, Sonagazi, Feni.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR11712-4R-227	114	169	7.33
BR11716-4R-105	113	168	7.63
BR11716-4R-102	112	165	7.44
BRRI dhan67 (Tol.ck)	101	145	7.33
BRRI dhan92 (Sen.ck)	109	158	7.44
CV (%)	1.99	0.81	5.66
$LSD_{0.05}$	4.10	2.45	0.79

PEST MANAGEMENT

Survey and monitoring of rice diseases

Survey was carried out at farmers' fields of Feni, Noakhali, Laxmipur, Cox's Bazar, Chattogram and Khagrachari districts both in T. Aman 2021 and Boro 2021-22. Sites were selected with the suggestion and collaboration of Upazila Agricultural Officer (UAO) of the Department of Agricultural Extension (DAE). Sub-Assistance Agricultural Officer (SAAO) of concerned block helped in site selection who were the front-line workers and very much familiar to the farmers as well as their fields.

Bacterial leaf blight (BLB), bacterial leaf streak (BLS), sheath rot, false smut and sheath blight infestation were observed in different scores during T. Aman season. BRRI dhan49 and BRRI dhan79 were affected by false smut disease in different locations due to fluctuation of environmental conditions during Aman season. BRRI dhan87 was affected by tungro in different locations during Aman 2021. BRRI dhan28, BRRI dhan29 and BRRI dhan84 were affected moderately by blast during Boro season. The farmers were suggested for preventive measures using fungicide.

Monitoring of insect pests and natural enemies by using light trap

Rice insect pests and their natural enemies were monitored throughout the reporting period by Pennsylvanian light traps from July 2021 to June 2022 at the experimental field of BRRI RS, Sonagazi, Feni. The abundance of leaf roller, stem borer, rice bug, green leafhopper, grasshopper, mole cricket, field cricket, and stink bug were found in the light trap during the reporting period. Some beneficial insects like lady bird beetle, spider, damsel fly, carabid beetle, staphynilid beetle were also found.

Evaluation of modern rice varieties against major insect pests

The objectives of the study were to investigate pest incidence and tolerance of the modern rice varieties and to select resistant rice varieties against major rice insect pests.

Insects are a major constraint to rice production. Yield loss due to insects and diseases has been estimated at about **15-25%.** All portions of the plant from root to panicle, are attacked by various insects. No insect pests resistance of modern rice varieties were found in Chattagram region.

So the programme has designed to evaluate the BRRI developed high yielding rice varieties against major rice insect pests

The experiment was conducted at the experimental field of BRRI RS, Sonagazi. Eight modern rice varieties were evaluated during Boro 2021-22. This experiment was laid out in a RCBD with three replications. Forty-one-day-old seedlings of each varietiy were transplanted in 3.15 m x 2.25 m plot using 2-3 seedlings at a spacing of 25 cm x 15 cm. The recommended fertilizer doses were 25-12-20-15-1.5 kg/ha (Urea -TSP-MOP- gypsum - zinc ,monohydrate). All the amounts of P K S and Zn were applied at the time of final land preparation and N was applied at three equal splits at 15,30 and 45 days after transplanting. All the intercultural operations were done when required but no insecticide was applied.

Insect infestation data were collected from 10 hills. Data on tiller/hill (no.), stem borer/hill (no.), rice bug/hill (no.), lady bird beetle/hill (no.), spider/hill (no.) were counted at mid tillering stage, maximum tillering stage, flowering and maturity stage of rice.

The experiment was initiated in December 2021 and completed in May 2022.

Locations: BRRI RS, Sonagazi

All of the varieties were allowed to natural infestation of SB and RB as well as LLB and spider. Infestation starts when most of the entries were at heading stage. Number of insects per hill was below the ETL for all varieties (Table 19). Nevertheless, BRRI dhan99 performed better yield of 8.93 t ha^{-1} over the other varieties and showed 153 days growth duration followed by BRRI dhan29 and BRRI dhan89 (Table 20).

PI: Sania Tamanna, SO, BRRI Sonagazi

CI: Md Al Imran Hasan, Md Nayeem Ahmed and Biswajit Karmakar, BRRI Sonagazi

Table 19. Incidence of SB/hill (no.), RB/hill (no.), LLB/hill (no), spider/hill (no.) on different varieties during Boro 2021-22 at BRRI RS, Sonagazi.

Entry	SB/hill (no.)	RB/hill (no.)	LLB/hill (no.)	Spider/hill (no.)
BRRI dhan29	0.3	0.3	0.5	0.3
BRRI dhan58	0.3	0.4	0.5	0.4
BRRI dhan89	0.3	0.5	0.2	0.2
BRRI dhan92	0.2	0.2	0.3	0.2
BRRI dhan96	0.3	0.2	0.5	0.2
BRRI dhan97	0.4	0.4	0.4	0.3
BRRI dhan99	0.4	0.4	0.8	0.5
Bangabandhu dhan100	0.3	0.2	0.2	0.4

Table 20. Performance of different varieties under SB/hill (no.), RB/hill (no.), LLB/hill (no.), Spider/hill (no.) during Boro 2021-22 at BRRI RS, Sonagazi

Entry	Growth duration(day)	Effective tiller/hill (no.)	Yield (t/ha)
BRRI dhan29	155	11	8.32
BRRI dhan58	150	14	5.61
BRRI dhan89	153	11	8.25
BRRI dhan92	158	13	7.63
BRRI dhan96	144	13	7.55

BRRI dhan97	150	15	7.13
BRRI dhan99	153	12	8.93
Bangabandhu dhan100	147	12	6.63
LSD 0.05	1.06	0.84	1.61
CV(%)	0.40	12.0	12.2

CROP-SOIL- WATER MANAGEMENT

Effect of potassium and sulphur on the performance of modern rice varieties in char land

Farmers of Feni and Noakhali char area ares using few amounts of potassium (K) and sulphur (S) fertilizer for rice cultivation. But Potassium has significant role in plant growth and development. The farmers of char land argue that long time rice cultivation without application of potassium fertilizer may reduce soil fertility and increase soil salinity. It also reduces rice yield significantly. So, it is very important to know the effect of potassium and sulphur in char land rice cultivation. This experiment is designed to show the effect of potassium on rice yield to the farmers of char land.

The trial was conducted to know the effect of potassium in char land rice cultivation as well as to show the effect of potassium on rice yield to the farmers of char land.

This experiment was conducted in BRRI RS, Sonagazi farm during Boro 2022. It was done in RCB design with three replications and the variety BRRI dhan88 was used. From this experiment rice grain yield, tiller/m^2, panicle/m^2, grain/panicle, 1000 grain weight, plant height and unfilled grain percent data were collected. Different levels of fertilizer doses were used as follows

Treatment

T1	: Absolute control (No fertilizer)
T2	: STB dose fertilizer
T3	: STB dose fertilizer + 20% more K
T4	: STB dose fertilizer + 40% more K
T5	: BRRI recommended rate
T6	: Farmer’s practice

The field trial was conducted at BRRI RS farm, Sonagazi with six different fertilizer treatments in Boro 2021-22 season. In this trial BRRI dhan88 was used. The results showed that the treatment STB + 40% more potassium (K) produced maximum grain yield (6.22 tha^{-1}). But the treatments STB dose, STB + 20% more K, STB + 40% more K and BRRI recommended dose showed statistically similar grain yield which was statistically higher than treatment absolute control (3.02 tha^{-1}) followed by farmer’s practice (5.57 tha^{-1}), respectively (Table 21).

Table 21. Grain yield and yield contributing characters of fertilizer trial in Sonagazi with BRRI dhan88.

Treatment	GYTPHA	SYTPHA	PH (cm)	TPM	PPM	TGW (g)
T_1=Absolute control (No fertilizer)	3.02	4.41	74	184	162	20.32
T_2=STB dose fertilizer	5.83	6.74	87	301	263	19.76
T_3=STB dose fertilizer + 20% more K	6.04	6.71	88	314	279	20.18
T_4=STB dose fertilizer + 40% more K	6.22	6.88	89	313	271	19.70
T_5=BRRI recommended rate	6.00	6.56	87	311	268	19.60
T_6=Farmer’s practice	5.57	6.66	83	264	230	19.68
CV	7.87	5.87	2.96	8.36	7.55	4.72
LSD (0.05)	0.77	0.34	0.012	31	32	0.77

This experiment results indicated that potassium application increased rice grain yield.

Effect of micronutrient zinc on the performance of modern rice varieties

Zn is limited in saline soils causing a substantial reduction in yield (Shelley et al., 2016). Many lands in Chattogram region are zinc deficient and remained waterlogged. Most of the farmers of Chattogram region use imbalance fertilizers and most of the cases they don’t apply zinc in rice field.

The objectives of the trias were to evaluate the responses of the modern rice varieties under a range of zinc supplies and to determine the nutrient content in grain and straw as well as to investigate the nutrient (Zn) use efficiency of the rice varieties.

This field trial was conducted at BRRI RS farm, Sonagazi during Boro 2021-22. In this trial eight different zinc (Zn) doses were applied with three BRRI varieties such as BRRI dhan74, BRRI dhan84 and BRRI dhan88. The trial was conducted with three replications in split-plot design. All the intercultural activities and data collection were done following standard way.

The results of the trial showed that among the treatments variety mean recommended rate + 100% higher Zn (5.27 tha^{-1}) produced significantly higher grain yield across the varieties. The results also showed that among the varieties in treatments mean BRRI dhan74 (4.56 tha^{-1}) produced significantly higher grain yield followed by BRRI dhan84 (4.36 tha^{-1}) and BRRI dhan88 (4.15 tha^{-1}) respectively. BRRI dhan74 (5.72 tha^{-1}) and BRRI dhan84 (5.45 tha^{-1}) among the treatments recommended rate + 100% higher Zn produced significantly the highest grain yield and BRRI dhan88 in recommended rate + 50% higher Zn (Table 22).

Table 22. Response of different Zn levels on grain yield of the varieties.

Grain yield (t/ha)				
Variety/Treatment	**BRRI dhan84**	**BRRI dhan99**	**Bangabandhu dhan100**	**Treatment mean**
T1 = Recommended rate	5.78	6.74	5.67	6.07
T2 = T1-50% Zn	5.49	6.37	5.83	5.90
T3 = T1 –100% Zn	6.30	6.54	5.76	6.20
T4 = T1 + 50% higher Zn	6.18	6.31	6.22	6.24
T5 = T1 + 100% higher Zn	6.16	5.84	5.47	5.82
T6 = T1 but Zn will be applied by spraying	6.03	6.43	5.95	6.14
T7 = Soil test based (STB	5.20	6.77	5.20	5.72
T8 = Control	3.45	4.06	2.73	3.42
Variety mean	5.57	6.13	5.35	
CV (Rep*Treatment)			6.4	
CV (Rep*Treatment*Variety)			9.76	

This is one year season based results. For better understanding we need to repeat this experiment.

Nitrogen Use Efficiency on Modern Rice Varieties for Boro Season

Specific objectives of the experiment were to evaluate the responses of Bangabandhu dhan100 under a range of nitrogen supplies and to investigate the nitrogen use efficiency and to find out optimum nitrogen requirement for maximum yield of Bangabandhu dhan100.

Bangabandhu dhan100 was used as planting material. Thirty-eight-day-old seedlings were transplanted in 3m x 4m ($12m^2$) unit plot using 2-3 seedlings with 20 cm × 20 cm spacing. The experiment was laid out following randomized complete block design (RCBD) with three replications.

Seven levels of nitrogen applied in the experiment were as follows:

T1= BRRI Recommended dose: N, P, K, S and Zn @ 124, 22, 75, 20 and 4 kg ha^{-1} (270, 112, 150, 112 and 11 kg ha^{-1}),T2 = T1 – N, T3 = T1 but 50 kg N $ha^{-}1$, T4 = T1 but 100 kg N ha^{-1}, T5 = T1 but 150 kg N ha^{-1}, T6 = T1 but 200 kg N ha^{-1}, T7 = Soil test based (STB) nutrient rates (N, P, K, S and Zn @ 88, 15, 54, 6 and 1 kg ha^{-1}); Recorded in 2021, Soil Science Lab, BRRI, Gazipur. T8 = Control/Native Nutrient

Data to be collected were on nitial and post-harvest soil status, plant height at maturity, yield components, grain and straw yield, harvest index, grain and straw samples for analyses, partial factor productivity (PFP) of nitrogen, agronomic efficiency (AE) of nitrogen, recovery efficiency (RE) of nitrogen, physiological efficiency (PE) of nitrogen, internal efficiency (IE) of nitrogen, nutrient harvest index (NHI) of nitrogen and plant biomass.

The experiment was initiated in December 2021 and it was completion May 2022

PI: M A Biswas

CI: B Karmakar, M N Ahmed, M A I H Hasan and T Ferdous

In this experiment, eight different treatments were used. There was a positive effect of different N fertilizer doses on growth and yield components of Bangabandhu dhan100. The maximum plant height was recorded 103 cm under the treatment T_5 (T_1 but 150 kg N ha^{-1}) and the lowest plant height was 91cm under the treatment T_8 (Control/Native Nutrient). T_5 shows the highest number (161) of tiller/12 hill and the lowest number (133) of tiller/12hill was observed in T_8. The average highest panicle number/12 hill (144) was obtained in T_4 (T1 but 100 kg N ha^{-1}) treatment and the lowest panicle number/12 hill (112) was obtained in treatment T_8. Nutrient controlled plot produced the lowest yield compared to the other fertilizer treatments (Table 23). T_6 which provided the highest yield 6.69 t/ha whether the lowest yield was 3.90 t/ha at T_8. Finally, higher grain yield and straw yield was observed by the application of increased N rates than the recommended N rate.

Table 23. Effect of treatments on plant growth and yield contributing characters.

Treatment	GD (day)	Plant height at maturity (cm)	Grain weight (6m2)	Moisture Content (%)	No. of Tiller/12 hill	No. of panicle/12 hill	Straw weight kg/6m2	Length of panicle (cm)	Filled grains/2 hill	Unfilled grains/2 hill	TGW (g)	% Sterility	Yield (t/ha)
T1	140	100	3.72	23.5	145	130	10.81	24.17	2776	397	17.80	12.5	5.52
T2	144	95	2.63	21.9	148	134	7.91	15.93	2498	277	17.79	9.7	3.98
T3	142	95	2.99	23.5	147	135	9.39	23.06	2472	239	18.08	8.5	4.44
T4	143	97	3.92	22.4	155	144	11.50	23.72	2604	362	17.32	12.3	5.90
T5	143	103	4.10	23.5	161	140	11.29	24.29	1995	373	17.87	16.0	6.08
T6	145	102	4.41	21.9	145	127	13.86	23.23	3221	289	17.49	8.1	**6.69**
T7	141	95	2.89	21.3	155	139	9.69	22.14	1959	195	18.54	8.7	4.41
T8	135	91	2.61	22.9	133	112	8.55	21.74	2355	318	17.68	11.5	**3.90**
Grand average	**142**	**97**	**3.41**	**22.6**	**149**	**132**	**10.38**	**22.29**	**2485**	**306**	**17.82**	**10.9**	**5.11**

DS: 14 Dec 2021 **DT: 20 Jan 2022**

Note: Treat = Treatment, TGW = Thousand grain weight, GD = Growth duration

Optimizing Planting Geometry of Bangabandhu dhan100

Specific objectives:

The specific objectives of the trial was to investigate the responses of Bangabandhu dhan100 to varying plant spacings and to determine the optimum spacing for better performance of Bangabandhu dhan100.

Bangabandhu dhan100 was used as planting material. Thirty-eight-day-old seedlings were transplanted in 3m x 3m ($9m^2$) unit plot by using 2-3 seedlings/hill with six different spacing. The experiment was laid out following randomized complete block design (RCBD) with three replications.

BRRI recommended dose: N, P, K, S and Zn @ 124, 22, 75, 20 and 4 kg ha^{-1} (270, 112, 150, 112 and 11 kg ha^{-1}) was used in the experiment conducted in Boro 2021-22

Data to be collected were on plant height (cm) at maturity, days to flowering and maturity, number of tillers and panicles ha^{-1}, number of grains $panicle^{-1}$, number of sterile spikelets $panicle^{-1}$, sterility (%), 1000-grain weight, grain and straw yield (t ha^{-1}), harvest Index.

The experiment was initiated in December 2021 and it was completed in May 2022.

PI: B Karmakar

CI: M A Biswas, M A I Hasan and M R Uddin

In this experiment conducted in BRRI RS, Sonagazi six different spacing were used as treatment. The closest spacing (20 cm × 15 cm) produced the highest grain yield (5.29 t/ha), which was gradually decreased with increasing spacing. The spacing (30 cm × 30 cm) produced the highest number of filled grain and unfilled grain, but the yield was reduced due to lodging loss whether it provided the lowest yield was 3.96 t/ha (Table 1). T6 provided the highest number (203) of tiller, the highest number of panicle (184) per 12 hill respectively. There was significant difference seen in plant height between the spacing (30 cm × 30 cm) and (20 cm × 15 cm). Among the spacing (20 cm×15 cm) produced the highest grain yield (5.29

t/ha) which was statistically similar with the spacing 25 cm×15 cm (5.09 t ha-1) (Table 24). So, to get the highest grain yield from Bangabandhu dhan100, it is recommended to use closer spacing in coastal region, but if we want the highest tiller number and panicle number we can use wider spacing.

Table24: Effect of spacing on growth and yield components of rice, Boro 2021-22.

