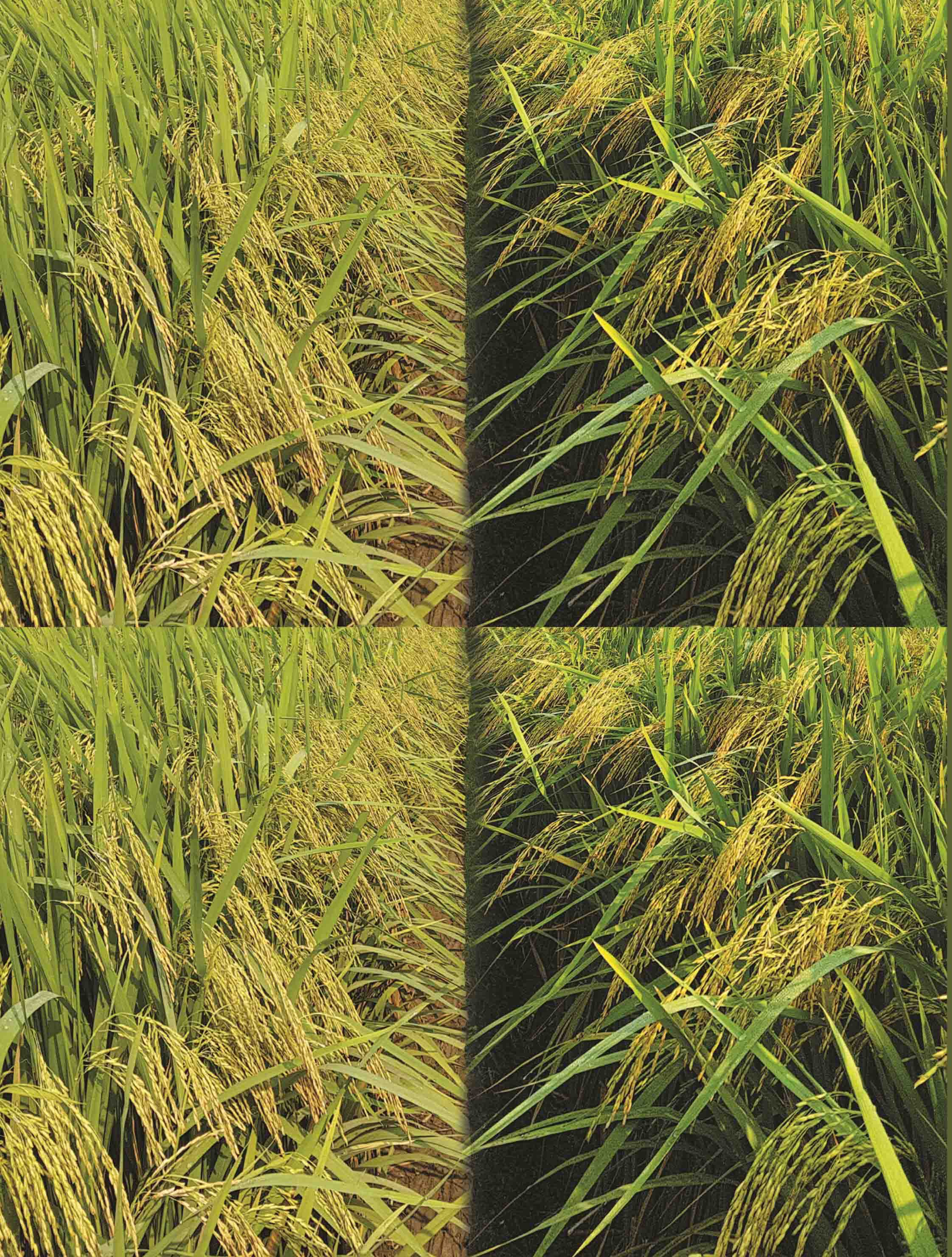


BRRI ANNUAL REPORT
2017-2018
Bangladesh Rice Research Institute

BRRI ANNUAL REPORT
2017-2018

Bangladesh Rice Research Institute

BRRI ANNUAL REPORT

For July 2017-June 2018

Bangladesh Rice Research Institute (BRRI)
Gazipur 1701, Bangladesh

Publication no. : 264
350 copies
October 2018

Published by
Director General
Bangladesh Rice Research Institute

Advisers
Dr Md Shahjahan Kabir
Dr Md Ansar Ali
Dr Tamal Lata Aditya

Edited by
M A Kashem

Proof reading
Md Saiful Malek Majumder

Suggested citation
Anonymous (2018) Annual Report of Bangladesh Rice Research Institute 2017-2018
BRRI, Gazipur 1701, Bangladesh, 354 pp.

Printed at
Swasti Printers
25/1, Babupura, Nilkhet, Dhaka 1205

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

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 2017 to June 2018. This document consists of the significant portions of the research covering eight programme areas.

The programme areas, such as 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 cost and resource-saving profitable technologies along with some management tools such as alternate wetting and drying (AWD) techniques, 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 rice research at BRRI.

(Dr Md Shahjahan Kabir)
Director General
BRRI

Personnel

Director General's Office
Dr Md Shahjahan Kabir, *PhD*
Director General
(Since 31 Aug 2017)

Research Wing
Md Ansar Ali, *PhD*
Director (Research)
(Till 1 Oct 2017)
Tamal Lata Aditya, *PhD*
Director (Research)
(Since 2 Oct 2017)
Munnujan Khanam, *PhD*
Principal Scientific Officer, TOC
Mohammad Abdul Momin, *MS, MBA*
Senior Liaison Officer

Administrative Wing
Md Shahjahan Kabir, *PhD*
Director (Administration and Common Service)
(Till 30 Aug 2017)
Md Ansar Ali, *PhD*
Director (Administration and Common Service)
(Since 2 Oct 2017)
Emran Hossain, *MS (BAU)*
Deputy Director (Administration and Common Service)
Md Abdul Aziz, *BA*
Assistant Director (Common Service)
(Till 2 Jan 2018)
Kawsar Ahmad, *BSS (Hons), MSS (RU)*
Assistant Director (Procurement)
Momotaz Shireen, *MA*
Assistant Director (Store)
Md Akkas Ali, *BSc*
Assistant Director (Administration)
Md Harunur Rashid, *BA*
Assistant Director (Common Service)