Treatment	GD	Plant height at maturity (cm)	Grain weight (9m2)	Moisture Content (%)	No. of Tiller/12 hill	No. of panicle/12 hill	Straw weight kg/9m2	Length of panicle (cm)	1000 weight grains (g)	% Sterility	Yield (t/ha)
T1=20 cm × 15cm	140	107.9	5.33	23.2	145	126	17.95	24.3	17.62	13.5	5.29
T2=20 cm × 20cm	143	110.4	4.48	22.7	162	144	17.67	25.6	17.78	15.7	4.47
T3=25 cm × 15cm	141	106.2	5.09	22.6	153	136	15.76	23.8	17.39	13.3	5.09
T4=30 cm × 15cm	143	111.6	5.00	22.6	143	127	15.17	23.8	18.44	14.1	5.00
T5=25 cm × 25cm	145	110.6	4.28	23.1	198	180	14.91	24.5	18.10	11.9	4.25
T6=30 cm × 30cm	145	108.8	3.97	22.7	203	184	15.45	24.7	17.35	12.0	3.96
Grand average	143	109.2	4.69	22.8	167	149	16.15	24.5	17.78	13.4	4.68

SOCIO-ECONOMIC AND POLICY

Stability analysis of BRRI developed Aus rice varieties

Twelve rice varieties were evaluated during Aus 2021 at BRRI RS, Sonagazi farm. Among the varieties, BRRI hybrid dhan7 ranked the top in terms of yield (6.86 t ha^{-1}) followed by BRRI dhan48 (5.51 t ha^{-1}). The variety BRRI dhan65, BR24 and BRRI dhan43 were found as low yielding varieties having grain yield 3.30, 3.33 and 3.42 t ha^{-1}, respectively (Fig. 1).

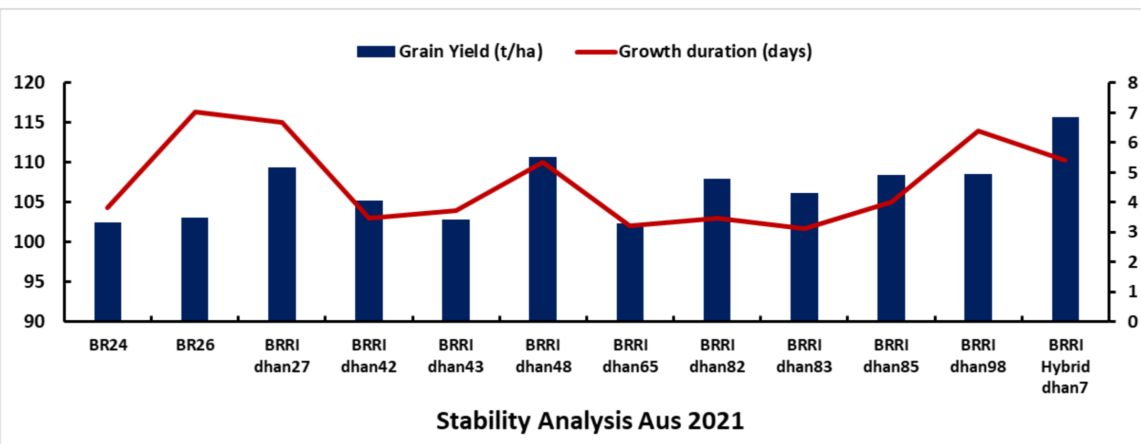


Fig. 1. Stability analysis of BRRI developed rice varieties in Aus 2021.

TECHNOLOGY TRANSFER

Seed Production and Dissemination Programme (SPDP)

SPDP during T. Aus 2021 under GOB. A total of 54 SPDPs were executed in 54 bigha land under 12 upazilas of five districts (Feni, Noakhali, Cox'sbazar, Rangamati and Bandarban) during Aus 2021 in collaboration with Department of Agricultural Extension (DAE). BRRI dhan82, BRRI dhan83, BRRI dhan85 and BRRI dhan98 were used in the SPDPs. Area of each SPDP was 1 bigha. BRRI provided input support like quality seeds, fertilizer and signboard while crop managements were done by the farmers under the supervision of DAE and BRRI. BRRI dhan98 produced the highest mean grain yield (5.37 tha^{-1}) followed by BRRI dhan82 (4.38 tha^{-1}) and the lowest grain yield was found in BRRI dhan83 (4.14 tha^{-1}). Mean growth duration of BRRI dhan82, BRRI dhan83, BRRI dhan85 and BRRI dhan98 was 107, 104, 108 and 113 days, respectively. Total production of all the varieties was 33,876 kg from which farmers retained 3,215 kg as seeds (13% of total production) for next season cultivation. About 2183 farmers gained awareness and knowledge about the varieties and 332 farmers (15% of total farmers) were motivated to cultivate the varieties.

SPDP during T. Aman 2021 under GOB. A total of 95 SPDPs were conducted in 285 bigha land under 20 Upazilas of four districts (Noakhali, Laxmipur, Khagrachari and Rangamati) during Aman 2021 in collaboration with DAE. BRRI dhan34, BRRI dhan71, BRRI dhan78, BRRI dhan79, BRRI dhan80, BRRI dhan87, BRRI dhan90 and BRRI hybrid dhan6 were used in the SPDPs. Area of each SPDP was three bigha. BRRI provided input support like quality seeds, fertilizer and signboard while crop management practices were done by the farmers under the supervision of DAE and BRRI. BRRI dhan87 produced the highest mean grain yield (6.02 t ha^{-1}) followed by BRRI hybrid dhan6 (5.90 tha^{-1}) and the lowest grain yield was found in BRRI dhan34 (3.30 tha^{-1}). Growth duration of BRRI dhan34, BRRI dhan71, BRRI dhan78, BRRI dhan79, BRRI dhan80, BRRI dhan87, BRRI dhan90 and BRRI hybrid dhan6 was 135, 115, 135, 136, 130, 127, 124 and 120 days, respectively. Total production of all the varieties was 201410 kg from which farmers retained 16,795 kg as seeds (13% of total production) for next season cultivation. About 9,657 farmers gained awareness and knowledge about the varieties and 1,284 farmers (15% of the total) were motivated to cultivate the varieties.

Farmers training. Farmers' trainings were arranged in Noakhali, Feni, Chattogram, Laxmipur, Bandarban, Cox's Bazar, Rangamati and Khagrachari districts with the collaboration of DAE as an important tool to train up farmers on updated modern rice cultivation technologies and to encourage them to adopt modern rice varieties with associated technologies. A total of 80 farmers trainings on 'Modern rice production technology' were conducted in eight different districts during the reporting period. In farmers training 1,770 male and 390 females farmers along with 208 male and 32 female DAE field stuffs participated in which they were trained up with rice production technology in different ecosystems especially on tidal submergence, salinity and favourable environment. A total of 2,400 farmers and DAE staffs were trained during the reporting period.

Field day. Field days were arranged for awareness building and to create interest among the farmers and concerned extension agents about the modern rice production technologies. These aided in wide publicity and familiarity of the institute, our technologies and BRRI's contribution towards national economy. About 100-120 persons (farmers, researchers, extension service providers, local leaders, public representatives and administrative people etc) were invited in a field day. A total of 38 field days were arranged during Aus, T. Aman and Boro seasons. Out of 38 field days 29 were funded by GOB, eight by Karmasuchi and one by Hybrid Rice Project. Nearly 3,520 progressive farmers, local leaders, DAE field staff, public representatives and NGO workers participated in those occasions.

ENRICHMENT OF SEED STOCK

Production of truthfully labeled seed (TLS)

Truthfully labeled seed (TLS) production activities were undertaken at BRRI research field during Aman 2021 and Boro 2021-22. This seed production category was an easy way without any supervision of SCA but quality was maintained providing our own facilities and declared truthfully. Seeds were produced as per physical and technical capacity, opportunity and local need of BRRI RS, Sonagazi. As a result, farmers purchased the seeds of BRRI released varieties. Seeds were also purchased by different organizations. Total production of TLS during Aman and Boro were 10,500 kg and 16,100 kg respectively.

Production of breeder seed

Nucleus seeds were supplied from Genetic Resources and Seed (GRS) Division for breeder seed production during Aman and Boro seasons. BRRI dhan34, BRRI dhan49, BRRI dhan82 and BRRI dhan87 were cultivated during Aman season whereas BRRI dhan28, BRRI dhan29 and BRRI dhan48 during Boro season. A total of 13.5 tons and 19 tons breeder seed were produced during Aman and Boro seasons respectively. All the produced seeds were sent to GRS division of BRRI, Gazipur.

F1 seed production of BRRI hybrid dhan5

In Boro2021-22 season, F1 seed production of BRRI hybrid dhan5 was conducted at the field of BRRI RS, Sonagazi. A total of 450 kg seed (0.34 t/ha) from BRRI hybrid dhan5 was obtained (Table 1).

Table 1: **F1 seed production of BRRI hybrid dhan5 during Boro, 2021-22.**

Combination	Plant height(cm)		50% flowering date		PER (%)	OCR (%)	Yield	
	A line	R line	A line	R line			kg/10 bigha	t/ha
BRRI7A/BRRI31R	91	99	125	139	79	41	450	0.34

DS: R1= 18 Nov 2021; R2= 24 Nov 2021; A= 14 Dec 2021

DT: R= 5 Jan 2022; A= 20 Jan 2022

PER (%) = panicle exertion rate; OCR (%) = Out crossing rate

BRRI RS, Kushtia

SUMMARY

A total of 37 experiments were conducted during Aus 2021 to Boro 2021-22 under the programme area of varietal development, rice farming systems, Crop-Soil-Water management and socio-economics and policy under Variety development program area a total of 30 trials (including Screening, AYT, RYT, ALART, MLT and AGGriNet) were conducted, of which 12 were in T. Aman and 19 were in Boro season. In addition, two trials of farming systems, four experiments of crop-soil-water management and three stability analysis experiments under socio-economic and policy programme were executed.

In the reporting year, 45 advanced breeding genotypes were evaluated during T. Aman season 2021 under RYT, ALART and MLT. The line BR238-5-1-4-2 (4.86 t/ha) at on-station and BRH11-2-4-7B at on-farm trial was marked as the best extra long slender type. Among long slender type lines BR9392-10-20-1B performed better in both on-farm and on-station conditions. BRH13-7-9-3-2B yielded the highest in on-station condition while all the tested lines of short slender type performed better in on-farm trial. BR10005-25-8-4-7-20 was found as the highest yielder in RYT-ZER. SVIN209 was marked as potential line in RLR-1 where none of the genotypes performed better in RLR-2 trial. BR10538-2-1-2-3-2 could be considered as promising material for DTR programme. Yield performance of Salt tolerant line BR11716-4R-123 was better than the tolerant check but lower than the susceptible check in STR-1 trial. In STR-2 trial BR11716-4R-105 was found as an excellent genotype. BR10397-3-2-1-1-8 (Xa21) and BR10393-4-1-1-1-1 out yielded the checks in MLT-1 trial where all of them failed to cross the yield line of checks in MLT-2.

On-firm evaluation of one advanced line BR9674-1-1-5-2-P4 was evaluated through advanced lines adaptive research trial (ALART) as ZER in T. Aman 2021 season. The line performed very poorly in regards to yield and other phenotypic considerations.

In Boro 2021-22 season a total of 122 advanced breeding lines were tested against different check varieties in screening, RYT, ALART, MLT and AGGriNet trial. A screening programme to identify prospective aerobic rice from local and BRRI developed rice varieties found six promising lines where IR18R1111a produced maximum yield. In the trial for short slender (SS) in Boro 2021-22 season all the evaluated genotypes performed better where BRH10-1-14-2-6B produced the highest yield. BR11-7-17-10B was reported as the highest yielding genotypes in Zira type yield trial. BR 10322-23-1-2-4 and BR 10322-23-6-3-7-B2 performed better among the tested lines in PQR, RYT. BR 11593-5 R-44 was found as the highest yielder in IRR-BPH, RYT where no attack of BPH was noticed. NGR 1255-1 yielded maximum with good phenotypic appearance. BR(Path)12454-BC2-69-97-39-5-44 as blast resistant material was found as the best yielder in both on-station and on-farm trials with no infestation of blast pathogen. BR11607-4R-46 and BR11604-4R-128 in RYT, DRR(BB-1) and BR11604-4R-129, BR11604-4R-52 and BR11604-4R-258 in RYT, DRR(BB-2) were marked as potential advanced lines.

The lines BR10601-5R-74 performed better than the other lines and check varieties in RYT, FBR(MD). In RYT, FBR(LD) BR11318-5R-10 yielded significantly higher than all the lines and check varieties. BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR1(Gaz)-P8(Hbj) line performed better in RYT, FBR(SD). IR17A1694 was found as the remarkable line in FBR-AGGriNET trial. Both the tested genotypes performed poor compared to the checks in FBR Bio. regional trial. From the result of RYT, Long slender BRH11-2-4-7B genotype would be a promising line.

On-firm evaluation of thirteen advanced lines were completed through ALART in Boro 2021-22 season. Among the supplied PQR breeding lines the yield of BR9930-2-3-3-1 (6.39 t/ha) was very similar to check varieties BRRI dhan50 and BRRI dhan63 but the yield was higher than BRRI dhan81. BRBa2-5-3 (7.16 t/ha) and BRBa3-1-7 (7.17 t/ha performed better than all checks in FBR-Barishal trial. In ALART for blast resistant rice the grain yield of all the supplied advanced lines were lower than the check variety BRRI dhan88 and very

similar to BRRI dhan28 with higher lodging tendency at maturity. In ALART for superior high yielding rice, the grain yield of the advanced line BRH13-7-9-3-2B was the highest (7.06 t/ha) but flowering of this line was uneven.

Under the rice farming systems programme area two separate trials were conducted of which one was on-station and the other was on-farm. On-station trial was designed to find out a suitable dose combination of nitrogen and potassium for popular varieties BRRI dhan63 and BRRI dhan87 in Boro-Fallow-T. Aman cropping pattern. In T. Aman 2021 the highest yield (6.73 t/ha) was recorded from the plot which was treated with Urea@STB-20% less and MoP@STB+30% additional. The dose combination of urea @STB+20% additional and MoP @STB+30% additional for BRRI dhan63 in Boro 2021-22 was reported as the best dose combination. Another on-farm trial was conducted to increase system productivity of Boro-Fallow-T. Aman cropping pattern through inclusion of mustard and high yielding rice varieties. The highest REY (15.98 t/ha) was recorded from the cropping pattern BARI Sorisha-14 (Relay)-BRRI dhan63-Fallow-BRRI dhan75.

To determine an optimum planting time and seedling age for BRRI dhan87, an experiment was conducted during T. Aman 2021 season under crop-soil-water management programme area. The experimental result revealed that 15 August was the best time to get the highest yield where no significant difference showed considering seedling age. Another findings from the evaluation of drought tolerance revealed that BRRI dhan71 produced highest yield (5.88 t/ha) when the perch water table went 35 cm below the soil surface during transplanted on 15 August. BRRI dhan87 also produced the highest yield (7.38 t/ha) when the water table went 35 cm below the soil surface. BRRI dhan71 and BRRI dhan87 can be grown up to 15 August with 35 cm below the surface area without sacrificing major yield. In Khustia, AWD treatment had the highest yield among the treatments, but irrigation application and yields of AWD and CROPWAT treatments did not have any major difference. Irrigation scheduling by CROPWAT model might be a potential approach to save irrigation water, but still needs in depth evaluation in terms of irrigation demand, irrigation received and yields.

Stability analysis of BRRI varieties were conducted to observe their performance under Genotype x Environment interaction. In T. Aus 2021 the highest yielder was BRRI dhan98 and the lowest was BR24. In T. Aman 2021 the highest yield was scored by BRRI dhan87 and the lowest by BRRI dhan37. Several varieties lodged during T. Aman. In Boro 2021-22 season the highest yielder was BRRI hybrid dhan2 and the lowest was BRRI dhan35.

A total of 22 batches of farmers' training were organized in the reporting year in which 660 farmers were trained. Modern rice varieties and relevant technologies were disseminated through 11 field days in which more than 1100 farmers participated. Total production of TLS during T. Aus, T. Aman and Boro were 1,300 kg, 1,920 kg and 2,178 kg respectively. In total, breeder seeds produced during T. Aman was 3.65 tons and Boro was 4.2 tons, respectively.

VARIETY DEVELOPMENT

Regional Yield Trial (RYTs)

T. Aman, 2021. All of the tested genotypes of ELS trial out yielded standard check BRRI dhan70 and local check Jirasail in both on-station and on-farm conditions. The highest yield was observed from the line BR238-5-1-4-2 (4.86 t/ha) in on-station and BRH11-2-4-7B (5.59 t/ha) in on-farm condition. In RYT-LS among the tested genotypes BR9392-10-20-1B out yielded (6.54 t/ha at BRRI farm and 6.22 t/ha at Sadar, Kushtia) both the standard checks BRRI dhan49 and BRRI dhan87 with shorter growth durations. Among the tested genotypes BRH13-7-9-3-2B and BRH13-2-4-7-2B under short slender trial out yielded all the checks at BRRI farm and in Sadar Kushtia, all the tested genotypes produced higher yield than the check varieties. A short duration (116 days) high yielding genotype BR10005-25-8-4-7-20 (6.62 t/ha) was found in zinc enriched rice RY trial. SVIN209 was found best the line (6.19 t/ha) with medium growth duration (138 days) as rainfed lowland rice. None of the tested breeding lines yielded higher than the check varieties in RLR-2 trial. BRRI dhan87 were found as the highest (6.51 t/ha) yielder in this trial. Tested drought tolerant rice lines were found as short duration in T. Aman, 2021-22 RY trial. BR10538-2-1-2-3-2 found as the highest yielder among the breeding lines. Salt tolerant line BR11716-4R-123 was the top most yielder (5.14 t/ha) among the advanced lines in STR-1. An excellent salt tolerant line BR11716-4R-105 was found in STR-2 that yielded 5.83 t/ha was the highest among tested advanced lines, higher than tolerant check BRRI dhan73 (4.77 t/ha) and very close to susceptible check BRRI dhan87 (6.01 t/ha). BR10397-3-2-1-1-8 (Xa21) and BR10393-4-1-1-1-1 out yielded all the check varieties with 6.34 t/ha and 6.51 t/ha respectively in MLT-1. The checks were the highest yielder than all the tested genotypes in MLT-2. BR10393-4-1-1-1-1 was found with very close yield (5.99 t/ha) to both the checks.