Accounts and Finance
Md Golam Rashid, *Mcom (Acct) CMA (Int)*
Deputy Director (Accounts and Finance)
Kazi Anwarul Azim, *BCom (Hons), MCom*
Assistant Director (Finance)

Aduit cell
Tarique Sala Uddin, *Bcom (Hons), MCom*
Audit Officer

Building and Construction
Md Zahid Hasan, *BScEngg (Civil)*
Executive Engineer
Md Ataul Haque Bhuiyan, *Dip-in-Engg (Civil)*
Assistant Engineer
Md Abdur Rob, *Dip-in-Engg (Civil)*
Assistant Engineer
Md Hasan Mahamud, *Dip-in-Engg (Civil)*
Assistant Engineer

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

Planning and Evaluation
Md Monirul Islam, *MSc Ag Econ*
Principal Planning Officer
Atia Rokhsana, *MS Ag Econ*
Senior Planning Officer
Md Saidul Islam, *MS Ag Econ*
Planning Officer

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

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

Plant Breeding Division
Tamal Lata Aditya, *PhD*
Chief Scientific Officer and Head
(Till 20 Jan 2018)

Md Alamgir Hossain, *PhD*
Chief Scientific Officer and Head
(Since 21 Jan - 30 Jun 2018)
A S M Masuduzzaman, *PhD*
Chief Scientific Officer
Khandakar Md Iftekharuddaula, *PhD*
Principal Scientific Officer
Deputation (CRF of TRB Project)
Partha Sarathi Biswas, *PhD**
Principal Scientific Officer
Mohammad Akhlasur Rahman, *PhD*
Principal Scientific Officer
Mahmuda Khatun, *PhD*
Principal Scientific Officer
Md Abdul Kader, *PhD*
Senior Scientific Officer
Md Ruhul Amin Sarker, *PhD*
Senior Scientific Officer
Sharmistha Ghosal, *MS**
Senior Scientific Officer
Md Rafiqul Islam, *MS*
Senior Scientific Officer
Ratna Rani Majumder, *MS**
Senior Scientific Officer
Md Anisuzzaman, *MS*
Senior Scientific Officer
Hasina Khatun, *MS**
Scientific Officer
Tapas Kumer Hore, *MS*
Scientific Officer
M M Emam Ahmed, *MS*
Scientific Officer
A K M Shalahuddin, *MS*
Scientific Officer
Nusrat Jahan, *BScAg (Hons)*
Scientific Officer

Biotechnology Division
Md Enamul Hoque, *PhD*
Chief Scientific Officer (Additional Charge) & Head
Shahanaz Sultana, *PhD*
Senior Scientific Officer
Jannatul Ferdous, *PhD*
Senior Scientific Officer
Nilufar Yasmin Shaikh, *PhD*
Senior Scientific Officer
S M Hisam Al Rabbi, *PhD*
Scientific Officer
Ripon Kumar Roy, *MS*
Scientific Officer
Md Arafat Hossain, *MS*
Scientific Officer
Shampa Das Joya, *MS*
Scientific Officer

Genetic Resources and Seed Division
Mohammad Khalequzzaman, *PhD*
Chief Scientific Officer and Head
Mir Sharf Uddin Ahmed, *PhD*
Principal Scientific Officer
Ebna Syod Md Harunur Rashid, *PhD*
Senior Scientific Officer
Md Abubakar Siddique, *MS*
Senior Scientific Officer
Armin Bhuiya, *PhD*
Scientific Officer
Hasina Begum, *PhD*
Scientific Officer
Mohammad Zahidul Islam, *PhD*
Scientific Officer
Md Humayun Kabir Baktiar, *MS**
Scientific Officer
Tonmoy Chakrabarty, *BS (Ag)*
Scientific Officer
Nadia Akter, *BSc Ag (Hons)*
Scientific Officer

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, *MS**
Senior Scientific Officer
Habibul Bari Shozib, *PhD*
Senior Scientific Officer
Shakir Hosen, *MS*
Scientific Officer

Hybrid Rice Division

Md Jamil Hasan, *PhD*
Principal Scientific Officer and Head
Ashish Kumar Paul, *MScAg*
Senior Scientific Officer
Priya Lal Biswas, *PhD*
Senior Scientific Officer
Md Kamal Hossain, *PhD*++
Senior Scientific Officer
Mosammat Umma Kulsum, *MS**
Scientific Officer
Afsana Ansari, *PhD*
Scientific Officer
Anowara Akter, *MS**+
Scientific Officer
Md Hafizar Rahman, *MS**+
Scientific Officer
Laila Ferdousi Lipi, *MS*
Scientific Officer

Agronomy Division

Md Gous Ali, *PhD*
Principal Scientific Officer and Head
Md Shahidul Islam, *PhD*
Principal Scientific Officer
Md Khairul Alam Bhuiyan, *PhD*
Senior Scientific Officer
Md Adil Badshah, *PhD***
Senior Scientific Officer
Selima Zahan, *MS*
Senior Scientific Officer
Amena Sultana, *PhD***
Senior Scientific Officer
Nasima Akter, *PhD*
Senior Scientific Officer
Md Zakaria Ibne Baki, *MS**+
Scientific Officer
Md Mostofa Mahbub, *MS***
Scientific Officer
Lutfun Nahar, *MS*
Scientific Officer
Romana Akter, *BSC*
Scientific Officer

Soil Science Division

Jatish Chandra Biswas, *PhD*
Chief Scientific Officer and Head
(PRL from 31 Dec 2017)
Md Rafiqul Islam, *PhD*
Chief Scientific Officer (Current charge) and Head
A Islam, *PhD*
Principal Scientific Officer
U A Naher, *PhD*
Principal Scientific Officer
M M Haque, *PhD*
Senior Scientific Officer
Fahmida Rahman, *PhD*
Senior Scientific Officer
A T M Sakhawat Hossain, *PhD*
Senior Scientific Officer
Masuda Akter, *PhD*
Senior Scientific Officer
S M Mofijul Islam, *PhD*
Senior Scientific Officer
M Iqbal, *PhD*
Senior Scientific Officer
M N Ahmed, *MS*
Scientific Officer
M N Islam, *MS*
Scientific Officer
M I U Sarkar, *MS*
Scientific Officer
F Alam, *MS**+
Scientific Officer
Mahmuda Akter, *MS*
Scientific Officer
Afsana Jahan, *MS*
Scientific Officer

Irrigation and Water Management Division

Md Towfiqul Islam, *PhD*
Principal Scientific Officer and Head
Md Maniruzzaman, *PhD*
Principal Scientific Officer
Md Mahbubul Alam, *PhD*
Senior Scientific Officer
Ms Shahana Parveen, *PhD*
Senior Scientific Officer
ABM Zahid Hossain, *PhD*
Senior Scientific Officer

Debjit Roy, *MS**
Senior Scientific Officer
Mir Nurul Hasan Mahmud, *MS**
Senior Scientific Officer
Priya Lal Chandra Paul, *MS**
Senior Scientific Officer
Md Belal Hossain, *MS*
Scientific Officer
Mst ShetaraYesmin, *MS*
Scientific Officer

Plant Physiology Division
Rumena Yasmeen, *PhD*
Chief Scientific Officer
(Addl. Charge) and Head
Munnujan Khanm, *PhD*
Principal Scientific Officer
(Deputed to TOC)
Salma Pervin, *PhD*
Senior Scientific Officer
Md Sazzadur Rahman, *PhD*
Senior Scientific Officer
Md Mamunur Rashid, *PhD*
Senior Scientific Officer
Salma Akter, *MS*
Scientific Officer
Tuhin Halder, *MS*
Scientific Officer
Avijit Biswas, *MS*
Scientific Officer

Entomology Division
Sheikh Shamiul Haque, *PhD*
Chief Scientific Officer (Additional charge) and Head
Md Mosaddeque Hossain, *MS*
Principal Scientific Officer
Md Mofazzel Hossain, *PhD***
Principal Scientific Officer
Md Nazmul Bari, *PhD*
Senior Scientific Officer
ABM Anwar Uddin, *MS***
Senior Scientific Officer
Md Panna Ali, *PhD*
Senior Scientific Officer

Mir Md Moniruzzaman Kabir, *MS*
Scientific Officer
Farzana Nowrin, *MS*
Scientific Officer
Sadia Afrin, *MS*
Scientific Officer
Md Asif Rahman, *MS****
Scientific Officer

Plant Pathology Division
Md Abdul Latif, *PhD*
Principal Scientific Officer and Head
Tahmid Hossain Ansari, *PhD*
Principal Scientific Officer
Q S A Jahan, *PhD*
Principle Scientific Officer
Shamima Akter, *PhD**
Senior Scientific Officer
Mohammad Ashik Iqbal Khan, *PhD*
Senior Scientific Officer
Mohammad Abul Monsur
Senior Scientific Officer
Tuhina Khatun, *PhD*
Senior Scientific Officer
Md Rejwan Bhuiwan, *MS*
Senior Scientific Officer
Md Mamunur Rashid, *MS**
Senior Scientific Officer
Bodrun Nessa, *MS**+
Senior Scientific Officer
Montasir Ahmed, *BScAg (Hons)*
Scientific Officer
Anjuman Ara, *MS*
Scientific Officer
Sheikh Arafat Islam Nihad, *MS*
Scientific Officer
Rumana Aktar, *MS**
Scientific Officer
Hosne Ara Dilzahan, *MS**
Scientific Officer

Rice Farming Systems Division
F M Moinuddin, *MS*
Chief Scientific Officer and Head
(LPR on 16 oct 2017)

Abhijit Saha, *PhD*
Principal Scientific Officer
Muhammad Nasim, *PhD*
Principal Scientific Officer
S M Shahidullah, *PhD*
Senior Scientific Officer
Amina Khatun, *PhD*
Senior Scientific Officer
Nargis Parveen, *MS*
Senior Scientific Officer
ABM Jamiul Islam, *MS*[*+]
Senior Scientific Officer
Md Asad-Uz-Zaman, *MS*
Senior Scientific Officer
Bir Jahangir Shirazy, *BScAg*
Scientific Officer
ABM Mostafizur, *MS*
Scientific Officer
Lipiara Khatun, *MS*[***]
Scientific Officer
Tusher Chakrobarty, *MS*[***]
Scientific Officer

Agricultural Economics Division
Md Abu Bakr Siddique, *PhD*
Chief Scientific Officer and Head
Md Saiful Islam, *MS*
Principal Scientific Officer
Md Jahangir Kabir, *PhD*
Principal Scientific Officer
Md Abdus Salam, *PhD*
Senior Scientific Officer
Mohammad Ariful Islam, *PhD*
Senior Scientific Officer
Md Imran Omar, *MS*
Senior Scientific Officer
Md Abdur Rouf Sarkar, *MS*
Senior Scientific Officer
Md Chhiddikur Rahman, *PhD*
Scientific Officer
Afroza Chowdhury, *MS*
Scientific Officer
Md Shajedur Rahman, *MS*
Scientific Officer
Limon Deb, *MS*
Scientific Officer

Agricultural Statistics Division
Md Ismail Hossain, *PhD*
Principal Scientific Officer and Head
Niaz Md Farhat Rahman, *MS*
Senior Scientific Officer
Md Abdul Qayum, *MSc*
Senior Scientific Officer
Md Abdullah Aziz, *MS*
Senior Scientific Officer
Md Abdullah Al Mamun, *MSc*
Scientific Officer

ICT Cell
S M Mostafizur Rahman, *BSc*
System Analyst
Ful Miah, *BSc*
Cartographer (Senior IT Officer)
Md Mahfuz Bin Wahab, *MS*
Programmer
Kabita, *MSc*
Assistant Programmer

Farm Management Division
Krishna Pada Halder, *PhD*
Chief Scientific Officer and Head
Md Sirajul islam, *MS*
Principal Scientific Officer
Md Mamunur Rashid, *MS*
Scientific Officer
Setara Begum, *MS*[***]
Scientific Officer
Kamal Uddin Ahammed, *Dip in Agril.*
Farm Manager
Md Abdus Salam Mollah, *Dip in Agril.*
Farm Manager