Boro 2021-22. A screening programme of aerobic rice composed of 23 lines against the check BRRI dhan81 was executed where six lines produced higher yield than the check. The highest yield was found from the line IR18R1111a (6.98 t/ha). It was observed that growth duration of all the tested lines were longer (>138 days) than the check variety. BRH10-1-14-2-6B produced highest yield which was 6.25 t/ha among short slender (SS) lines. Among four genotypes of Zira type line BR11-7-17-10B produced the highest yield (5.61 t/ha). BR10322-23-1-2-4 (5.69 t/ha) and BR10322-23-6-3-7-B2 (5.84 t/ha) these two breeding lines under PQR could not significantly perform better than the check varieties. In RYT IRR-BPH all the lines were free of BPH attack. BR 11593-5 R-44 was found as the highest yielder (7.00 t/ha) among the tested lines. RYT for Barishal resulted that all the genotypes performed satisfactory with good phenotypic appearance. NGR 1255-1 was the highest yielder (7.50 t/ha) among the lines. BR (Path)12454-BC2-69-97-39-5-44 was statistically insignificant highest yielder in both on-station (6.80 t/ha) and on-farm trial (6.35 t/ha). All the tested lines were found blast resistant. Advanced breeding lines in both DRR-BB trial appeared as BB resistant. BR11607-4R-46 (7.46 t/ha) and BR11604-4R-128 (7.44 t/ha) in RYT DRR (BB-1) and BR11604-4R-129, BR11604-4R-52 and BR11604-4R-258 in RYT DRR (BB-2) yielded more than 7.5 t/ha. Nine advanced breeding lines and two check varieties were evaluated in RYT (FBR_LD) of which BR11318-5R-10 (7.53 t/ha) exhibited better yield performance than the checks BRRI dhan89 (7.20 t/ha) and BRRI dhan92 (6.50 t/ha). Thirteen advanced breeding lines and two check varieties were tested in RYT (FBR_MD) experiments of which BR10601-5R-75 (7.26 t/ha) performed better than both of the check varieties BRRI dhan81 (5.32 t/ha) and BRRI dhan96 (6.71 t/ha). Seven advanced breeding lines and four standard checks BRRI dhan63, BRRI dhan81, BRRI dhan89 and BRRI dhan92 were tested under RYT (FBR_AGGRiNET). The highest yield was recorded in IR17A1694 (7.12 t/ha) which was higher than the three check varieties except the check variety BRRI dhan92 (7.28 t/ha). Four advanced breeding lines and two standard check BRRI dhan81 and BRRI dhan96 were evaluated in RYT (FBR_SD) experiment of which BRRI dhan29-SC3-28-16-10-6-HR6 (Com)-HR1(Gaz)-P8(Hbj) line (7.01 t/ha) performed better than all the tested lines and check varieties BRRI dhan81 (6.26 t/ha) and BRRI dhan96 (5.39 t/ha). Two advanced breeding lines and two standard checks BRRI dhan88 and BRRI dhan96 were tested under RYT (FBR_Bio) experiment of which none of the tested lines performed better than the checks BRRI dhan88 (6.48 t/ha) and BRRI dhan96 (6.35 t/ha). BRH11-2-4-7B genotype performed exceptional yield (6.33 t/ha) compared to all the genotypes and check variety.

On-farm evaluation of breeding lines through advanced lines ALART. The general and specific adaptability of some potential advanced breeding lines were tested in farmers' field collaborating with DAE and feedback information was collected from the farmers as well as extension people. Lines were supplied from Adaptive Research Division (ARD) of BRRI HQ.

T. Aman 2021. One advanced line along with three standard checks BRRI dhan49, BRRI dhan72 and BRRI dhan87 were evaluated under ZER, ALART. Although the advanced genotypes BR9674-1-1-5-2-P4 completed the shortest life cycle, grain yield of that line (4.45 t/ha) was lower than all the check varieties. As the line showed uneven flowering as well as susceptibility to sheath blight and false smut disease, it was not recommended for further trial.

Boro 2021-22. Four categories of ALARTs were conducted during Boro 2021-22 such as PQR, FBR, BRR and SHR. The trials were conducted at Sadar Upazila of Kushtia District. Collected results reported that in case of PQR, performance of advanced lines was poor than the check variety BRRI dhan63. In ALART FBR, the advanced lines BRBa2-5-3 (7.16 t/ha) and BRBa3-1-7 (7.17 t/ha) performed better than all the checks with good phenotypic acceptance. In case of ALART, BRR, the grain yield of all the supplied advanced lines were lower than the check variety. In ALART SHR, one advanced line BRH13-7-9-3-2B produced the highest yield with uneven flowering.

RICE FARMING SYSTEMS

Yield response of rice to different rates of Nitrogen and Potassium fertilizer in Boro-Fallow -T. Aman cropping pattern in Kushtia. Popular varieties of T. Aman and Boro seasons of Kushtia region were tested in this trial. BRRI dhan87 and BRRI dhan63 were used respectively in T. Aman and Boro season to observe the interaction effect of different doses of nitrogen and potassium fertilizer. A very clear interaction effect of N and K on BRRI dhan87 was reported from the experiment in T. Aman 2021 season. The highest yield (6.73 t/ha) was recorded from the plot which was treated with urea@STB-20% less and MoP@STB+30% additional. Another trial was conducted using BRRI dhan63 in Boro 2021-22 season. Here the result revealed that the highest yield (5.83 t/ha) was recorded from the dose combination of urea @STB+20% additional and MoP @STB+30% additional. Due to prolonged cold during last Boro season and algae problem in experiment plot yield was slightly reduced.

Increasing the system productivity of the dominant cropping pattern in Kushtia region (Boro-Fallow-T. Aman). A suitable Boro-fallow-T. Aman dominated block in Kushtia Sadar Upazila (Vill.: Alampur) was selected for this on-farm trial. Maximum REY yield (15.98 t/ha) was recorded from CP 3 where fallow period was managed with BARI Sorisha-14 and used a short duration T. Aman vareity BRRI dhan75.

CROP-SOIL-WATER MANAGEMENT

Determination of optimum planting time and seedling age for yield maximization of BRRI dhan87 at Kushtia region. The experiment was established at BRRI RS Kkushtia farm during Aman 2021 under three seedling age (S1=20 days, S2= 25 days & S3= 30 days) and four transplanting dates (T1= 15 July, T2= 30 July, T3= 15 August and T4= 30 August). In case of transplanting time, the highest yield was observed at the 3rd transplanting time of 15 August, 2021 (T3) which was statistically similar to 1st and 2nd transplanting times of 15 July and 30 July (T1 and T2). On the other hand, in case of seedling age there is no significant yield difference among the treatments. The highest growth duration was found at the 1st transplanting of 15 July 2021.

Evaluation of drought tolerance ability of newly released BRRI variety in drought prone area. The experiment was conducted at BRRI RS, Kushtia to identity the effect of different water stress and transplanting time on two rice varieties in Aman 2021 season. Three irrigation treatments, two rice varieties along with two transplanting dates were used for the experiment. BRRI dhan71 produced the highest yield (5.88 t/ha) when the perch water table went 35 cm below the soil surface during transplanted on 15 August, while it produced the lowest yield (4.25 t/ha) on rainfed condition transplanted at 30th August. BRRI dhan87 also produced the highest yield (7.38 t/ha) when the water table went 35 cm below the soil surface. It produced almost similar results to all the treatments when it was transplanted on 15 August. After delaying transplanting upto 30 August, it gave lower yield. BRRI dhan87 can be transplanted up to 15 August and water treatment may be used upto 35 cm below the soil surface. BRRI dhan71 can be grown up to 15 August with 35 cm below the surface area without sacrificing major yield.

Determining minimum irrigation water requirement of rice at different regions of Bangladesh through water balance from on-farm demand and model simulation. The experiment was conducted for two seasons (T. Aman and Boro) in 2021-22 at the research field of BRRI RS, Kushtia. BRRI dhan87 and BRRI dhan58 were transplanted in T. Aman 2021 and Boro 2021-22 seasons respectively. In Khustia, during T. Aman season, drought occurred at the later part of the season as rain ceased. The control treatment (i.e., continuous standing water in the field) received the highest amount while CROPWAT treatments required comparatively less irrigation. Both AWD and CROPWAT treatment saved irrigation compared to continuous standing water treatment. Yields were similar in AWD and CROPWAT treatments and yield of control treatment was different than the other two treatments. During Boro 2021-22 season, the total growth span of BRRI dhan58 was 150 days, however, 105 days after transplanting (vegetative, reproductive, and ripening stage) was taken into consideration in this study. The actual water requirement was calculated using the total measured evapotranspiration (ET) during this time (105 days). Predicted water requirement was simulated by CROPWAT model. Presumably, treatment T_1 received highest amount of irrigation water in response to total irrigation requirement because the field was kept almost saturated all the time during the experiment. The AWD treatment (T_2) received comparatively lower irrigation than continuous standing water treatment. Generally, received amounts of irrigation in T_2 and T_3 were closer. In Khustia, AWD treatment had the highest yield among the treatments, but irrigation application and yields of AWD and CROPWAT treatments did not have any major difference. Irrigation scheduling by CROPWAT model might be a potential approach to save irrigation water, but still needs in depth evaluation in terms of irrigation demand, irrigation received and yields.

SOCIO-ECONOMICS AND POLICY

Stability analysis of BRRI varieties. The experiment was conducted to maintain season, year and location-wise database on the yield performance of BRRI varieties. The number of varieties tested in T. Aus, T. Aman and Boro were 13, 47 and 47 respectively. The unit plot size was 3 m x 3 m with 20 cm x 20 cm spacing. The trial was designed in RCB with three replications. Fertilizer was applied as per BRRI recommendation. The seedling age during transplanting time was 26 days, 28 days and 40 days in Aus, T. Aman and Boro seasons respectively.

Stability analyses of BRRI varieties were conducted to observe their performance under Genotype Environment interaction. In T. Aus, the highest yielder was BRRI dhan98 and the lowest was BR24. In T. Aman, the highest yield was scored by BRRI dhan87 and the lowest by BRRI dhan37. Several varieties lodged during T. Aman. In Boro season, the highest yielder was BRRI hybrid dhan2 and the lowest was BRRI dhan35.

TECHNOLOGY TRASNFER

Farmers' training, field day and varietal demonstration. In the reporting year, 22 batches of farmers' training were organized in which 660 farmers participated. Modern rice varieties and relevant technologies were disseminated through field demonstration and 11 field days in which more than 1100 farmers participated. A total of 430 demonstrations of newly BRRI released HYVs and hybrids were conducted under GoB, Hybrid Rice and TRB projects in the farmers' fields in Kushtia, Chuadanga, Meherpur, Magura and Jhenaidah districts. The varieties included BRRI dhan48, BRRI dhan82, BRRI dhan83, BRRI dhan85, BRRI hybrid dhan7 in T. Aus season. Whereas BRRI dhan71, BRRI dhan75, BRRI dhan87, BRRI dhan90 and BRRI hybrid dhan6 were included in T.

Aman and BRRI dhan50, BRRI dhan58, BRRI dhan63, BRRI dhan81, BRRI dhan84, BRRI dhan86, BRRI dhan89, BRRI dhan92, Bangabandhu dhan100 and BRRI hybrid dhan5 were included in Boro season.

ENRICHMENT OF SEED STOCK

Production of truthfully labeled seed (TLS). Truthfully labeled seed (TLS) production activities were conducted at BRRI research field during T. Aus 2021; T. Aman 2021 and Boro 2021-22. This seed production category was an easy way without any supervision of SCA but quality was maintained providing our own facilities and declared truthfully. Seeds were produced as per physical and technical capacity, opportunity and local need of BRRI RS, Kushtia. Total production of TLS during T. Aus, T. Aman and Boro were 1,300 kg, 1,920 kg and 2,178 kg respectively.

Breeder Seed Production. Nucleus seeds were supplied from GRS Division BRRI for breeder seed production during T. Aman and Boro season. BRRI dhan48 and BRRI dhan87 were cultivated during T. Aman season 2021. BRRI dhan63 was cultivated during Boro season 2021-22. All the produced seeds were sent to GRS Division of BRRI HQ, Gazipur. In total, breeder seeds produced during T. Aman was 3.65 tons and Boro was 4.2 tons, respectively.

Table 1. Performance of Extra Long Slender (ELS) lines in RYT, T. Aman 2021.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grains/ panicle	1000 grain wt. (g)	Yield (t/ha)
DS-30 Jun 2021		RYT: ELS-1 (on-station)			DT-25 Jul 2021	
BRH11-2-4-7B	125	111	245	110	24.04	4.79
IR12A177	124	116	249	112	26.38	4.71
BR238-5-1-4-2	122	116	247	115	26.51	4.86
BRRI dhan70 (ck)	126	141	228	108	19.92	4.61
Jirasail Local (ck)	109	115	241	115	19.20	2.64
$HSD_{0.05}$	0.77	4.15	26.74	12.55	0.85	0.67
CV (%)	0.3	1.8	5.9	5.9	1.9	8.2
DS-30 Jun 2021		RYT: ELS-2 (on-farm)			DT-28 Jul 2021	
BRH11-2-4-7B	127	116	245	105	25.02	5.59
IR12A177	126	116	253	113	25.99	5.47
BR238-5-1-4-2	127	115	258	105	25.86	5.52
BRRI dhan70 (ck)	130	146	237	120	19.15	5.46
Jirasail Local (ck)	110	120	217	126	18.86	3.64
$HSD_{0.05}$	0.53	6.04	25.47	10.97	1.02	0.50
CV (%)	0.0	2.6	5.5	5.1	2.4	5.2

Table 2. Performance of long slender (LS) lines in RYT, T. Aman 2021.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grains/ panicle	1000 grain wt. (g)	Yield (t/ha)
DS-30 Jun 2021		RYT: LS-1 (on-station)			DT-25 Jul 2021	
BR9392-10-20-1B	126	120	228	131	19.95	6.54
BR10247-4-7-4B	112	102	244	142	17.24	5.43
BR1010247-14-18-4	111	100	247	143	18.28	3.80
BR9392-1-9-7-5B	114	102	227	134	19.78	4.73
BR9392-40-50-1B	118	105	239	139	18.50	5.95
BRRI dhan87 (Ck)	129	127	257	128	23.68	5.96
BRRI dhan49 (Ck)	134	116	212	104	19.40	5.63
$HSD_{0.05}$	0.77	4.64	20.08	18.75	1.15	0.33
CV (%)	0.4	2.4	4.8	8.0	3.3	3.8

DS-30 Jun 2021		RYT: LS-2 (on-farm)			DT-28 Jul 2021	
BR9392-10-20-1B	127	113	265	114	20.65	6.22
BR10247-4-7-4B	115	108	281	98	18.15	5.22
BR1010247-14-18-4	116	106	290	102	19.42	5.11
BR9392-1-9-7-5B	120	115	257	112	21.07	4.97
BR9392-40-50-1B	123	106	307	98	22.47	5.01
BRRI dhan87 (Ck)	133	128	253	108	23.90	5.97
BRRI dhan49 (Ck)	141	103	289	136	19.07	5.43
$HSD_{0.05}$	0.92	4.06	31.14	9.25	1.38	0.43
CV (%)	0.4	2.4	6.3	4.7	3.8	4.5

Table 3. Performance of Short Slender (SS) lines in RYT, T. Aman 2021.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grains/ panicle	1000 grain wt. (g)	Yield (t/ha)
DS-30 Jan 2021		RYT: SS-1 (on-station)			DT-25 Jul 2021	
BRH13-7-9-3-2B	125	130	290	103	24.61	6.39
BRH13-1-9-7B	120	113	295	92	21.42	4.98
BRH10-1-14-2-6B	119	112	311	99	22.14	5.10
BRH13-2-4-7-2B	125	127	261	97	24.63	6.04
BRRI dhan49 (ck)	134	111	292	106	23.14	5.12
BRRI dhan87 (ck)	130	137	285	107	24.53	5.86
Jirasail Local (ck)	129	113	281	133	19.64	4.70
$HSD_{0.05}$	1.1	3.45	19.39	9.83	0.66	0.45
CV (%)	0.5	1.6	3.8	5.2	1.6	4.6
DS-30 Jan 2021		RYT: SS-2 (on-farm)			DT-28 Jul 2021	
BRH13-7-9-3-2B	129	122	262	122	23.36	6.08
BRH13-1-9-7B	126	111	275	128	20.62	6.24
BRH10-1-14-2-6B	125	109	271	129	20.20	5.86
BRH13-2-4-7-2B	127	107	248	135	19.32	5.83
BRRI dhan49 (Ck)	132	103	284	122	20.65	4.86
BRRI dhan87 (Ck)	127	125	233	118	23.39	5.41
Jirasail Local (Ck)	0	0	0	0	0	0
$HSD_{0.05}$	0.63	4.56	31.01	9.11	1.24	0.40
CV (%)	0.3	2.2	6.5	4.0	3.3	3.9

Table 4. Performance of some Aerobic lines, Boro 2021-22.

Designation	Growth Duration (Days)	Plant Height (cm)	Panicle/m^2	Grains/ Panicle	1000 grain wt. (g)	Yield (t/ha)
IR18R1103a	147	99.0	252	145	18.58	5.65
IR18R1066a	145	104.1	248	117	18.74	5.87
IR18R1117a	143	113.6	263	139	19.79	6.13
IR18R1137a	145	106.6	245	112	18.49	6.23
IR18R1145a	144	109.9	247	124	20.37	5.78
IR18R1148a	149	113.5	272	128	17.83	5.30
IR18R1153a	142	98.5	253	122	21.31	6.51
IR18R1154a	145	106.9	263	116	19.07	5.11
IR18R1156a	149	123.9	251	115	18.87	5.53
IR18R1160a	146	119.9	255	105	20.61	5.39
IR18R1162a	145	109.5	240	105	18.69	5.44
IR18R11010a	147	116.1	267	116	20.75	5.54
IR18R1162a	147	120.3	253	111	20.13	5.53
IR18R1068a	147	118.9	243	119	20.72	6.78
IR18R1073a	146	110.9	266	102	18.25	5.95
IR18R119a	147	114.3	242	134	18.37	5.80

IR18R1121a	148	111.5	244	136	19.69	5.53
IR18R1123a	147	117.8	266	105	20.75	5.75
IR18R1181a	148	118.3	286	103	21.25	6.07
IR18R1164a	147	114.5	259	104	19.80	6.31
IR18R1089a	146	114.7	246	110	20.79	5.78
IR18R1111a	147	116.2	248	103	24.12	6.98
IR19L1007a	145	119.1	254	101	17.82	6.26
BRRI dhan81 (ck)	138	107.8	270	104	20.64	6.19
$HSD_{0.05}$	0.75	2.26	30.89	6.26	0.72	0.67
CV (%)	0.3	1.2	7.4	3.3	2.2	7.0

DS-15 Dec 2021 DT-27 Jan 2022

Table 5. Performance of short slender (SS) and zira type lines in RYT, Boro 2021-22.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grains/ panicle	1000 grain wt. (g)	Yield (t/ha)
DS-11 Dec 2021		RYT: SS			DT-24 Jan 2022	
BRH10-1-14-2-6B	153	102.9	254	170	16.75	6.25
BRH9-3-2B	153	103.5	257	172	15.93	5.82
BRH13-1-9-7B	153	103.6	241	154	16.29	5.83
BRH17-23-8-2-7B	152	107.4	266	129	20.74	5.67
BRH13-2-4-7-2B	153	105.3	230	144	16.81	5.91
BRRI dhan28 (ck)	152	111.5	326	119	21.19	5.62
BRRI dhan81 (ck)	149	103.5	259	124	21.80	5.39
$HSD_{0.05}$	0.72	3.7	27.54	26.58	1.34	0.68
CV (%)	0.3	2.0	5.9	10.3	4.1	9.1
DS-15 Dec 2021		RYT: Zira type			DT-27 Jan 2022	
BRH15-24-7B	156	88.9	308	108	17.39	5.16
BR9392-1-9-7-5B	159	99.7	279	94	23.80	5.54
BRH13-9-5-3B	158	91.5	295	140	18.52	5.40
BR11-7-17-10B	156	91.5	268	129	15.94	5.61
Zirashail (ck)	155	97.9	310	96	17.65	3.93
BRRI dhan81 (ck)	153	91.7	288	81	21.14	4.64
$HSD_{0.05}$	1.74	8.35	53.88	31.73	3.61	0.86
CV (%)	0.6	4.9	10.2	15.9	10.4	9.4

Table 6. Performance of Premium Quality Rice (PQR) lines in RYT, Boro 2021-22.

Designation	Growth duration (days)	Plant height (cm)	Panicle/m^2	Grains/ panicle	1000 grain wt. (g)	Yield (t/ha)
V1= BR 10322-23-1-2-4	155	115.4	332	96	19.47	5.96
V2= BR 10322-23-6-3-7-B2	155	108.3	348	94	18.40	5.84
V3= BRRI dhan50 (ck)	157	92.5	337	97	18.57	5.70
V4= BRRI dhan63 (ck)	156	95.2	321	103	21.75	7.01
V5= BRRI dhan81 (ck)	155	103.7	293	107	22.88	6.11
$LSD_{0.05}$	**1.03**	4.27	11.65	3.68	1.28	0.39
CV (%)	**0.35**	2.20	1.90	1.97	3.36	3.40

DS-15 Dec 2021 DT-22 Jan 2022

Table 7. Performance of Insect Resistant Rice (BPH) lines in RYT, Boro, 2021-22.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain wt. (g)	Grains/ panicle	Yield (t/ha)
V1= BR 11593-5 R-55	167	129.1	265	85	26.94	6.03
V2= BR 11593-5 R-70	168	123.3	275	93	24.28	6.13

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain wt. (g)	Grains/ panicle	Yield (t/ha)
V3= BR 11592-5 R-11	161	122.8	272	118	21.63	6.65
V4= BR 11593-5 R-79	168	121.2	253	83	26.26	5.92
V5= BR 11593-5 R-73	169	119.3	251	86	25.51	5.50
V6= BR 11595-5 R-24	163	124.2	280	117	23.06	6.89
V7= BR 11593-5 R-44	164	125.9	255	95	26.88	7.00
V8= BRRI dhan88 (ck)	159	97.3	310	91	23.12	6.17
V9= BRRI dhan58 (ck)	162	111.4	269	118	21.47	6.27
V10= T27A (R. Ck)	161	137.6	233	59	23.15	3.03
$HSD_{0.05}$	1.77	12.11	21.05	12.99	0.64	0.88
CV(%)	0.37	3.41	2.70	4.70	0.90	5.07

DS-5 Dec 2021 DT-20 Jan 2022

Table 8. Performance of some advanced breeding lines in RYT-Barishal, Boro 2021-22.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain wt. (g)	Grains/ panicle	Yield (t/ha)
V1= NGR 414-1	161	112.8	257	135	21.87	7.14
V2= NGR 418-1	159	112.2	242	148	21.65	7.49
V3= NGR 467-2	168	114.8	265	116	21.84	6.97
V4= NGR 521-2	161	113.8	276	123	21.59	6.68
V5= NGR 522-1	160	112.3	274	123	21.84	6.39
V6= NGR 750-1	159	123.9	288	121	21.66	7.25
V7= NGR 796-2	161	115.7	343	127	22.00	7.19
V8= NGR 1161-3	159	113.9	307	118	21.43	7.23
V9= NGR 1255-1	160	127.7	238	137	21.30	6.85
V10= NGR 1308-2	159	115.2	322	150	23.32	7.50
V11= BRRI dhan58 (ck)	159	110.9	302	124	21.33	7.23
V12= BRRI dhan89 (ck)	168	130.9	273	137	24.63	7.48
$HSD_{0.05}$	NS	7.92	40.31	3.18	NS	0.72
CV (%)	-	2.28	4.81	4.86	12.5	3.41

DS-2 Dec 2021 DT-17 Jan 2022

Table 9. Performance of some blast resistant advanced lines RYT-DRR(Blast), Boro 2021-22.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grains/ panicle	1000 grain wt. (g)	Yield (t/ha)
DS-11 Dec 2021		RYT: Blast (on-station)			DT-20 Jan 2022	
V1= BR(Path)12454-BC2-87-24-32-1-29	164	124.0	293	103	21.09	5.74
V2= BR(Path)12454-BC2-56-81-27-3-30	163	120.6	287	102	20.94	5.87
V3= BR(Path)12454-BC2-69-97-39-5-44	165	104.9	267	133	21.02	6.80
V4= BR(Path)12454-BC2-71-91-6-23-26	165	116.8	288	114	19.71	6.38
V5= BR(Path)12454-BC2-75-32-31-39-7	162	118.7	251	132	20.96	6.22
V6= BR(Path)12454-BC2-48-10-88-81-32	170	104.7	253	118	20.26	6.19
V7= BR(Path)12454-BC2-13-81-88-87-HR	169	119.5	268	118	20.17	5.99
V8= BRRI dhan29 (S. CK)	163	103.3	299	98	20.78	5.96
V9= BRRI dhan89 (S. CK)	161	110.9	237	124	22.26	6.38
V10= BRRI dhan92 (S. CK)	162	122.6	256	108	22.80	5.94
$HSD_{0.05}$	2.79	15.74	42.35	34.18	2.05	NS
CV (%)	0.58	4.69	5.36	10.16	3.33	5.97
DS-05 Dec 2021		RYT: Blast (on-farm)			DT-27 Jan 2022	
V1= BR(Path)12454-BC2-87-24-32-1-29	167	114.4	286	96	21.41	5.29
V2= BR(Path)12454-BC2-56-81-27-3-30	166	119.3	280	95	21.26	5.42
V3= BR(Path)12454-BC2-69-97-39-5-44	168	109.1	260	126	21.34	6.35

V4= BR(Path)12454-BC2-71-91-6-23-26	168	116.7	281	107	20.03	5.93
V5= BR(Path)12454-BC2-75-32-31-39-7	165	122.9	244	125	21.28	5.77
V6= BR(Path)12454-BC2-48-10-88-81-32	173	114.0	246	111	20.58	5.74
V7= BR(Path)12454-BC2-13-81-88-87-HR	172	117.5	261	111	20.49	5.54
V8= BRRI dhan29 (S. ck)	166	105.9	292	91	21.10	5.76
V9= BRRI dhan89 (S. ck)	164	117.0	230	117	22.58	6.18
V10= BRRI dhan92 (S. ck)	165	124.7	249	101	23.12	5.74
$SD_{0.05}$	2.79	8.17	42.30	34.18	2.05	NS
CV (%)	0.58	2.40	5.50	10.81	3.28	6.36

Table 10. Performance of some BB resistant advanced lines in RYT-DRR(BB-1), Boro 2021-22.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grains/ panicle	1000 grain wt. (g)	Yield (t/ha)
V1= BR11604-4R-77	161	127.8	207	108	24.37	5.77
V2= BR11607-4R-111	161	107.3	279	111	26.08	7.00
V3= BR11604-4R-128	159	108.7	277	101	27.64	7.44
V4= BR11600-4R-105	159	105.9	266	105	24.36	6.56
V5= BR11600-4R-140	157	112.6	277	97	25.22	6.28
V6= BR11600-4R-82	159	105.1	328	79	26.36	6.80
V7= BR11607-4R-156	159	105.4	274	90	28.46	6.87
V8= BR11607-4R-184	159	110.1	336	84	26.94	7.02
V9= BR11607-4R-42	161	108.5	279	104	28.73	6.93
V10= BR11607-4R-46	159	108.0	254	108	27.92	7.46
V11= BR11607-4R-6	160	101.5	267	122	23.51	6.15
V12= BR11607-4R-79	159	108.9	255	101	25.10	6.89
V13= BRRI dhan88 (Std. ck)	156	101.1	271	123	20.32	6.21
V14=IRBB60 (Res. ck)	166	91.9	256	121	24.46	7.03
$HSD_{0.05}$	1.58	10.94	37.60	12.57	1.84	1.27
CV(%)	0.33	3.39	4.57	4.02	2.38	6.27

DS-5 Dec 2021 D/T-19 Jan 2022

Table 11. Performance of some BB resistant advanced lines in RYT-DRR(BB-2), Boro 2021-22.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grain/ panicle	1000 grain wt. (g)	Yield (t/ha)
V1= BR11604-4R-110	168	127.5	295	99	22.33	5.31
V2= BR1160-4R-147	165	126.4	277	103	23.83	6.22
V3= BR11604-4R-35	164	132.0	353	75	26.35	6.31
V4= BR11600-4R-72	165	126.1	303	109	23.74	7.02
V5= BR11607-4R-153	161	94.7	303	95	28.15	7.22
V6= BR11607-4R-2	165	108.6	297	89	27.81	6.26
V7= BR11607-4R-20	164	107.3	287	91	28.35	6.77
V8= BR11600-4R-287	152	121.4	265	93	26.18	5.88
V9= BR11604-4R-118	166	124.7	257	91	28.52	6.48
V10= BR11604-4R-122	165	130.3	323	95	21.43	5.63
V11= BR11604-4R-129	164	125.1	300	112	25.11	7.83
V12= BR11604-4R-24	166	124.5	257	134	23.51	7.20
V13= BR11604-4R-52	163	125.6	317	116	23.91	7.56
V14=BR11604-4R-258	159	108.6	264	89	35.22	7.74
V15= BRRI dhan58 (sus ck)	158	109.1	317	90	24.48	6.59
V16= BRRI dhan89 (Sus ck)	164	128.1	294	140	22.46	8.39
V17=IRBB60 (Res. ck)	164	92.6	274	115	24.52	6.95
$HSD_{0.05}$	1.54	7.70	37.17	14.41	1.30	0.59
CV(%)	0.31	2.31	4.14	4.61	1.66	2.82

DS-5 Dec 2021 DT-19 Jan 2022

Table 12. Performance of some high yielding breeding lines in RYT trial (LS), Boro 2021-22.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grains/ panicle	1000 grain wt. (g)	Yield (t/ha)
BRH11-2-4-7B	156	103.9	270	92	26.26	6.33
BRH10247-14-18-4	151	109.7	283	98	21.51	6.01
BRH10247-4-7-4B	152	106.1	284	104	21.52	5.69
BRRI dhan28 (ck)	151	108.1	306	97	22.13	5.60
$LSD_{0.05}$		3.18	9.99	7.28	0.66	0.29
CV (%)		3.64	4.29	9.12	3.55	5.97

DS-11 Dec 2021 DT-24 Jan 2022

Table13. Performance of Favourable Boro rice (FBR-MD) lines in RYT, Boro 2021-22.

Designation	Growth duration (day)	Panicle/m^2	Plant height (cm)	Grain/ Panicle	1000 grain wt. (g)	Yield (t/ha)
V1=SVIN109	152	308	112.13	109	25.04	7.05
V2=IR17A2433	155	260	133.80	87	23.62	5.22
V3=BR8899-14-4-1-2-2-1	148	248	92.40	102	25.00	6.3
V4=BR10317-5R-57	148	247	109.60	133	21.42	7.17
V5=BR10601-5R-74	152	277	115.87	142	21.75	7.26
V6=BR10623-5R-15	153	273	119.20	132	21.45	5.10
V7=BR11303-5R-53	153	310	125.13	107	24.19	6.45
V8=BR11318-5R-21	152	257	113.93	120	21.05	6.45
V9=BR11318-5R-63	152	308	115.20	106	25.31	6.81
V10=BR11337-5R-72	152	280	107.87	145	19.21	6.68
V11=BR11342-5R-23	152	300	124.67	106	24.64	6.28
V12=BR9945-5R-21	149	298	111.20	132	16.75	5.51
V13=BR9945-5R-25	153	265	121.40	135	22.02	6.60
V14=BRRI dhan81(ck)	148	250	103.13	101	21.01	5.32
V15=BRRI dhan96(ck)	151	318	104.07	127	22.69	6.71
CV (%)	0.63	14.44	3.71	9.26	3.90	4.75
$LSD_{(0.05)}$	0.77	33.00	3.45	8.99	0.71	0.24

DS: 14 Dec 2021 DT: 25 Jan 22

Table14. Performance of Favourable Boro rice (FBR-LD) lines in RYT, Boro 2021-22.

Designation	Growth duration (day)	Panicle/m^2	Plant height (cm)	Grain/ Panicle	1000 grain wt. (g)	Yield (t/ha)
V1=BR10301-5R-89	170	320	123.40	125	20.13	6.17
V2=BR10599-5R-375	170	308	128.33	121	24	7.27
V3=BR10604-5R-10	169	280	125.80	109	25.77	7.13
V4=BR10604-5R-58	163	305	122.93	102	20.85	5.80
V5=BR11318-5R-10	165	300	123.47	137	22.63	7.53
V6=BR11318-5R-106	167	282	113.20	109	23.07	6.72
V7=BR11318-5R-140	163	312	122.87	125	21.95	6.32
V8=BR11318-5R-148	164	218	118.40	146	22.11	6.36
V9=BR11318-5R-84	168	340	125.6	115	20.80	7.28
V10=BRRI dhan89(ck)	171	248	125.73	120	24.82	7.20
V11=BRRI dhan92(ck)	172	312	130.07	95	25.90	6.50
CV (%)	0.70	11.83	2.33	10.63	4.41	4.17
$LSD_{(0.05)}$	0.96	28.35	2.35	10.30	0.83	0.23

DS: 2 Dec 2021 DT: 17 Jan 22

Table 15. Performance of Favourable Boro Rice (FBR-AGGRiNET) lines in RYT, Boro, 2021-22.

Designation	Growth duration (day)	Panicle/m^2	Plant height (cm)	Grain/ panicle	1000 grain wt. (g)	Yield (t/ha)
V1=IR17A2433	160	297	134.4	80	23.84	5.76
V2=IR12A173	156	315	112	111	25.96	6.94
V3=IR17A2241	164	317	124.87	89	23.30	6.23
V4=IR08N134	157	263	106.13	107	28.44	6.96
V5=IR17A1694	156	280	114.47	114	25.01	7.12
V6=IR16A3667	161	333	113.13	89	25.83	6.39
V7=IR17A1650	151	317	104.67	112	22.74	6.06
V8=BRRI dhan63(ck)	155	320	94.40	105	20.69	6.33
V9=BRRI dhan81(ck)	151	287	114.27	104	20.7	5.25
V10=BRRI dhan89(ck)	160	278	119.13	124	24.65	6.83
V11=BRRI dhan92(ck)	155	327	114.60	103	25.78	7.28
CV (%)	0.69	7.78	2.41	10.03	4.24	6.09
LSD $_{(0.05)}$	0.89	19.24	2.24	8.48	0.84	0.32

DS: 11 Dec 2021 DT: 26 Jan 2022

Table 16. Performance of Favorable Boro Rice (FBR-SD) lines in RYT, Boro, 2021-2022.