Farm Machinery and Postharvest Technology Division
Muhammed Abdur Rahman, *PhD*
Chief Scientific Officer
Md Durrul Huda, *PhD*
Principal Scientific Officer
AKM Saiful Islam, *PhD*
Principal Scientific Officer
Md Golam Kibria Bhuiyan, *MS*
Senior Scientific Officer

Md Anwar Hossen, *MS*
Senior Scientific Officer
Bidhan Chandra Nath, *MS*
Senior Scientific Officer
Md Kamruzzaman Milion, *MSc in Engg*[*]
Senior Scientific officer
Subrata Paul, *M Engg*
Senior Scientific officer
Md Ashraful Alam, *MS*[*+]
Scientific Officer
Md Kamruzzaman Pintu, *MS*
Scientific officer
Sharmin Islam, *MS*
Agricultural Engineer
Haimonti Paul, *MS*
Agricultural Engineer
Md Monirul Islam, *MS*
Scientific Officer
Md Mizanur Rahman, *MS*
Scientific Officer

Workshop Machinery and Maintenance Division
Mahbubul Alam Zami, *PhD*
Principal Scientific Officer and Head
Biraj Kumar Biswas, *PhD*
Senior Scientific Officer
Mohammad Afzal Hossain, *MS*[*+]
Senior Scientific Officer
Hafizur Rahaman, *BSc Agril Eng*[*+]
Scientific Officer

Adaptive Research Division
Md Shafiqul Islam Mamin, *PhD*
Chief Scientific Officer and Head
Md Atiqul Islam, *PhD*
Principal Scientific Officer
Md Humayun Kabir, *PhD*
Principal Scientific Officer and PD, SPIRA
Biswajit Karmakar, *PhD*
Senior Scientific Officer
Dr Md Humayun Kabir, *PhD*
Senior Scientific Officer
Md Fazlul Islam, *PhD*
Senior Scientific Officer
Muhammad Habibur Rahman Mukul, *MS*[*+]
Senior Scientific Officer
Shamsunnaher, *MS*[*]
Scientific Officer
Rajesh Barua, *MS*[*]
Scientific Officer
Md Romel Biswash, *MS*[***]
Scientific Officer
Golam Sarwar Jahan, *MS*
Scientific Officer

Training Division
Md Islam Uddin Mollah, *PhD*
Chief Scientific Officer and Head
Md Shahadat Hossain, *PhD*
Principal Scientific Officer
Md Fazlul Islam, *PhD*
Senior Scientific Officer
Shahanaz Parveen, *PhD*
Senior Scientific Officer

BRRI RS, Barishal
Md Alamgir Hossain, *PhD*
Chief Scientific Officer and Head
(1 Jun 2007-29 Jan 2018)
Mohammod Hossain, *PhD*
Principal Scientific Officer and Head
(30 Jan 2018-30 Jun 2018)
Muhammad Sajidur Rahman, *MS*
Principal Scientific Officer
Sheikh Maniruzzaman, *MS*[*+]
Scientific Officer
Golam Sarwar Jahan, *MS*
Scientific Officer
Palash Kumar Kundu, *MS*
Scientific Officer
Hasibur Rahman Hera, *MS*
Scientific Officer
M A Salam Mollah, *Dip in Ag*
Farm Manager

BRRI RS, Bhanga
Mohammad Amir Hossain, *PhD*
Principal Scientific Officer and Head
Md Iftekhar Mahmud Akhand, *MS*
Senior Scientific Officer
Md Isfatuzzaman Bhuiyan, *MS*
Scientific Officer

BRRI RS, Cumilla
Helal Uddin Ahmed, *PhD*
Chief Scientific Officer and Head
Md Abdul Muttaleb, *PhD*
Principle Scientific Officer

Md Salim Mian, *PhD*
Senior Scientific Officer
Md Mamunur Rashid, *PhD*
Senior Scientific Officer
Md Adil, *MS*
Scientific Officer
Faruk Hossain Khan, *MS*
Scientific Officer

BRRI RS, Habiganj
Md Nazmul Bari, *PhD*
Senior Scientific Officer and Head
Fahmida Rahman, *PhD*
Senior Scientific Officer
ATM S Hossain, *PhD*
Senior Scientific Officer
M M Haque, *PhD*
Senior Scientific Officer
Md Abu Sayed, *PhD*
Scientific Officer
Md Romel Biswas, *MS**
Scientific Officer
Fahamida Akter, *MS*
Scientific Officer
Md Sajedur Rahman, *MS*
Scientific Officer

BRRI RS, Rajshahi
Aminul Islam, *PhD*
Principal Scientific Officer and Head
(From 18 April 2018)
Md Rafiqul Islam, *PhD***
Chief Scientific Officer (Current Charge) and Head
Shamima Akter, *PhD*
Senior Scientific Officer
Md Shafiqul Alam, *BSc Ag (Hons)*
Senior Scientific Officer
Md Harun-Ar-Rashid, *PhD*
Senior Scientific Officer
Anjuman Ara, *MS*
Scientific Officer
Fahamida Akter, *MS*
Scientific Officer

BRRI RS, Rangpur
Md Abu Bakar Siddique Sarker, *PhD*
Principal Scientific Officer and Head
Md Ruhul Amin Sarker, *PhD*
Senior Scientific Officer
Md Rokebul Hasan, *MS*
Senior Scientific Officer
Shila Pramanik, *MS**+*
Senior Scientific Officer
Mir Mehedi Hasan, *MS*
Scientific Officer
Md Ehasanul Haq, *MS*
Scientific Officer, TRB

BRRI RS, Satkhira
Md Ibrahim, *PhD*
Principal Scientific Officer and Head
Satyen Mondal, *PhD*
Senior Scientific Officer
Md Mamunur Rahman, *PhD*
Senior Scientific Officer
Sanjoy Kumer Debsharma, *MS*
Scientific Officer

BRRI RS, Sonagazi
Md Rafiqul Islam, *MSCAg*
Principal Scientific Officer and Head
Md Zakaria Ibne Baki, *MS*
Scientific Officer
Md Hasibur Rahaman Hera, *MS*
Scientific Officer
Md Mostofa Mahbub, *MS****
Scientific Officer
Md Niaz Morshed, *MS***
Scientific Officer

BRRI RS, Kushtia
Muhammad Sajidur Rahman, *MSc*
Principal Scientific Officer and Head
Md Mahbubur Rahman Dewan, *MS*+*
Senior Scientific Officer
Md Hannan Ali, *MS*
Scientific Officer
Md Eftekhar Uddin, *BSc Ag (Hons)*
Scientific Officer

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

Weather information

Introduction. 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 (°C), rainfall (mm), sunshine hours (hours/day) and solar radiation (Cal/cm^2/day) during the reporting period (July 2017-June 18) as recorded from BRRI headquarters and seven regional stations (BRRI RS) Rangpur, Barishal, Habiganj, Bhanga, Rajshahi, Sonagazi and Cumilla by Plant Physiology Division.

Temperature. The highest mean maximum temperature was recorded at Rajshahi (34.8°C) in June followed by Barishal (34.67°C) in March, Cumilla (34.52°C) in September, Bhanga (34.09°C), Gazipur and Habiganj (33.5°C), Sonagazi (32.22°C) in June and Rangpur (31.5°C) in August (Fig. 1). The mean maximum temperature was quite high during June in most of the stations. However, as usually the mean minimum temperature was the lowest in January for all the stations and among the the BRRI RSs the lowest was recorded in Rangpur (9.4°C).

Rainfall. An unusual rainfall pattern was observed in all the stations where rainstart from April. The maximum rainfall received by Gazipur (3700 mm) during the reporting period year and it was the lowest in Rajshahi (796 mm). Irrespective of station the highest rainfall occurs in August 2017 and no rainfall occurs in January 2018 (Fig. 2).

Solar radiation and solar hours. The monthly mean solar radiation was relatively low during the rainy season and also the months of December to February as usual. The highest mean solar radiation prevailed in Marchat, Gazipur, Rangpur, Barishal, Habiganj, in April at Bhanga and Sonagazi, in May at Cumilla and in June at Rajshahi. The mean solar radiation varied from 219 to 445 cal/cm^{2}per day for all the stations (Fig. 3). Solar hours per day was the lowest during the rainy season and the highest observed in November.

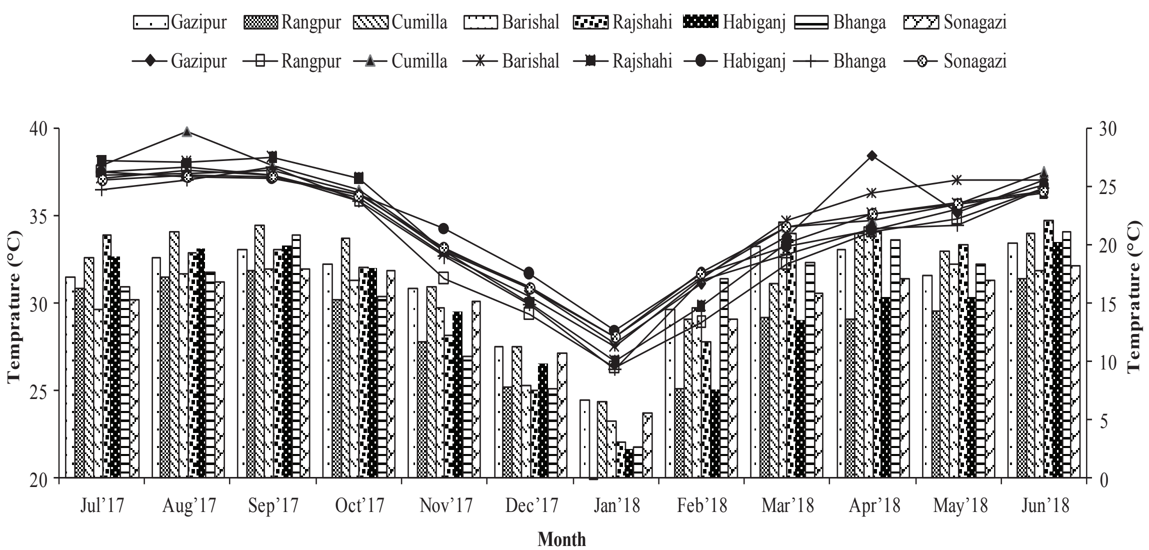


Fig. 1. Maximum and minimum temperature of BRRI HQ, Gazipur and seven rigional station of BRRI during the period of July 2017 to June 2018. (Bar graph in primary axis and line graph in secondary axis show Maximum and minimum temperature respectivly)

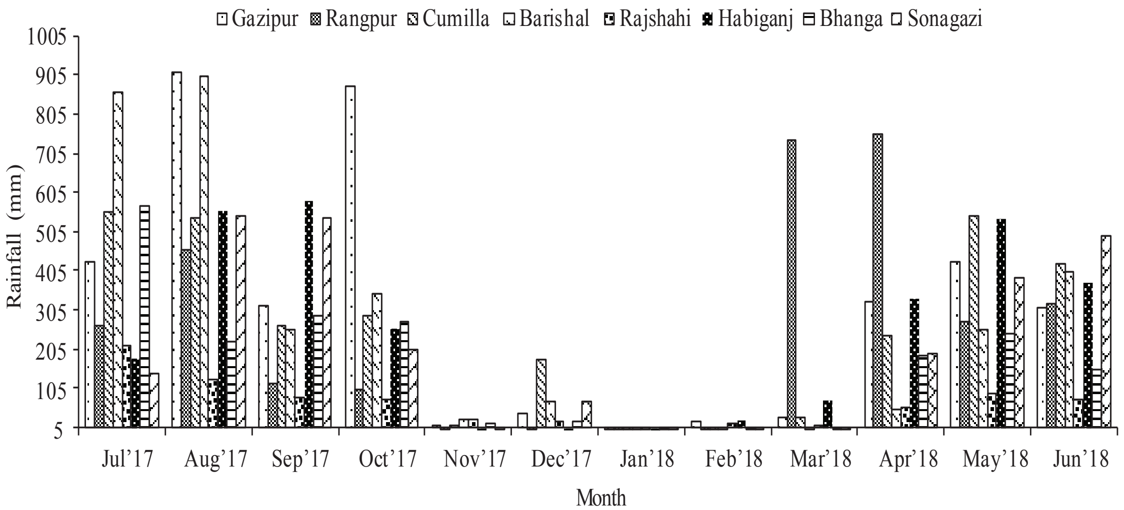


Fig.2. Rainfall data of BRRI headquater and Seven different station of BRRI during the period of July 2017 to June 2018.