Designation	Growth duration (day)	Panicle/m^2	Plant height (cm)	Grain/ panicle	1000 grain wt. (g)	Yield (t/ha)
V1=IR17A1694	141	205	93.4	111	24.56	5.04
V2=BRRI dhan29-SC3-28-16-10-6-HR6(Com)- HR1(Gaz)-P8(Hbj)	141	210	100.2	123	23.29	7.01
V3=BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR2(Gaz)-P11(Hbj)			No germination			
V4=IR17A1723	136	265	106.4	110	27.61	5.30
V5=BRRI dhan81(Ck)	156	250	101.5	99	21.05	6.26
V6=BRRI dhan96(Ck)	158	310	98.3	116	22.28	5.39
CV (%)	-	1.53	2.38	7.71	0.92	3.33
LSD $_{(0.05)}$	-	1.04	4.01	5.85	0.17	0.13

DS: 11 Dec 2021 DT: 25 Jan 2022

Table17. Performance of Favorable Boro Rice (FBR-Bio) lines in RYT, Boro, 2021-2022

Designation	Growth duration (day)	Panicle/m^2	Plant height (cm)	Grain/ panicle	1000 grain wt. (g)	Yield (t/ha)
V1=BR(Bio)10381-AC32-3	160	282	120.27	122	15.79	5.74
V2=BR(Bio)10381-AC1-2	149	235	102.27	93	18.86	5.15
V3=BRRI dhan88(Ck)	150	260	101.4	98	20.69	6.48
V4=BRRI dhan96(Ck)	154	268.33	101.53	139	19.5	6.35
CV (%)	0.45	5.63	2.58	14.53	3.98	6.28
LSD $_{(0.05)}$	0.56	11.99	2.24	13.43	0.61	0.30

DS: 8 Dec 2021 DT: 22 Jan 2022

Table 18. Performance of some advanced genotypes (ZER) in ALART, T. Aman, 2021

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grains/ panicle	1000 grain wt. (g)	Yield (t/ha)
V1=BR9674-1-1-5-2-P4	122	115	217	99	23.05	4.45
V2=BRRI dhan49	133	99	257	115	18.84	5.76
V3= BRRI dhan72 (ck)	126	115	246	117	27.42	5.63
V4= BRRI dhan87 (ck)	126	119	268	119	22.52	5.90

$LSD_{0.05}$	-	6.70	31.46	10.99	1.10	0.13
CV (%)	-	3.00	6.37	4.88	2.02	1.15

DS-10 Jul 2021 DT-8 Aug 2021

Table19. Performance of some advanced genotypes (PQR) in ALART, Boro 2022.

Designation	Growth duration (day)	Panicle/m^2	Plant height (cm)	Grain/ panicle	1000 grain wt. (g)	Yield (t/ha)
V1=BR9930-2-3-2-2	154	279	119.2	100	26.65	5.88
V2=BR9930-2-3-3-1	155	260	119.13	120	24.62	6.39
V3=BRRI dhan50(Ck)	156	315	88.33	113	20.03	6.54
V4=BRRI dhan63(Ck)	156	319	88.87	95	23.08	6.83
V5=BRRI dhan81(Ck)	145	314	100.87	104	23.51	5.78
CV (%)	0.6	4.3	4.4	8.3	4.6	8.1
LSD $_{(0.05)}$	1.68	23.88	8.62	16.54	2.04	0.95

DS-8 Dec 2022 DT-25 Jan 2022

Table 20. Performance of some advanced genotypes (FBR) in ALART Boro, 2022.

Designation	Growth Duration (day)	Panicle/m^2	Plant height (cm)	Grain/ panicle	1000 grain wt. (g)	Yield (t/ha)
V1=BRBa1-4-9	165	277	116.87	114	22.7	6.94
V2=BRBa2-5-3	154	275	98.6	114	22.21	7.16
V3=BRBa3-1-7	156	287	99.53	112	22	7.17
V4=BRBa3-2-4	155	270	98.73	120	21.45	6.36
V5=BRRI dhan58(ck)	156	292	96.2	127	21.26	6.62
V6=BRRI dhan89(ck)	162	278	111.2	131	22.44	7.00
CV (%)	0.6	5.3	3.1	9.1	3.9	6.2
LSD $_{(0.05)}$	1.58	27.06	5.89	19.92	1.58	0.78

DS-8 Dec 2021 DT-25 Jan 2022

Table 21. Performance of some advanced genotypes (BRR) in ALART, Boro 2022.

Designation	Growth duration (day)	Panicle/m^2	Plant height (cm)	Grain/ panicle	1000 grain wt. (g)	Yield (t/ha)
V1=BR(Path)12452-BC3-42-22-11-4	142	306	98.53	78	21.75	4.39
V2=BR(Path)12452-BC6-53-21-11-4	146	308	102	105	21.62	5.75
V3=BR(Path)13784-BC3-61-1-6-HR6	146	286	98.33	102	24.47	5.79
V4=BR(Path)13784-BC3-63-6-4-HR6	145	270	99.33	99	23.58	5.81
V5=BRRI dhan28 (Ck)	144	261	98	108	21.90	5.32
V6=BRRI dhan88 (Ck)	144	303	89.93	109	20.91	6.04
CV (%)	0.6	7.4	4.4	8.7	2.4	7.1
LSD $_{(0.05)}$	1.44	39.09	7.91	15.85	0.96	0.71

DS-08 Dec 2022 DT-25 Jan 22

Table 22. Performance of some advanced genotypes (SHR) in ALART, Boro 2022.

Designation	Growth Duration (Day)	Panicle/m^2	Plant height (cm)	Grain/ panicle	1000 grain wt. (g)	Yield (t/ha)
V1=BRH11-9-11-4-5B	157	271	96.27	150	17.42	6.62
V2=BRH13-2-4-6-4B	155	232	102.13	166	16.16	5.90
V3=BRH13-7-9-3-2B	160	265	111.33	166	19.22	7.06
V4=BRRI dhan63(Ck)	152	260	91.93	124	21.27	6.48
V5=Zirashail (Ck)	148	274	110.13	114	19.82	5.74
CV (%)	0.4	5.9	2.5	4.8	3.7	8.0
LSD $_{(0.05)}$	1.21	28.7	4.89	13.01	1.30	0.96

DS-8 Dec2022 DT-25 Jan 22

Table 23. Yield response of BRRI dhan87 to different rates of nitrogen and potassium fertilizer in T. Aman 2021.

Treatment Combination		Yield
Urea	MoP	(t/ha)
STB	*STB*	6.07
STB	*STB + 30% additional*	6.16
STB	*STB + 60% additional*	6.07
STB+20% additional	STB	6.51
STB+20% additional	STB + 30% additional	6.41
STB+20% additional	STB + 60% additional	6.29
STB-20% less	*STB*	6.46
STB-20% less	***STB + 30% additional***	**6.73**
STB-20% less	*STB + 60% additional*	6.57
CV%		***6.36***

DS: 15 Jul 2021 DT:9 Aug 2021

Table 24. Yield response of BRRI dhan63 to different rates of nitrogen and potassium fertilizer in Boro 2021-22.

Treatment combination		Yield
Urea	**MoP**	(t/ha)
STB	*STB*	5.24
STB	*STB + 30% additional*	5.01
STB	*STB + 60% additional*	5.43
STB	*BRRI Recomm.*	5.16
STB+20% additional	STB	5.71
STB+20% additional	**STB + 30% additional**	**5.83**
STB+20% additional	STB + 60% additional	5.56
STB+20% additional	BRRI Recomm.	5.51
STB-20% less	*STB*	4.88
STB-20% less	*STB + 30% additional*	5.12
STB-20% less	*STB + 60% additional*	4.61
STB-20% less	*BRRI Recomm.*	4.89
BRRI Recomm.	STB	5.21
BRRI Recomm.	STB + 30% additional	5.21
BRRI Recomm.	STB + 60% additional	5.01
BRRI Recomm.	BRRI Recomm.	5.20
CV%		***9.04***

D/S: 15 Dec 2021 DT:27 Jan 2022

Table 25 . Performance of different cropping patterns.

Cropping pattern			**Season wise grain yield (t/ha)**	**REY (t/ha)**
CP 1	:	BRRI dhan63- Fallow -BRRI dhan87	6.37 – F – 5.65	12.02
CP 2	:	BARI Sorisha-14 (Relay) - BRRI dhan63 - Fallow - BRRI dhan87	1.24 – 6.29 – 5.62	15.45
CP 3	:	BARI Sorisha-14 (Relay)- BRRI dhan63 - Fallow - BRRI dhan71	1.34 – 6.32 – 5.51	15.65
		BARI Sorisha-14 (Relay)- BRRI dhan63 - Fallow - BRRI dhan75	1.33 – 6.39 – 5.79	**15.98**
FCP(ck)	:	BRRI dhan28 - Fallow - BRRI dhan49	5.71 – F – 5.31	11.02

** Price: Mustard –80 Tk/kg and Paddy – 28 tk/kg

Table 26. Yield maximization of BRRI dhan87 during T. Aman 2021 BRRI at RS, Kushtia.

Treatment	GD (Day)	Plant height (cm)	panicle/m^2	Grains/ panicle	1000 grain wt. (g)	Yield (t/ha)
T1 S1	136	126	243	98	22.49	6.56
T1 S2	130	126	230	114	22.73	6.27
T1 S3	130	124	231	126	23.55	6.65
T2 S1	133	126	215	102	22.60	6.30
T2 S2	127	125	205	112	22.45	6.26
T2 S3	125	127	235	123	22.47	6.14
T3 S1	131	117	216	146	23.05	6.70
T3 S2	128	114	235	144	23.59	6.76
T3 S3	125	117	275	134	23.63	6.69
T4 S1	132	94	208	101	23.88	5.09
T4 S2	127	95	245	109	24.60	5.46
T4 S3	122	95	240	104	24.23	4.60
$HSD_{0.05}$		5.27	33.74	23.32	1.01	0.72
CV(%)		2.7	8.6	11.7	2.6	6.9

T1= 15 Jul, T2= 30 Jul, T3= 15 Aug and T4= 30 Aug

S1= 20 days, S2= 25 days and S3= 30 days

BRRI RS, Sirajganj

SUMMARY

Tested entries NGR 467-2, NGR 750-1 and NGR 1255-1 produced about 0.8 tha^{-1} higher yield over the check variety, BRRI dhan58 in RYT of favourable Boro rice (Barishal) during Boro 2021-22.

In RYT of superior high yielding rice variety (SS-Short Slender), all the tested entries showed about 1.0-1.5 t ha^{-1} higher yield over the check varieties BRRI dhan28 and BRRI dhan81 during Boro 2021-22.

In RYT of superior high yielding rice variety (Long- Slender), genotype BRH11-2-4-7B produced significantly higher yield over the standard the check BRRI dhan28 during Boro 2021-22.

In RYT of insect resistant rice (BPH), all the entries produced significantly higher yield over the standard check variety, T27A. However, BR 11595-5 R-24 produced about 0.93 t ha^{-1} higher yield over the check variety BRRI dhan88 with similar duration during Boro 2021-22.

In RYT of disease resistant rice for BB(1), None of the entries produced statistically higher yield over the standard check variety IRBB60. However, BR11600-4R-82 produced higher yield of 7.86 t ha^{-1} with shorter growth duration (149 days) over the check IRBB60 (167 days) during Boro 2021-22.

In RYT of disease resistant rice for BB(2), none of the entries produced statistically higher yield over the standard check varieties. However, BR11604-4R-24 produced higher yield (8.88 t ha^{-1}) with similar growth duration over the check variety BRRI dhan89 during Boro 2021-22.

In MLTof Blast, BR(Path)13800-BC3-224-12, BR(Path)13800-BC3-134-252, BR(Path)13800-BC3-126-166 showed statistical similar yield performance with the check variety BRRI dhan29. However, the highest yield (9.20 tha^{-1}) was obtained from genotype BR(Path)13800-BC3-224-12 with similar growth duration (165 days) over check variety BRRI dhan29 during Boro 2021-22.

In ALART, insect (BPH) resistant rice (IRR), None of the entries produced higher yield over the check variety BRRI dhan93. But BR9880-40-1-3-34 produced statistically higher yield over the check variety BRRI dhan87 during T. Aman 2021.

In MLTof blast resistant rice (BRR), genotypes BR(Path)12452-BC3- 42-22-11-4 and BR (Path)13784-BC3- 63-6-4-HR6 produced statistically higher yield over the check varieties during Boro 2021-22.

In MLT of Favourable noro rice (FBR-Barishal), Two genotype (BRBa1-4-9 & BRBa3-1-7) showed statistical higher yield performance over the check varieties during Boro 2021-22

In MLT of premium quality rice (PQR), Genotype BR9930-2-3-3-1 produced the highest yield (8.37 tha-1) over others which was statistically similer with the check variety BRRI dhan63 and BR9930-2-3-2-2 during Boro 2021-22.

In MLT of superior high yielding rice (SHR), BRH13 -2-4-6-4B produced the highest yield (8.37 t ha^{-1}) over the others which was statistically similer with BRH11 -9-11-4-5B & check variety BRRI dhan63 during Boro 2021-22.

In T. Aman2021, higher grain yield of 6.14 and 5.78 tha^{-1} was observed with treatment T_4 (cow dung @ 5 t ha^{-1}) + 50% of RDF) followed by T_7 (Poultry manure 3 t ha^{-1} + 50% of RDF) which is significantly higher compared to the other treatments. In Boro 2021-22, Significantly higher grain yield of 6.32 t ha^{-1} was observed with T_2 (Recom. Dose of fertilizer- (N-P-K-S @ 69-10.4-41-10.8 kg ha^{-1}) followed by treatment T_3 (Vermi compost @ 1 tha^{-1} + 50% of RDF (5.82 tha^{-1})

For improving soil-water availability for crop production in charland by amendment practices, T_1 (compaction with clay soil at the layer of 20-30 cm) followed by T_5 (cowdung added at the top soil (0-10 cm) @ 5 tha^{-1} at top layer of soil (0-10 cm) is effective for taller plant height and higher grain yield (5.73 t/ha) was found in T_1 followed by T_2 (Top soil (0-10 cm) mixed with 50% of clay soil).

In T. Aman season, 30% less recommended fertilizer with Biochar (@ 2.0 and 4.0 t ha^{-1}) produced similar yield with full recommended fertilizer alone. In Boro 2020-21 season, application of biochar @ 4 t/ha with recommended fertilizer resulted in the highest yield of BRRI dhan89 than the other treatments

Regional Yield Trial (RYT)

Development of rainfed lowland rice (RLR), T. Aman 2021. Two genotypes were evaluated along with BRRI dhan49, BRRI dhan71 and BRRI dhan87 as standard checks at farmer's field of Mirjapur, Sherpur, Bogura. None of the tested entries produced higher yield over the check varieties.

Favorable boro rice (Barishal), Boro 2021-22. Ten genotypes were grown along with the check varieties BRRI dhan58 and BRRI dhan89 at BRRI RS, Sirajganj. None of the tested entries produced higher yield over the check variety, BRRI dhan89 but NGR 467-2, NGR 750-1 and NGR 1255-1 produced higher yield over the check variety, BRRI dhan58 (Table 1).

Table 1. Effect of different genotype on growth duration (GD) and yield (tha^{-1}) of rice during Boro 2020-21.

Designation	GD (day)	Yield (tha^{-1})
NGR 414-1	154	6.51±0.06
NGR 418-1	154	6.47±0.28
NGR 467-2	161	7.94±0.35
NGR 521-2	153	6.02±0.05
NGR 522-1	156	5.88±0.91
NGR 750-1	158	7.83±0.22
NGR 796-2	160	7.17±0.69
NGR 1161-3	162	6.99±0.53
NGR 1255-1	162	7.99±0.42
NGR 1308-2	153	5.35±0.31
BRRI dhan58 (ck)	156	7.14±0.32
BRRI dhan89 (ck)	161	8.59±0.11
$Lsd_{0.05}$	-	1.28
CV (%)	-	10.77

DS. 20 Nov 2021 D/TP: 3 Jan 2022

1.3 Superior high yielding rice variety (SS-Short Slender), Boro 2021-22. Five genotypes were grown along with check varieties BRRI dhan28 and BRRI dhan81 at BRRI RS, Sirajganj. The special fertilizer doses were 40-17-20-15-1.5kg Urea-TSP-MOP-Gypsum-$ZnSo_4$/Bigha. 1/4th urea, total amount of TSP, MP, gypsum and $ZnSo_4$ was applied at the final land preparation. All the tested entries produced significantly higher yield over the check varieties except BRH17-23-8-2-7B (Table 2).

Table 2. Effect of different genotypes on growth duration (day) and yield (tha^{-1}) of rice during Boro 2021-22.

Designation	GD (day)	Yield (t ha^{-1})
BRH10-1-14-2-6B	150	8.08±0.04
BRH9-3-2B	150	7.22±0.34
BRH13-1-9-7B	148	8.05±0.70
BRH17-23-8-2-7B	143	5.89±0.19
BRH13-2-4-7-2B	150	7.61±0.35
BRRI dhan28	143	6.48±0.38
BRRI dhan81	148	6.30±0.21
$Lsd_{0.05}$	-	1.16
CV (%)	-	9.17

DS: 25 Nov 2021 D/TP: 8 Jan 2022

1.4 RYT (Long Slender), Boro 2021-22

Three (3) genotypes were grown along with check variety BRRI dhan28 at BRRI RS, Sirajganj. Genotype BRH11-2-4-7B produced significantly higher yield (6.33 tha^{-1}) over standard check BRRI dhan28 (5.78).

Insect Resistant Rice (BPH), Boro 2021-22. Seven genotypes were grown along with check varieties BRRI dhan58, BRRI dhan88 and T27A at BRRI RS, Sirajganj. No BPH infestation was observed in this trial. All the entries produced significantly higher yield over the standard check variety T27A, but staistically similar with BRRI dhan58 and BRRI dhan88. However, BR 11595-5 R-24 produced highest yield of 8.73 tha^{-1} with similer growth duration of BRRI dhan88 (147 days) (Table 3).