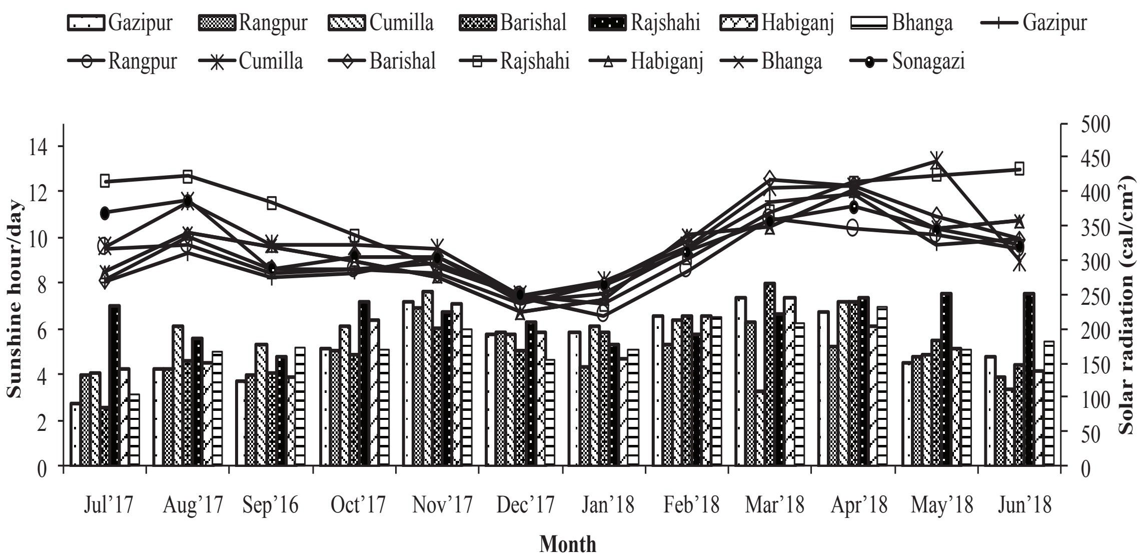


Fig. 3. Sunshine hour/day and solar radiation/day of BRRI HQ and seven regional station of BRRI during the period of July 2017 to June 2018. (Bar graph in primary axis and line graph in secondary axis show sunshine hour and solar radiation respectivly).

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

DTF	=	days to flowering
DWSR	=	Direct wet seeded rice
DWR	=	deepwater rice
ET	=	evapotranspiration
FS	=	foundation seed
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
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
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

For the development of rice varieties under different ecosystems 483 crosses were made, 258 crosses were confirmed and in pedigree nursery, 22,535 individual plants were selected from F_2 population based on phenotypic performance of each cross and in RGA, 2,35,773 individual plants were advanced from F_2 population. In pedigree nursery, 5,292 individual plants were selected from F_3 to F_7 generations based on phenotypic performance of each cross and 446 fixed lines were bulked. In RGA, 1,44,867 individual plants were advanced from F_3 to F_6 generations. From LST, 68 genotypes were selected based on yield and other agronomic performances. A total of 556 genotypes from observational trial (OT) and 399 advanced breeding lines were selected from yield trials (PYT, SYT, RYT, AYT and PVT). In confined field trial, one GR2E line namely IR112060 GR2-E:2-7-63-2-96 was selected and evaluated at five locations viz. Gazipur, Cumilla, Habiganj, Rajshahi, Barishal under government approval. A total of 35 germplasms from different biotic and abiotic screening nurseries were selected to use as parent in the breeding programme.

Four promising genotypes BR7358-5-3-2-1-HR2 (Com) for favourable Boro ecosystem, NERICA10-7-PL2-B for T. Aus, BR6848-3B-12 for upland Aus rice and BR7831-59-1-1-4-5-1-9-P1 for Zn enriched rice were evaluated by National Seed Board (NSB) field evaluation team and have been released as BRRI dhan81, BRRI dhan82, BRRI dhan83 and BRRI dhan84 respectively. BRRI dhan81 showed 0.6 t/ha higher yield than BRRI dhan28 and growth duration similar to BRRI dhan28 in Boro 2016-17. BRRI dhan82 produced 0.4 t/ha higher yield than BRRI dhan48 (4.3 t/ha). The growth duration of the variety was around five days earlier than BRRI dhan48 in T. Aus 2017-18. BRRI dhan83 showed 0.9 t/ha higher yield than the check variety BRRI dhan43 in upland Aus 2017-18. BRRI dhan84 showed similar yield and growth duration of BRRI dhan28 with high Zn (27.6 mg/kg) in Boro 2016-17. One genotype, BRRI dhan29-SC3-28-16-10-8-HR1 (Com) were evaluated by NSB team during Boro 2017-18 and showed 0.6 t/ha higher yield than the check variety BRRI dhan28 with similar growth duration to the check.

Upland rice (Aus). Upland rice (Aus) is synonymous to direct seeded rice (DSR-Aus) or broadcast Aus rice in Bangladesh that is important for growing short duration varieties (90-100 days) to increase cropping intensity for boosting up rice production. The main emphasis was given to develop varieties in combination of multiple traits such as quick seedling emergence and vigorous growth, short growth duration (90-95 days), tolerance to lodging, drought and pre-harvest sprouting; medium bold to medium slender grains and good eating quality. Forty-eight crosses were made using 32 parents, 39 crosses were confirmed as true hybrid, In total, 315 superior individual plants were selected from 16 F_2 population based on phenotypic performance of each cross. 1,079 progenies and 101 fixed lines were selected from pedigree nurseries. Seven entries were selected out of 28 from observational yield trial (OYT) based on growth duration, yield, homogeneity and other morpho-agronomic traits. Seven advanced lines were selected from preliminary yield trial (PYT#1 and PYT#2) for further evaluation. A PVT was conducted of BR6848-3B-12 and released as the variety BRRI dhan83. Table 1 presents agronomic features and grain characteristics of this variety.

Investigators: M Akhlasur Rahman, Nusrat Jahan and M Ruhul Quddus

Transplant Aus rice (T. Aus). The project aimed to develop short duration (105-110 days), high yield potential genotypes having tolerance to lodging and heat (high temperature) at reproductive phase, pre-harvest sprouting and good grain quality. In total, 13 crosses were made using 17 parents and 1893 F_1 seeds were obtained; eleven crosses were confirmed as true hybrid; 28,170 progenies from 29 crosses were advanced from F_2 generations through field RGA; 8,816 progenies from nine crosses were advanced from F_3 generations through field RGA, 113 progenies were selected from F_4 and F_6 generations in pedigree nurseries. Twelve genotypes were selected from 30 entries in observational trial (OT) and 11 advanced lines were selected from 16 entries in PYT on the basis of homogeneity in respect to plant height, phenotypic acceptability at vegetative and maturity stages and physicochemical properties. In regional yield trial (RYT), seven genotypes were

Table 1. Performance of the proposed variety BRRI dhan83, B. Aus 2017-18.

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-lose (%)
BRRI dhan83 (BR6848-3B-12)	104	104	3.83	53	2.6	LB	1.3	7.2	26.0
BRRI dhan43 (ck)	105	105	2.82	60	2.4	MB	1.5	7.3	26.7

*Mean of eight locations (BRRI HQ farm, Gazipur; Kapasia, Gazipur; Gopalganj; BRRI RS farm, Habiganj; Tetuia , Habiganj sadar; Tanore, Rajshahi; Kushtia sadar; Veramara, Kushtia).

selected based on growth duration, PAcp, grain quality and grain yield compared to popular cultivar BR26 and BRRI dhan48. In proposed variety trial (PVT), NERICA10-7-PL2-B was recommended by SCA team to release as a variety BRRI dhan82 for T. Aus season (Table 2).

Investigators: T L Aditya, M Khatun, M M Emam Ahmed and S Das

Improvement of rice for shallow flooded environment. The Major objectives were to develop high yielding (4.0-5.0 t/ha) rice varieties for 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. In total, 31 crosses were made using 22 parents and 266 F_1 seeds were produced from single cross and 410 F_1 seeds were produced from multiple cross. Ten crosses were confirmed out of 15 crosses as true hybrid. Totally 2,850 progenies were advanced through RGA. The performance of the breeding lines in yield trial was not satisfactory. Seed of the local cultivars and parental genotypes were increased and genetic purity was maintained.

Investigators: A S M Masuduzzaman, K M Iftekharuddaula, AKM Shalahuddin and T L Aditya

Development of rainfed low land rice. Efforts were made for the development of genotypes superior to standard varieties and adaptable to rainfed lowland environment in T. Aman season. In the reporting year, eight crosses were made, 14 crosses were confirmed and 784 plants were selected from 11 F_2 populations. From pedigree nursery 703 segregating progenies and 58 fixed lines were isolated. Fifty-four genotypes were selected from observational trial (OT), from IRLON three genotypes were selected, 46 genotypes were selected from PYT, 12 genotypes were selected from SYT, and three lines were selected from RYT and two lines were selected from ALART.

Investigators: M A Kader, T K Hore, M M Rahman and T L Aditya

Development of salt tolerant rice. The general objective of this project was to develop high yielding rice varieties tolerant to salt stress as salinity is one of the major constraints for the rainfed lowland and Boro rice ecosystem in southern coastal zone of Bangladesh. Having a focus on this content hotspot area for this experiment suited to the southern belt of Bangladesh and the water salinity for the reporting season T. Aman and Boro 2017-18 (Figs. 1 and 2).

In T. Aman, 20 crosses were made using 26 parents. A total of 18 F_1's for T. Aman season were confirmed and selected. The field rapid generation advance (FRGA) method was applied at BRRI farm, Gazipur and pedigree nursery yield trials were conducted in Khulna and Satkhira during T. Aman and Boro season. Figures 1 and 2 show water salinity levels of different experimental locations. Eleven F_2 population comprising 32,800 progenies were

Table 2. Performance of the variety BRRI dhan82 under proposed variety trial (PVT), T. Aus 2017-18.

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-lose (%)
BRRI dhan82 (NERICA10-7-PL2-B)	110	102	4.72	67.0	2.2	MB	1.5	7.6	27.0
BRRI dhan48 (ck)	106	107	4.30	68.0	2.6	MB	1.4	8.6	26.4

Mean of six locations (Rangpur; Sonagazi; Kushtia; Habiganj; Kapasia and BRRI farm, Gazipur).

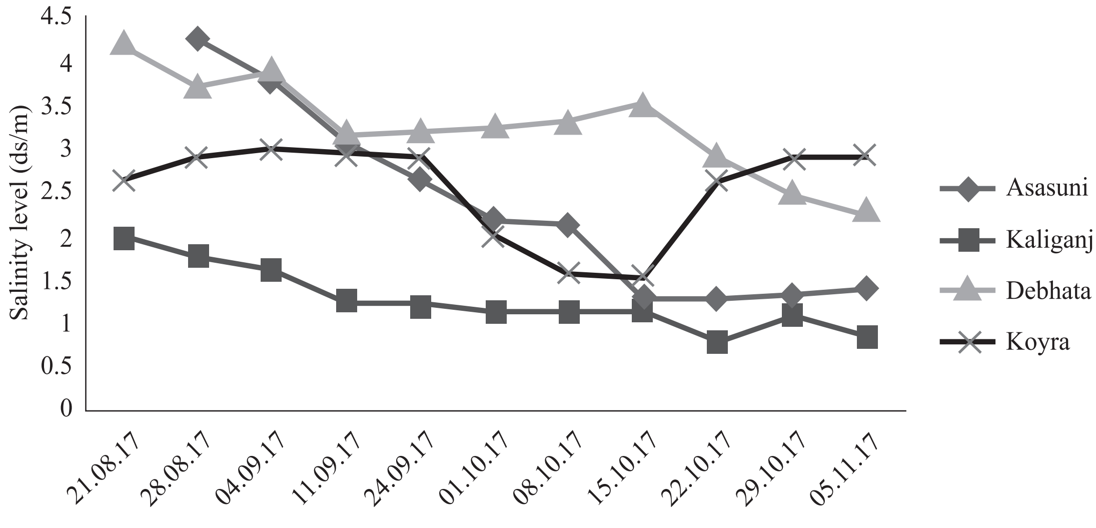


Fig. 1. Water salinity levels of different experimental location in Satkhira, T. Aman 2017-18.