Table 3. Effect of different genotype on growth duration and yield in Boro 2021-22.

Designation	GD (day)	Yield (t ha^{-1})
BR 11593-5 R-55	163	8.14±0.59
BR 11593-5 R-70	165	8.06±0.33
BR 11592-5 R-11	157	7.31±0.03
BR 11593-5 R-79	157	8.10±0.64
BR 11593-5 R-73	157	7.19±0.52
BR 11595-5 R-24	147	8.73±0.46
BR11593-5 R-44	156	7.87±0.32
BRRI dhan88 (ck)	147	7.80±0.64
BRRI dhan58 (ck)	156	7.28±0.72
T27A (R. ck)	162	5.21±0.61
$Lsd_{0.05}$	-	1.30
CV (%)	-	10.0

DS: 20 Nov 2021 D/TP: 2 Jan 2022

Development of disease resistant rice for BB(1), Boro 2021-22. Twelve genotypes were grown along with BB resistant check IRBB60 and BRRI dhan88 at BRRI RS, Sirajganj. None of the entries produced statistically higher yield over the standard check variety, IRBB60. However, BR11600-4R-82 produced higher yield of 7.86 tha^{-1} with lower growth duration (149 days) over check IRBB60 (167 days) (Table 4).

Table 4. Effect of different genotype on growth duration and yield in Boro 2021-22.

Designation	GD (day)	Yield (tha^{-1})
BR11604-4R-77	151	6.98±0.92
BR11607-4R-111	158	7.57±1.04
BR11607-4R-128	146	7.07±1.14
BR11600-4R-105	151	6.98±0.92
BR11600-4R-140	147	6.34±0.62
BR11600-4R-82	149	7.86±1.27
BR11607-4R-156	155	7.17±0.53
BR11607-4R-184	155	6.41±0.30
BR11607-4R-42	151	7.17±0.63
BR11607-4R-46	152	6.83±0.48
BR11607-4R-6	153	7.52±0.44
BR11607-4R-79	152	7.02±0.65
BRRI dhan88 (ck)	151	6.56±0.61
IRBB60 (Std ck)	167	7.11±0.45
$Lsd_{0.05}$	-	2.18
CV (%)	-	18.42

DS: 28 Nov 2021 D/TP: 16 Jan 2022

Development of disease resistant rice for BB (2), Boro 2021-22.

Forteen genotypes were grown along with BB resistant check IRBB60 and BRRI dhan58 as well as BRRI dhan89 at BRRI RS, Sirajganj. None of the entry produced significantly higher yield over check varieties. However, BR11604-4R-24 produced higher yield (8.88 t ha^{-1}) with similar growth duration over the check variety BRRI dhan89 (Table 5).

Table 5. Effect of different genotype on growth duration and yield in Boro 2021-22.

Designation	GD (day)	Yield (tha^{-1})
BR11604-4R-110	165	8.36±0.55
BR11604-4R-147	153	7.43±0.90
BR11604-4R-35	153	7.45±0.98
BR11604-4R-72	156	7.77±0.85
BR11607-4R-153	153	6.86±0.35
BR11607-4R-2	156	8.18±0.42
BR11607-4R-20	156	8.34±0.47
BR11600-4R-287	154	8.18±0.57
BR11604-4R-118	161	8.41±0.24
BR11604-4R-122	161	7.98±0.73
BR11604-4R-129	161	7.91±0.59
BR11604-4R-24	165	8.88±0.16
BR11604-4R-52	161	7.78±0.30
BR11607-4R-258	155	8.55±0.20
BRRI dhan58 (Sus ck)	156	8.71±0.44
BRRI dhan89 (Sus ck)	163	8.77±0.52
IRBB60 (Res ck)	167	8.68±0.87
$Lsd_{0.05}$	-	1.41
CV (%)	-	10.41

DS: 28 Nov 2021 D/TP: 16 Jan 2022

Multilocation Trial (MLT) for Blast, Boro 2021-22

Multilocation Trial (MLT) of Blast and Bacterial blight was conducted at BRRI RS, Sirajganj. Eight genotypes were grown along with the check varieties BRRI dhan29 and BRRI dhan58. Among the test entries, genotype BR (Path)13800-BC3-224-12, BR (Path)13800-BC3-134-252, BR (Path)13800-BC3-126-166 showed statistically similar yield performance with the check variety BRRI dhan29. However, the highest yield (9.20 t ha^{-1}) was obtained from genotype BR (Path)13800-BC3-224-12 with similar growth duration (165 days) over the check variety BRRI dhan29 (Table 6).

Table 6. Effect of genotypes on growth duration and yield in Boro 2021-22.

Designation	GD (day)	Yield (tha^{-1})
BR(Path)13800-BC3-109-181	152	5.56±0.44
BR(Path)13800-BC3-118-37	163	7.19±0.96
BR(Path)13800-BC3-124-133	164	8.13±0.36
BR(Path)13800-BC3-126-166	164	8.66±0.23
BR(Path)13800-BC3-134-96	163	8.06±0.45
BR(Path)13800-BC3-134-252	163	8.71±0.56
BR(Path)13800-BC3-125-143	165	8.40±0.02
BR(Path)13800-BC3-224-12	165	9.20±0.26
BRRI dhan29 (check)	163	8.55±1.13
BRRI dhan58 (check)	155	7.05±0.03
$Lsd_{0.05}$	-	2.15
CV (%)	-	11.94

DS: 28 Nov 2021 D/TP: 6 Jan 2022

Advanced Line Adaptive Research Trial (ALART)

Insect (BPH) resistant rice (IRR), T. Aman 2021. The experiment was conducted at the farmer's field of Roha, Raiganj, Sirajganj. Two genotypes including two checks (BRRI dhan87 and BRRI dhan93) were evaluated. None of the entry gave higher yield over check variety, BRRI dhan93. But BR9880-40-1-3-34 produced statistical higher yield over check variety BRRI dhan87 (Table 7).

Table 7. Performance of different entries under ALART IRR during T. Aman, 2021 at Roha, Raiganj, Sirajganj

Designation	GD (day)	Plant height (cm)	Panicle m^{-2}	Yield (tha^{-1})
BR9880-40-1-3-34	130	124.2±1.35	199±19.47	6.50±0.09
BR9880-27-4-1-18	121	123.0±0.81	171±3.33	5.59±0.06
BRRI dhan87 (ck.)	121	125.7±0.57	215±14.89	5.41±0.22
BRRI dhan93 (ck.)	130	131.7±2.19	179±4.67	6.86±0.07
$Lsd_{0.05}$	-	4.59	43.73	0.38
CV (%)	-	1.82	11.45	3.11

DS: 28 Nov 2021 D/TP: 6 Jan 2022

Blast resistant rice (BRR), Boro 2021-22. The experiment was conducted at the farmer's field of Dobila, Tarash, Sirajganj. Six genotypes including two checks (BRRI dhan28 and BRRI dhan88) were evaluated.Genotypes BR(Path)12452-BC3- 42-22-11-4 and BR(Path)13784-BC3- 63-6-4-HR6 produced statistical higher yield over the check varieties. (Table 8).

Table 8. Performance of different entries under ALART BRR at Dobila, Tarash, Sirajganj during Boro 2021-22.

Genotype	GD (day)	Plant height (cm)	Panicle m^{-2}	Yield (tha^{-1})
BR(Path)12452-BC3- 42-22-11-4	149	123.2±0.73	447±7.45	9.40±0.22
BR(Path)12452-BC6- 53-21-11-4	149	127.9±1.83	397±14.52	7.28±0.21
BR(Path)13784-BC3- 61-1-6-HR3	146	115.1±0.55	410±5.78	8.93±0.05
BR(Path)13784-BC3- 63-6-4-HR6	146	113.5±0.83	431±12.72	9.87±0.02
BRRI dhan28 (ck.)	142	117.7±1.09	371±8.17	8.45±0.04
BRRI dhan88 (ck.)	146	114.5±0.53	391±18.72	8.88±0.21
$Lsd_{0.05}$		2.46	34.93	0.46
CV (%)		1.14	4.71	2.91

DS: 28 Nov 2021 D/TP: 29 Dec 2021

Favourable boro rice (FBR-Barishal), Boro 2021-22. The experiment was conducted at the farmer's field of Konabari, Kamarkhanda, Sirajganj. Six genotypes including two checks (BRRI dhan58 and BRRI dhan89) were evaluated. Two genotypes (BRBa1-4-9 and BRBa3-1-7) showed statistically higher yield performance over the check varieties followed by BRBa2-5-3 (Table 9). However, the highest panicle m^{-2} was obtained from BRBa2-5-3, which is statistically similer with BRBa3-1-7 and BRBa1-4-9.

Table 9. Performance of different entries under ALART FBR-Barishal at Konabari, Kamarkhanda, Sirajganj during Boro 2021-22.

Genotype	GD (day)	Plant height (cm)	Panicle m-^{2}	Yield (tha^{-1})
BRBa1-4-9	152	122.4±1.49	3036.77	9.00±0.18
BRBa2-5-3	152	99.7±0.75	338±26.56	8.61±0.19
BRBa3-1-7	156	104.9±2.02	334±19.92	8.85±0.20
BRBa3-2-4	152	122.2±1.48	279±10.50	8.25±0.12
BRRI dhan58 (ck.)	150	108.0±0.66	290±12.14	6.88±0.12
BRRI dhan89 (ck.)	156	108.3±0.53	296±2.52	7.46±0.25
$Lsd_{0.05}$		4.03	49.17	0.59
CV (%)		2.00	8.81	3.97

DS: 4 Dec 2021 D/TP: 17 Jan 2022

Premium quality rice (PQR), Boro 2021-22. The experiment was conducted at the farmer's field of Paikosha, Kamarkhanda, Sirajganj. Five genotypes including three checks (BRRI dhan50, BRRI dhan63 and BRRI dhan81) were evaluated. Genotype BR9930-2-3-3-1 produced the highest yield (8.37 tha-1) over the others which is statistically similer with the check variety BRRI dhan63 and BR9930-2-3-2-2 (Table 10). However, the highest panicle m^{-2} was obtained from the check variety BRRI dhan50 followed by BRRI dhan63.

Table 10. Performance of different entries under ALART PQR at Paikosha, Kamarkhanda, Sirajganj during Boro 202-22.

Genotype	GD (day)	Plant height (cm)	Panicle m-2	Yield (tha^{-1})
BR9930-2-3-2-2	155	114.8±0.63	211±8.37	8.03±0.23
BR9930-2-3-3-1	152	115.9±0.56	195±9.21	8.37±0.31
BRRI dhan50 (ck)	155	95.7±0.27	274±6.66	7.38±0.29
BRRI dhan63 (ck)	149	93.9±0.58	256±21.06	8.12±0.28
BRRI dhan81 (ck.)	146	101.8±1.86	214±11.79	5.86±0.11
$Lsd_{0.05}$		3.41	43.98	0.89
CV (%)		1.74	10.15	6.27

D/S: 4 Dec 2021 D/TP: 18 Jan 2022

Superior high yielding rice (SHR), Boro 2021-22. The experiment was conducted at the farmer's field of Konabari, Kamarkhanda, Sirajganj. Five genotypes including two checks (BRRI dhan63 and Zirashail) were evaluated. Among three genotypes BRH13 -2-4-6-4B produced the highest yield (8.37 tha-1) performance over the others which was statistically similer with BRH11 -9-11-4-5B and the check variety BRRI dhan63 (Table 11). However, the highest panicle m^{-2} was obtained from the check variety Zirashail followed by BRRI dhan63.

Table 11. Performance of different entries under ALART SHR at Konabari, Kamarkhanda, Sirajganj during Boro 2021-22.

Genotype	GD (day)	Plant height (cm)	Panicle m^{-2}	Yield (tha^{-1})
BRH11 -9-11-4-5B	153	98.96±2.43	317.67±22.73	7.66±0.49
BRH13 -2-4-6-4B	153	103.82±3.84	304.00±3.79	8.56±0.14
BRH13 -7-9-3-2B	155	117.52±4.23	294.67±14.99	7.15±0.24
BRRI dhan63 (Ck.)	151	93.08±0.43	326.00±9.54	7.36±0.30
Zirashail (CK)	149	109.43±2.33	350.00±15.04	6.53±0.83
$Lsd_{0.05}$		9.43	51.84	1.28
CV (%)		4.79	8.64	9.12

DS: 4 Dec 2021 D/TP: 18 Jan 2022

CROP-SOIL-WATER MANAGEMENT PROGRAMME

Integrated nutrient management for growth and yield improvement of rice in charland ecosystem. The experiment was conducted at BRRI RS, Sirajganj in T. Aman 2021 and Boro 2021-22 season. BRRI dhan87 in T. Aman and BRRi dhan89 in Boro season were used as test variety. The nutrient management treatments were: T_1 = Control (No fertilizer), T_2 = Recom. Dose of Fertilizer (RDF) (N-P-K-S @ 69-10.4-41-10.8 kg ha^{-1}), T_3 = Vermi-compost (1.0 t ha^{-1}) + 50% of RDF, T_4 = Cowdung (5.0 t ha^{-1}) + 50% of RDF, T_5 = AEZ Based Fertilizer Dose (N-P-K-S-Zn@ 76-15-42.5-8.1-1.8 kg ha^{-1}), T_6 = Tricho-compost (2.0 t ha^{-1}) + 50% of RDF, T_7 = Poultry Manure (3.0 tha^{-1}) + 50% of RDF. In T. Aman season, higher grain yield of 6.14 and 5.78 tha^{-1} was observed with treatment T_4 (cow dung @ 5 tha^{-1}) + 50% of RDF) followed by T_7 (Poultry Manure 3 tha^{-1} + 50% of RDF) which is significantly higher compared to the other treatment. On the otherhand lower grain yield (4.02 t ha^{-1}) was found in control treatment (Table 12). In Boro season, significantly higher grain yield of 6.32 t ha^{-1} was observed with T_2 (Recom. dose of fertilizer- (N-P-K-S @ 69-10.4-41-10.8 kg ha^{-1}) followed by treatment T_3 (Vermi-compost @ 1 tha^{-1} + 50% of RDF (5.82 tha^{-1}) due to higher number of panicles and more grains panicle^{-1}. On the otherhand, lower grain yield (4.27 tha^{-1}) was found in control treatment (Table 13).

Table 12. Yield of BRRI dhan87 as influenced by integrated nutrient management at BRRI RS, Sirajganj.

Treatment	Yield (tha^{-1})
T_1= Control (No fertilizer)	4.02
T_2= Recom. dose of fertilizer (RDF) (N-P-K-S @ 69-10.4-41-10.8 kg ha^{-1}	5.02
T_3= Vermicompost (1 tha^{-1}) + 50% of RDF	5.44
T_4= Cowdung (5 tha^{-1}) + 50% of RDF	6.14
T_5= AEZ based fertilizer dose (N-P-K-S-Zn@ 76-15-42.5-8.1-1.8 kg ha^{-1})	5.07
T_6= Tricho-compost (2 tha^{-1}) + 50% of RDF	4.71
T_7=Poultry Manure (3 tha^{-1}) + 50% of RDF	5.78
$LSD_{0.05}$	0.85
CV (%)	9.3

DS: 11 Jul 2021 D/TP: 9 Aug 2021

Table 13. Effect of different treatment on plant height, yield and yield contributing characters of rice during Boro 2021-22.

Treatment	Plant height (cm)	Panicle m^{-2}	Grain panicle^{-1}	Yield (tha^{-1})
T_1	97.8±1.89	226±4.70	132±2.96	4.27±0.07
T_2	102.2±2.23	258±7.26	157±6.34	6.32±0.10
T_3	100.9±2.24	252±6.43	155±7.40	5.82±0.14
T_4	100.3±0.45	253±6.39	143±4.41	5.24±0.14
T_5	104.4±1.76	240±3.71	143±5.69	5.36±0.16
T_6	101.4±1.86	229±5.81	140±3.38	4.89±0.07
T_7	108.1±1.83	249±6.06	137±6.33	5.77±0.17
$Lsd_{0.05}$	5.62	19.41	17.27	0.40
CV (%)	3.09	4.47	6.75	4.14

DS: 22 Nov 2021 D/TP: 10 Jan 2022

Improving soil-water availability for crop production in Charland by amendment practices

The study was carried out at BRRI RS farm, Sirajganj during T. Aman 2021 season. The study consists of five amendment practices as: T_1= Compaction with clay soil at the layer of 20-30 cm, T_2= Top soil (0-10 cm) mixed with 50% of clay soil, T_3= Vermi-compost added at the top soil (0-10 cm) @ 5 tha^{-1}, T_4= Biochar added at the top soil (0-10 cm) @ 5 tha^{-1}, T_5= Cowdung added at the top soil (0-10 cm) @ 5 tha^{-1} and T_6= Control. Bangabandhu dhan100 was used as a cultivar. Plant height and grain yield were statistically significant and different by amendment practices. Taller plant height (135.85 cm) in compaction followed by cowdung added at top layer of soil (0-10 cm). Higher grain yield (5.73 t/ha) was found in compaction followed by clay mixing at top layer. About 30% yield increased by compaction over control followed by clay mixing (Table 14).

Table 14. Effect of different soil amendments practices on yield and yield components of rice at BRRI experimental farms, Sirajganj during T. Aman 2021.

Treatment	Plant height (cm)	Panicle hill^{-1} (No.)	Grain panicle^{-1} (No.)	Sterility (%)	Grain yield (t ha^{-1})	Yield increased over control (%)
Compaction (T1)	135.9	10	115	13.4	5.73	30.5
Clay mixing at top layer (T2)	114.3	11	113	12.3	4.72	15.7
Vermicompost added (T3)	117.6	12	116	18.2	4.69	15.1
Biocher added (T4)	118.0	10	115	15.8	4.13	3.6
Cowdung added (T5)	122.2	11	119	11.8	4.55	12.5
Control (T6)	118.3	10	113	14.3	3.98	--
$Lsd_{0.05}$	6.68	ns	ns	ns	0.99	
CV%	2.4				4.3	

DS: 29 May 2021 D/TP: 5 Jul 2021

4.3 Effect of Biochar on Rice Yield and Soil Health on problem soils

The study was conducted at BRRI RS, Sirajganj during 2021-22 season. The experiment was initiated in T. Aman 2019 consisting of four treatments: T_1= Control, T_2= Recommended fertilizer (RF), T_3= RF + biochar @ 2 t ha^{-1} and T_4= RF + biochar @ 4 t ha^{-1}. The recommended dose of N-P-K-S was 100-15-40-10 kg ha^{-1} in T. Aman and 138-21-75-18 kg ha^{-1} in Boro season. Biochar was applied only in Boro season and incorporated with soil before seven days of transplanting. In T. Aman season, 30 % fertilizer was reduced from the recommended dose in the biochar treated plots. In T. Aman season, 30% less recommended fertilizer with Biochar (@2.0 and 4.0 t ha^{-1}) produced similar yield with full recom. fertilizer alone. treatment T_2-T_4 produced similar grain yield. In Boro 2020-21, application of biochar @ 4 t/ha with recommended fertilizer resulted in the highest yield of BRRI dhan89 than the other treatments (Table 15).

Table 15. Effect of biochar on the yield of rice at BRRI RS farm, Sirajganj.

Treatment	Grain yield (tha^{-1})	
	T. Aman 2021 (BRRI dhan87)	Boro 2021-22 (BRRI dhan89)
T_1= Control	4.21 b	3.12 c
T_2=Rec. fertilizer	6.52 a	6.18 b
T_3=Rec. fertilizer + BC @ 2 t ha^{-1*}	6.55 a	6.52 b
T_3=Rec. fertilizer + BC @ 4 t ha^{-1*}	6.44 a	7.30 a
CV (%)	4.41	5.69

TECHNOLOGY TRANSFER

Training and fair. Thirteen farmer's training programmes on modern rice production technology were conducted at different upazilas of Bogura region in collaboration with DAE. A total of 390 farmers were trained through these programmes. Among the participants, 30 and 360 were female and male, respectively. Training was very much helpful to minimize knowledge gap on modern rice production technologies. Eight in-house trainings were arranged at BRRI regional station to improve the capability of office staffs for office management. Moreover, BRRI RS, Sirajganj participated in five country Fairs held from January 2022 to March 2022 at differefnt upazilas of Sirajganj district.

Breeder and truthfully leveled seed production. Nucleus seed stock was collected from GRS Division of BRRI. Single seedling was transplanted per hill. For breeder seed production, all official formalities with SCA and BRRI authority were performed through proper channel. Breeder seed was produced in T. Aman and Boro seasons, side by side, TLS seed was produced in Aus, T. Aman and Boro seasons. Considering three seasons (Aus, T. Aman and Boro), breeder and TLS seeds were produced 7.65 and 12.49 tons, respectively.

Advisory and clinical service. Any serious problem related to rice production at farmers' field was addressed duly in co-operation with the Department of Extension (DAE), Bangladesh Agricultural Development Corporation (BADC and Seed Certification Agency (SCA).

BRRI RS, Gopalganj

SUMMARY

In ALART T. Aman 2021, salt tolerance rice (STR-1 and STR-2) were conducted at farmer's fields of Sadar, Bagerhat (STR1) and Rampal, Bagerhat (STR2). One advanced line IR108158-B-2-AJY1-1 produced an average higher yield (5.77 t ha^{-1}) than the standard checks BRRI dhan73 (5.12 t ha^{-1}) and BRRI dhan87 (5.64 t ha^{-1}) with similar growth durations. Four ALARTs of SHR, favourable Boro rice (FBR-Barishal), STR-1 and STR-2 were conducted during Boro 2021-22 at farmer's field in Gopalganj. In ALART (SHR), ALART (FBR), ALART (STR-1) and ALART (STR-2) Boro, all the advanced lines produced higher yield than the standard checks.

Four RYTs, two for salt tolerance rice (STR-1 and STR-2), one for (ZER) and one for (RLR) were conducted during T. Aman 2021. Five RYTs namely RYT (SS), RYT (LS) ,RYT (FBR) ,RYT (STR-1) AND RYT (STR-2) were conducted during Boro 2021-22.

One hundred and twenty-four Aman rice germplasm were collected from Faridpur region. This rice germplasm were rejuvenated to increase the seed for further evaluation and utilization. Another experiment was conducted to characterize 54 pigmented rice germplasm through 51 agro-morphological traits (20 quantitative and 31 qualitative characters) using the Rice Germplasm Descriptors and Evaluation Form, GRSD, BRRI

During the reporting year, seven varietal replacements through Head to Head (HTH) demonstrations each of one bigha (33 decimal) of land, three in Aman 2021 and four in Boro 2021-22 were conducted under the TRB-BRRI project. Besides, two block demonstrations each of 100 bigha in Boro season were conducted at Kotalipara, Gopalganj and Shoronkhola, Bagerhat under the GoB fund for increasing cropping intensity in the coastal Barishal and Khulna region through water resources and soil salinity management project.

A total of 415 (20 in Aus, 145 in T. Aman and 250 in Boro) field demonstrations (about 1 bigha each) of newly released BRRI modern rice varieties were conducted in different farmers' fields in Gopalganj, Bagherhat and Narail districts.

On the other hand, 14 farmers' training and 10 field days in different locations of BRRI RS, Gopalganj recommended areas were organized. BRRI RS, Gopalganj also participated in one krishi mela (Agricultural fair).

In the reporting year, 4.52 tons of breeder seeds of different BRRI varieties were produced and sent to the GRS Division, BRRI HQ, Gazipur. BRRI RS, Gopalganj`also produced 12.49 tons of TLS of BRRI developed rice varieties.

VARIETAL DEVELOPMENT

ALART (STR-1 and STR-2) T. Aman 2021

Advanced Line Adaptive Research Trial (ALART) for salt tolerant rice (STR-1 and STR-2) were conducted at farmers' fields of Sadar, Bagerhat (STR1) and Rampal, Bagerhat (STR2) during T. Aman 2021. Three advanced lines IR108158-B-2-AJY1-1, IR15T1464 and TP30649 along with BRRI dhan73 and BRRI dhan87 as checks were tested at farmers' fieldin two locations (Table 1). One advanced line IR108158-B-2-AJY1-1 produced an average higher yield (5.77 t ha^{-1}) than the standard checks BRRI dhan73 (5.12 t ha^{-1}) and BRRI dhan87 (5.64 t ha^{-1}) with similar growth durations.

Investigators: Faruk Hossain Khan, Mohammad Zahidul Islam and Md Atiqul Islam

ALART Boro 2021-22

Four ALARTs of SHR, favourable Boro rice (FBR-Barishal), salt tolerant rice (STR-1 and STR-2) were conducted during Boro 2021-22 at farmers field in Gopalganj.

ALART (SHR) Boro

Three advanced lines along with BRRI dhan63 and Zirashail as checks were grown at Neemtala, Haridaspur, Gopalganj Sadar during Boro 2021-22. All the advanced lines produced a higher yield (6.77-7.58 t ha^{-1}) than the standard checks BRRI dhan63 (6.11 t ha^{-1}) and Zirashail (5.27 t ha^{-1}) with 16 days longer growth durations (Table 2).

Investigators: Faruk Hossain Khan, Srijan Chandra Das, Mohammad Zahidul Islam and Md Atiqul Islam

ALART (FBR) Boro

Four advanced lines along with BRRI dhan58 and BRRI dhan89 as checks were grown at Neemtala, Haridaspur, Gopalganj sadar during Boro 2021-22. All the advanced lines produced higher yield (7.60-7.94 t ha^{-1}) than the standard checks BRRI dhan58 (6.59 t ha^{-1}) and BRRI dhan89 (7.48 t ha^{-1}) with 5-7 days longer growth durations(Table 3).

Investigators: Faruk Hossain Khan, Srijan Chandra Das, Mohammad Zahidul Islam and Md Atiqul Islam

ALART (STR-1) Boro

Three advanced lines along with BRRI dhan67 and BRRI dhan92 as checks were tested at Babupara, Tungipara during Boro 2021-22. All the advanced lines produced higher yield (6.77-7.03 t ha^{-1}) than the standard checks BRRI dhan67 (5.80 t ha^{-1}) and BRRI dhan92 (6.65 t ha^{-1}) (Table 4).

Investigators: Srijan Chandra Das, Faruk Hossain Khan, Mohammad Zahidul Islam and Md Atiqul Islam

ALART (STR-2) Boro

Three advanced lines (BR11712-4R-227, BR11716-4R-105 and BR11716-4R-102) along with BRRI dhan67 and BRRI dhan92 as checks were tested at Babupara, Tungipara during Boro 2021-22. All the advanced lines produced higher yield (6.72-6.97 t ha^{-1}) than the standard checks BRRI dhan67 (5.51 t ha^{-1}) and BRRI dhan92 (6.61 t ha^{-1}). The mean growth duration of all the advanced lines is >160 days (Table 5).

Investigators: Srijan Chandra Das, Faruk Hossain Khan, Mohammad Zahidul Islam and Md Atiqul Islam

Table 1. Grain yield and ancillary characters of ALART (STR-1 and STR-2) genotypes during T. Aman 2021.

	Sadar, Bagerhat (STR1)			Rampal, Bagerhat (STR2)			
Genotype	PH (cm)	GD (day)	Yield (t ha^{-1})	PH (cm)	GD (day)	Yield (t ha^{-1})	Yield(t ha^{-1})
IR108158-B-2-AJY1-1	120	129	5.43	119	130	6.10	5.77
IR15T1464	123	128	5.51	127	127	5.43	5.47
TP30649	122	126	5.62	123	127	5.49	5.56
BRRI dhan73 (Tol. ck)	120	124	4.91	115	125	5.32	5.12
BRRI dhan87(Sus. ck)	124	131	5.52	127	132	5.76	5.64
$LSD_{0.05}$	1.57	3.50	0.25	2.33	2.43	0.14	0.12
CV(%)	1.47	2.12	5.21	4.27	2.16	5.58	4.45

Table 2. Grain yield and ancillary characters of ALART (SHR) genotypes during Boro 2021-22.

Genotype	Plant height (cm)	Growth duration(day)	Yield (t ha^{-1})
V1 = BRHII9-11-4-5B	101.20	161	7.31
V2 = BRH13-2-4-6-4B	100.73	163	7.58
V3 = BRH13-7-9-3-2B	119.67	162	6.77
V4 = BRRI dhan63 (ck)	94.00	144	6.11
V5 = Zirashail (ck)	103.33	143	5.27
$LSD_{0.05}$	6.40	1.41	0.86
CV%	3.28	0.49	6.88

Table 3. Grain yield and ancillary characters of ALART (FBR) genotypes during Boro 2021-22.

Genotype	Plant height (cm)	Growth duration(day)	Yield (t ha^{-1})
V1 = BRBa 1-4-9	128	160	7.89
V2 = BRBa 2-5-3	110	162	7.60
V3 = BRBa 3-1-7	111	163	7.94
V4 = BRBa 3-2-4	114	159	7.82
V5 = BRRI dhan58(ck)	111	154	6.59
V6 = BRRI dhan89(ck)	125	158	7.48
$LSD_{0.05}$	6.00	2.00	0.66
CV%	1.83	0.44	3.11

Table 4. Grain yield and ancillary characters of ALART (STR-1) genotypes during Boro 2021-22.

Genotype	Plant height (cm)	Growth duration(days)	Yield (t ha^{-1})
V1 = BR11715-4R-186	124.5	164	6.83
V2 = BR11723-4R-27	122.2	161	7.03
V3 = BR11723-4R-12	125.9	163	6.77
V4 = BRRI dhan67 (ck)	102.60	147	5.80
V5 = BRRI dhan92 (ck)	108.33	157	6.65
$LSD_{0.05}$	4.97	2.41	0.39
CV%	1.50	0.54	2.12

Table 5. Grain yield and ancillary characters of ALART (STR-2) genotypes during Boro 2021-22.

Genotype	Plant height (cm)	Growth duration(day)	Yield (t ha^{-1})
V1 = BR11712-4R-227	126	163.3	6.91
V2 = BR11716-4R-105	118	162.0	6.97
V3 = BR11716-4R-102	121	164.3	6.72
V4 = BRRI dhan67 (ck)	102.3	148.0	5.51
V5 = BRRI dhan92 (ck)	108	156.0	6.61
$LSD_{0.05}$	7.09	2.36	0.34
CV%	2.19	0.53	1.82

RYT T. Aman 2021

RYT (STR-1) T. Aman

Eight advanced lines along with BRRI dhan73 and BRRI dhan87 as checks were grown at BRRI RS, Gopalganj during T. Aman 2021. Five advanced lines produced a higher yield (6.32-6.75 t ha^{-1}) than the standard checks BRRI dhan73 (6.01 t ha^{-1}) and BRRI dhan87 (6.23 t ha^{-1}) with similar growth durations except for BR11716-4R-120 (Table 6).

RYT (STR-2) T. Aman

Eight advanced lines along with BRRI dhan73 and BRRI dhan87 as checks were tested. Five advanced lines produced higher yield (6.64-7.08 t ha^{-1}) than the standard checks BRRI dhan73 (5.91 t ha^{-1}) and BRRI dhan87 (6.38 t ha^{-1}) with similar growth durations except BR11716-4R-129 (Table 7).

RYT (ZER) T. Aman

Two advanced lines along with BRRI dhan72 and BRRI dhan87 as checks were grown. The advanced line BR10022-2-8-9-5-22 produced higher yield (6.81 t ha^{-1}) than the standard checks (BRRI dhan72 and BRRI dhan87). The mean growth duration of advanced line BR10022-2-8-9-5-22 was similar to the check variety BRRI dhan87 and six days longer than the other check BRRI dhan72 (Table 8).

RYT (RLR) T. Aman

Five advanced lines along with BRRI dhan49, BRRI dhan71 and BRRI dhan87 as checks were tested. Two advanced lines produced higher yield (6.37-6.89 t ha^{-1}) than the standard three checks (BRRI dhan49, BRRI dhan71 and BRRI dhan87). On the other hand, five advanced lines produced higher yield (6.09-6.89 t ha^{-1}) than the two checks namely BRRI dhan49 and BRRI dhan71 (Table 9).

RYT Boro 2021-22

RYT (SS) Boro

Five advanced lines along with BRRI dhan28 and BRRI dhan81 as checks were evaluated. The average grain yield of all the advanced lines (6.85-7.00 t ha^{-1}) was higher than the checks BRRI dhan28 and BRRI dhan81 (5.97-6.35 t ha^{-1}) (Table 10).

RYT (LS) Boro

Three advanced lines were tested against one check variety BRRI dhan28. Three advanced lines produced a higher yield (6.30-6.90 t ha^{-1}) than the standard check BRRI dhan28 (5.98 t ha^{-1}) with similar and a few days longer growth duration (Table 11).

RYT (FBR) Boro

Ten advanced lines along with BRRI dhan58 and BRRI dhan89 as checks were tested. One advanced line produced higher yield (9.20 t ha^{-1}) than the standard checks (BRRI dhan58 and BRRI dhan89). On the other hand, seven advanced lines produced higher yield (7.03-9.20 t ha^{-1}) than the check BRRI dhan58 (6.99 t ha^{-1}) (Table 12).

RYT (STR-1) Boro

Eight advanced lines along with BRRI dhan89, BRRI dhan67 and BRRI dhan97 as checks were grown. None of the tested genotypes produced higher yield (5.97-7.34 t ha^{-1}) than the check variety BRRI dhan89 (7.83 t ha^{-1}). But three advanced lines produced higher yield (6.71-7.34 t ha^{-1}) than both the checks (BRRI dhan67 and BRRI dhan97) with similar growth duration (Table 13).

RYT (STR-2) Boro

Nine advanced lines along with BRRI dhan89, BRRI dhan67 and BRRI dhan97 as checks were tested. None of the tested genotypes produced higher yield (6.02-6.92 t ha^{-1}) than the check variety BRRI dhan89 (7.87 t ha^{-1}). But three advanced line produced higher yield (6.70-6.92 t ha^{-1}) than both eth checks (BRRI dhan67 and BRRI dhan97) with similar growth durations. (Table 14).

Table 6. Grain yield and ancillary characters of RYT (STR1) genotypes during T. Aman 2021.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR11716-4R-108	96	134	5.89
BR11716-4R-120	108	133	6.32
BR11723-4R-48	103	124	6.75
BR11723-4R-12	105	125	6.58
BR11716-4R-123	109	124	6.38
BR11716-4R-114	105	133	6.17
BR11716-4R-147	109	125	6.66
BR10672-1-3-7-12	104	115	4.88
BRRI dhan73(Tol.ck)	123	124	6.01
BRRI dhan87(Sus.ck)	124	124	6.23
$LSD_{0.05}$	5.37	3.42	0.33
CV%	8.02	4.59	8.65

Table 7. Grain yield and ancillary characters of RYT (STR-2) genotypes during T. Aman 2021.

Genotypes	Plant height (cm)	Growth duration (Days)	Yield (t ha^{-1})
BR11723-4R-172	107.67	124	6.80
BR11716-4R-102	109.25	123	7.08
BR11715-4R-186	107.32	126	6.64
BR11712-4R-218	106.67	125	6.38
BR11712-4R-227	111.27	126	6.68
BR11723-4R-27	105.93	128	6.38
BR11716-4R-129	108.30	129	6.80
BR11716-4R-105	109.00	128	5.99
BRRI dhan73(Tol.ck)	125.50	123	5.91
BRRI dhan87(Sus.ck)	124.40	125	6.38
$LSD_{0.05}$	4.48	1.30	0.23
CV%	6.48	1.68	5.66

Table 8. Grain yield and ancillary characters of RYT (ZER) genotypes during T. Aman 2021.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR10005-25-8-4-7-20	131	109	6.14
BR10022-2-8-9-5-22	137	124	6.81
BRRI dhan72(ck)	138	118	5.60
BRRI dhan87(ck)	138	125	6.27
$LSD_{0.05}$	3.29	7.20	0.48
CV%	2.47	6.17	8.01

Table 9. Grain yield and ancillary characters of RYT (RLR) genotypes during T. Aman 2021.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
SVIN209	109	132	6.89
SVIN172	102	128	6.09
IR98377-B-B-B-B-24	116	132	6.21
BR9840-52-1-2-1	122	128	6.37
BR8492-9-5-3-2-HR1	115	131	6.25
BRRI dhan49(ck)	115	139	5.47
BRRI dhan71(ck)	119	128	5.46
BRRI dhan87(ck)	122	127	6.35
$LSD_{0.05}$	4.69	2.72	0.33
CV%	5.88	3.01	7.77

Table 10. Grain yield and ancillary characters of RYT (SS) genotypes during Boro 2021-22.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRH10-1-14-2-6B	102.50	144	6.77
BRH9-3-2B	107.83	143	6.68
BRH13-1-9-7B	98.58	146	6.85
BRH17-23-8-2-7B	99.42	144	6.91
BRH113-2-4-7-2B	98.67	143	7.00
BRRI dhan28	104.33	140	5.97
BRRI dhan81	100.58	143	6.35
$LSD_{0.05}$	13.14	1.54	0.37
CV%	4.53	0.38	2.00

Table 11. Grain yield and ancillary characters of RYT (SS) genotypes during Boro 2021-22.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRH11-2-4-7B	117.33	148	6.90
BR10247-14-18-4	116.25	140	6.30
BR10247-4-7-4B	110.75	148	6.70
BRRI dhan28	97.83	139	5.98
$LSD_{0.05}$	11.08	2.28	0.33
CV%	5.02	0.79	2.62

Table 12. Grain yield and ancillary characters of RYT (FBR) genotypes during Boro 2021-22.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
NGR 414-1	102.50	149	9.20
NGR 418-1	102.08	152	7.37
NGR 467-12	106.42	153	7.84
NGR 521-2	100.33	151	7.88
NGR 522-2	100.25	152	7.03
NGR 750-1	109.42	152	7.06
NGR 796-2	105.83	152	6.67
NGR 1161-3	105.42	152	6.29
NGR 1255-1	114.75	153	7.37
NGR 1308-2	105.08	154	6.98
BRRI dhan58	102.92	152	6.99
BRRI dhan89	116.76	157	7.98
$LSD_{0.05}$	4.80	1.91	0.64
CV(%)	2.68	0.74	5.11

Table 13. Grain yield and ancillary characters of RYT (STR-1) genotypes during Boro 2021-22.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR10182-5-4-2	106.75	149	6.01
BR10187-1-4-12	110.92	143	7.34
BR10187-1-5-11	108.58	144	6.71
BR10188-10-1-18	117.08	149	5.97
BR9901-1-1-3-10	109.92	146	6.95
BR9904-1-3-3	137.67	150	6.05
BR9918-10-4-5	110.92	149	6.35
BR9926-7-7-6	116.58	149	6.42
BRRI dhan89	117.67	151	7.83
BRRI dhan67	121.33	145	5.83
BRRI dhan97	118.25	150	6.77
$LSD_{0.05}$	8.73	2.51	0.56
CV(%)	4.42	0.99	4.97

Table 14. Grain yield and ancillary characters of RYT (STR-2) genotypes during Boro 2021-22.

Genotypes	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
IR 108175-B-22-AJY 3-B-1	140.83	150	6.27
IR108604-2-1-AJY 3-B-1	108.42	150	6.02
IR108604-2-3-AJY 3-B-1	123.08	150	5.67
IR15T1399	112.08	150	6.29
TP20532	104.83	149	6.27
TP21654	102.33	149	6.92
TP24493	97.67	150	6.16
TP30629	109.83	148	6.70
TP30642	111.00	149	6.91
BRRI dhan89	116.25	151	7.87
BRRI dhan67	122.42	145	5.90
BRRI dhan97	118.33	150	6.68
$LSD_{0.05}$	7.55	2.25	0.36
CV(%)	3.91	0.89	3.28

RICE GERMPLASM COLLECTION AND CHARACTERIZATION

Germplasm collection and rejuvenation. One hundred and twenty four Aman rice germplasm were collected from Faridpur region. These rice germplasm were rejuvenated to increase the seed for further evaluation and utilization. The experiment was carried out under transplanted conditions using single row of 5.4 m long per accession with 20 × 20 cm spacing between rows and plants respectively. Fertilizers were applied @ 60:20:40 kg NPK/ha in T. Aman 2021. Appropriate control measures were taken for insect pests, diseases and weeds when necessary.

Investigator: Mohammad Zahidul Islam

Morphological characterization. One experiment was conducted to characterize 54 pigmented rice germplasm through 51 agro-morphological traits (20 quantitative and 31 qualitative characters) using the Rice Germplasm Descriptors and Evaluation Form of GRSD, BRRI. The experiments were conducted in BRRI RS, Gopalganj. The experiment was conducted using a single row of 5.4 m long for each entry/accession with a spacing of 20 × 20 cm between rows and plants, respectively during Boro 2021-22 season. Fertilizers were applied @ 80:20:40 kg NPK/ha in Boro season. Appropriate control measures were taken for insect pests, diseases and weeds when necessary.

Results. The present study exhibits high variability in most of the observed traits of pigmented Boro rice germplasm. The euclidean distance was calculated using quantitative data and a UPGMA dendrogram was constructed using 54 pigmented Boro rice germplasm. Cluster analysis indicated that the 54 pigmented rice germplasm could be divided into four categories, using the Euclidean

distance of 0.42 as the threshold value **(Fig. 1**). Maximum 39
genotypes were grouped into the cluster III and 11 in cluster II. The cluster I and IV contained the lowest (2) number of genotypes.

Investigators: Mohammad Zahidul Islam, Srijan Chandra Das and M S U Ahmed

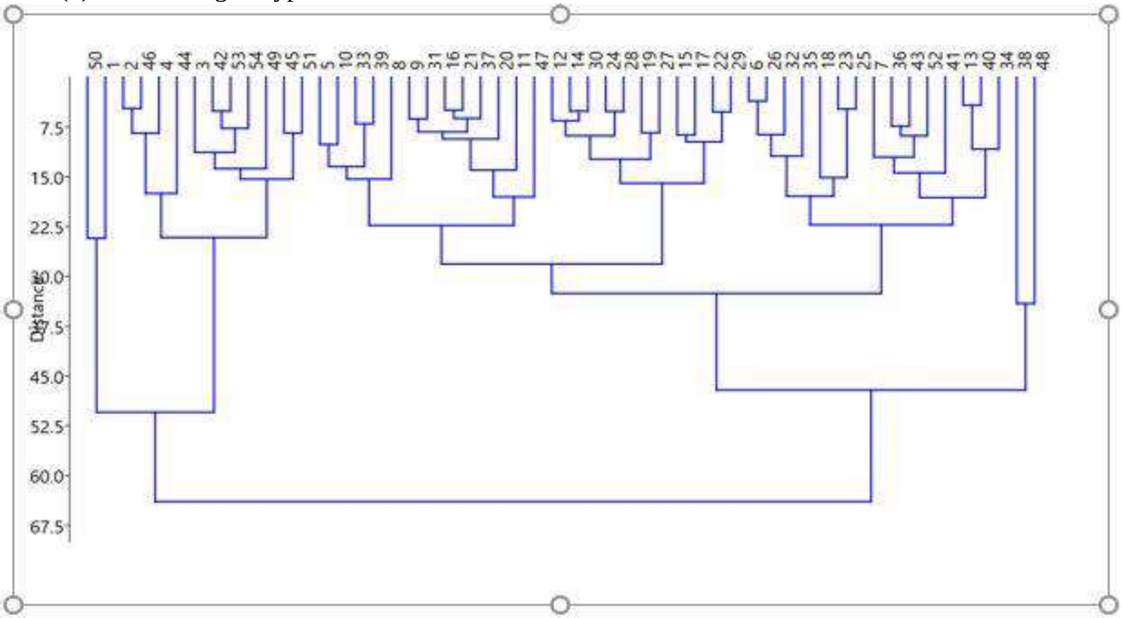


Fig. 1. UPGMA dendrogram of 54 pigmented Boro rice germplasm based on their morphological and yield component traits.

TECHNOLOGY TRANSFER

Variety replacement through Head to Head Adaptive Trial during T. Aman 2021 and Boro 2021-22 under TRB-BRRI project

Seven Head to Head Adaptive Trials (HHAT) were conducted in seven upazilas under two districts viz Gopalganj and Bagerhat during the reporting period.

T. Aman 2021 season

There are nine rice varieties viz short duration varieties BRRI dhan71, BRRI dhan75, BINA dhan-17, BINA dhan-22 and long duration varieties BRRI dhan80, BRRI dhan87, BRRI dhan93, BRRI dhan94 and BRRI dhan95 were used in T. Aman 2021 season. Among the short duration varieties, BRRI dhan75 produced the highest yield (6.62 t/ha) and BINA dhan-17 produced the lowest yield (5.90 t/ha) at Mollahat upazila in the Bagerhat district (Table 15). Among the long duration varieties, BRRI dhan87 recorded the highest yield 6.74 t/ha and 6.84 t/ha respectively at Tungipara upazila and Kashiani upazila in the Gopalganj district.

Boro 2021-2022 season

In Boro 2021-22 season, two groups (Long duration and Salinity eco-system) of BRRI modern rice varieties were tested at four locations of Gopalganj and Bagherhat districts viz BRRI dhan29, BRRI dhan58, BRRI dhan89, BRRI dhan92 and BINA dhan24 were used as long duration (LD) varieties and BRRI dhan28, BRRI dhan67, BRRI dhan97 and BRRI dhan99 were used as salinity eco-system varieties. Among these long duration varieties, BRRI dhan89 produced the highest yield in both the locations which was 8.18 t/ha (Mollahat upazila) and 7.80 t/ha (Gopalganj sadar upazila) in Bagerhat and Gopalganj districts respectively. In case of salinity eco-system BRRI dhan67 yielded the highest in both the locations which was 5.89 t/ha (Rumpal upazila) and 5.71 t/ha (Tungipara upazila) in Bagerhat and Gopalganj districts respectively (Table 16).

Table 15. Grain yield of head-to-head adaptive trails under TRB project in Aman 2021 season.

Grain yield (t/ha)									
Location	BRRI dhan71	BRRI dhan75	BINA dhan-17	BINA dhan-22	BRRI dhan80	BRRI dhan87	BRRI dhan93	BRRI dhan94	BRRI dhan95
Mollahat, Bagerhat	6.35	6.62	5.90	6.27	-	-	-	-	-
Tungipara, Gopalganj	-	-	-	-	5.83	6.74	5.82	6.42	5.81
Kashiani, Gopalganj	-	-	-	-	5.07	6.84	6.31	6.34	5.97

Table 16. Grain yield of head-to-head adaptive trails under TRB project in Boro 2021-2022 season.

Grain yield (t/ha)									
Location	BRRI dhan29	BRRI dhan58	BRRI dhan89	BRRI dhan92	BINA dhan24	BRRI dhan28	BRRI dhan67	BRRI dhan97	BRRI dhan99
Gopalganj Sadar, Gopalganj	7.00	6.34	8.18	7.89	6.35	-	-	-	-
Mollahat, Bagerhat	6.80	6.34	7.80	7.34	6.62	-	-	-	-
Tungipara, Gopalganj	-	-	-	-	-	4.92	5.89	4.99	5.46
Rumpal, Bagerhat	-	-	-	-	-	4.96	5.71	5.00	5.44

Block Demonstration

Two block demonstrations were conducted in two locations during Boro 2021-22 season under the increasing cropping intensity in the coastal Barishal and Khulna region through water resources and soil salinity management project which is GoB funded. Among the two varieties BRRI dhan67 was cultivated at Purba khada, Shoronkhula, Bagerhat district around hundred bighas salinity prone areas and Bangabandhu dhan100 was conducted at Doxkhin Dhigoliya, Kotalipara, Gopalganj district around sixty bighas. The average grain yield of BRRI dhan67 was 6.10 t/ha with growth duration of 144 days recorded at Shoronkhula, Bagerhat district. On the other hand, the average grain yield of Bangabandhu dhan100 was 7.58 t/ha with growth duration of 147 days recorded at Kotalipara, Gopalganj district. At the maturity of the crops, two field day was arranged in both the locations with the help of DAE personnel. During the field day, the demo farmers shared their experiences with neighbouring farmers, which made them interested in these varieties to cultivate those on their own land and thereby demand for quality seeds were generated.

Field Demonstration

A total of 415 (20 in Aus, 145 in T. Aman and 250 in Boro) field demonstrations (about 1 bigha each) of newly released BRRI modern rice varieties were conducted in different farmer's field in Gopalganj, Bagherhat and Narail districts. Among them, 232 trials in the Gopalganj district, 100 trials in the Bagherhat district and 83 trials in the Narail district were conducted during Aus 2021, T. Aman 2021 and Boro 2021-22 seasons. Farmer's acceptance of BRRI hybrid dhan7 in T. Aus season, BRRI dhan75, BRRI dhan87, BRRI hybrid dhan6 in T. Aman Season and BRRI dhan74, BRRI dhan89, BRRI hybrid dhan5 in Boro season were found very high in those respective areas for their grain size, panicle length and high yield.

Farmers Training

In the reporting year**,** fourteen farmer's training was organized in different locations in Gopalganj, Bagerhat and Narail districts (Table 17). Among them 420 participants consisting farmers, DAE personnel attended and improved their knowledge level about modern rice production technologies and maintenance with the cooperation of DAE and the financial assistance of the GoB fund.

Table 17. Farmers training on modern rice cultivation and blast disease management in different regions during 2021-22.

	Upazila	No. of trainees				Total trainees
		SAAO		Farmer		
		M	F	M	F	
GoB fund, BRRI RS, Gopalganj						
	Gopalganj	-	-	155	25	180
	Bagerhat	-	-	154	26	180
	Narail	-	-	43	17	60
Total				352	68	420

Field Day and Krishi Mela

Ten field days were organized in the block demonstration in the Gopalganj, Bagerhat and Narail districts during T. Aman 2021 and Boro 2021-22 seasons which was funded by GoB. The items of the programmes included the high yielding hybrid rice variety development through modernization of research project and increasing cropping intensity in the coastal Barishal and Khulna region through water resources and soil salinity management project. About 1,250 progressive farmers as well as extension personnel, administrative people and local leaders attended those field days. Most of the farmers were interested to cultivate new rice varieties in their areas specially BRRI dhan67, BRRI dhan75, BRRI dhan87, BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI Hybrid dhan5 and BRRI hybrid dhan6. BRRI RS, Gopalganj also participated in one Krishi Mela (Agricultural fair) with similar production activities.

Seed production and dissemination in July 2021-June 2022

In the reporting year, a total of 1,420 kg, 4,400 kg and 6,670 kg truthfully labelled seeds (TLS) were produced in T. Aus, T. Aman and Boro season respectively. In total 1,600 kg breeder seed was produced in T. Aman season and 2,920 kg breeder seed of different BRRI varieties was produced in Boro season. In total 4,520 kg of breeder seed was sent to the GRS Division, BRRI HQ, Gazipur (Tables 18 and 19). On the other hand, a total of 855 kg (2.15 t ha^{-1}) of F_1 seed (BRRI hybrid dhan5) was produced in Boro season (Table 20). In three seasons, 6.41 tons 7of TLS were distributed among the farmers for dissemination in Gopalganj, Bagerhat and Narail districts.

Table 18. Breeder and TLS seed production in T. Aus 2021 and T. Aman 2021 season.

Variety	Breeder seed (kg)	TLS (kg)	Variety	Breeder seed (kg)	TLS (kg)
T. Aus			T. Aman		
BRRI dhan48	-	220	BRRI dhan87	1600	800
BRRI dhan82	-	500	BRRI dhan52	-	570
BRRI dhan85	-	500	BRRI dhan67	-	400
BRRI dhan98	-	200	BRRI dhan71	-	100
			BRRI dhan75	-	150
			BRRI dhan76	-	1000
			BRRI dhan77	-	380
			BRRI dhan91	-	350
			Bangabandu dhan100	-	650
Total		1420	Total	1600	4400

Table 19. Breeder and TLS seed production in Boro 2021-2022 season.

Variety	Breeder Seed (kg)	TLS (kg)
Boro 2021-22		
BRRI Hybrid dhan5	-	-
BRRI dhan58	-	400
BRRI dhan67	1450	1100
BRRI dhan74	1470	830
BRRI dhan88	-	400

Variety	Breeder Seed (kg)	TLS (kg)
BRRI dhan89	-	1000
BRRI dhan92	-	540
BRRI dhan96	-	430
BRRI dhan97	-	300
BRRI dhan99	-	350
Bangabandu dhan100	-	1320
Total	2920	6670

Table 20. F_1 Seed production of BRRI hybrid dhan5.

Hybrid	Plant height (cm)		50% flowering		Plot area (Acre)	Seed yield (kg)	Seed yield (t ha^{-1})
	A line	R line	A line	R line			
BRRI 17A/BRRI31R	86	97	120	140	1.0	855	2.15

Investigators: Mohammad Zahidul Islam, Faruk Hossain Khan, Srijan Chandra Das, Priya Lal Chandra Pal and Md Jamil Hasan


BRRI dhan97


BRRI dhan98


BRRI dhan99