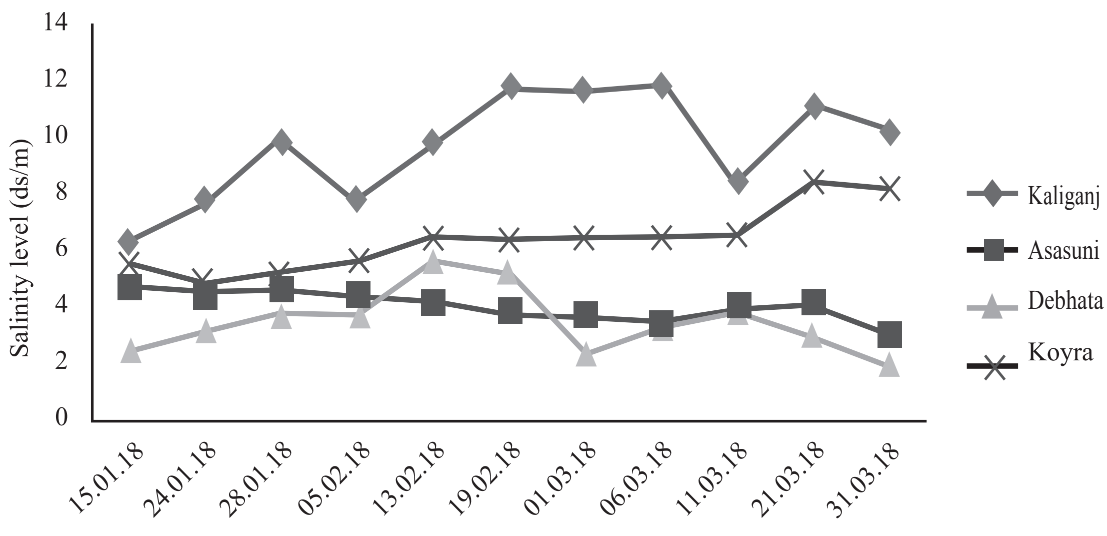


Fig. 2. Water salinity levels of different experimental location in Satkhira, Boro 2017-18.

grown in hotspot (Satkhira) in RGA method and 20,822 progenies were harvested as F_3. Segregating populations were grown followed by RGA method comprising T. Aman and Boro season.

Twelve crosses from F_2 yielded 25,250 progenies of F_3, 14,750 F_3 produced 13,500 F_4. Ten thousand one hundred fifty and 2,062 progenies of F_4 and F_5 were also grown to generate 9,900 and 2,050 progenies for the subsequent next generations respectively. Figure 3 shows the RGA field during the reporting year.

Nineteen genotypes (out of 87 genotypes) from BR lines and thirteen (out of 45 genotypes) were selected from IRSSTN in OYT. Seventeen entries (out of 26 genotypes) were selected from two PYT trials. Eight entries (out of 14 genotypes) were selected from SYT.

In PVS preference analysis BR9536-B-10-1-26 and BR8727-B-2-1-1 were the most preferred genotype.

In Boro season, 54 crosses were made. Ninety-one F_1s were confirmed, selected and registered in the BRRI cross list. Twenty-five F_2 populations were selected and bulked crosswise. A total of 269 progenies were selected from seven F_3 and 14 F_4 generations. Thirty-one entries out of 87 genotypes were selected from OYT. Thirty-three entries out of 127 genotypes were selected from STBN, OYT. Fourteen entries out of 34 genotypes were selected from PYT#1 and PYT#2. Three entries out of seven genotypes were selected from AYT. In PVS preference analysis, IR87870-6-1-1-1-1-B was the most preferred genotype out of 10 entries by the farmers over the locations.

Investigators: M Akhlasur Rahman, Nusrat Jahan, M Ruhul Quddus, S K Debshama, R Farzana and M Ibrahim

Development of premium quality rice (PQR), T. Aman. Efforts were made to develop aromatic and non-aromatic fine quality rice with national standards (Kalizira/Chinigura/Kataribhog/Radhunipagol type), anti-oxidant enriched (black and red) rice and photosensitive rice for domestic use and export. In T. Aman 2017-18, a total of 43 crosses (15 crosses for PQR, 12 for Anti-oxidant enriched rice and 16 for photosensitive rice) were made, two crosses were confirmed and 173 plants were selected from 15 F_2 populations. From pedigree nurseries, 163 progenies with 16 fixed lines were selected from 223 progenies of 39 crosses in F_3- F_7 populations. Thirty-four genotypes selected out of 108 from observational trial (OT) based on growth duration, yield and homogeneity in other morpho-agronomic traits. In PYT 25 genotypes were selected out of 32 genotypes. In SYT-1 and 2, a total of 18 genotypes were selected out of 26 genotypes having 0.6-1.1 t/ha yield advantage over check varieties Kalizira, Chinigura, Kataribhog, BRRI dhan34 and BRRI dhan37. Six materials were promoted to ALART from RYT, which had 1.0-1.5 t/ha yield advantage over the check varieties Kalizira, Chinigura, Kataribhog, BRRI dhan34 and BRRI dhan37. One promising advanced breeding line (BR8538-2-1-2) promoted to proposed variety trail (PVT) from ALART for NSB team evaluation in T. Aman 2018-19. The PVT line performed better in ALART having 3.72-4.55 t/ha grain yield with 10 days earlier growth duration than BRRI dhan34 (Table 3).

Investigators: T L Aditya, M R Islam and Anisar Rahman

Development of premium quality rice (PQR), Boro. Efforts were made to develop aromatic and non-aromatic fine quality rice with international (Basmati/Banglamati/Balam type) standards for domestic use and export. In Boro, a total of 13 crosses were made while seven crosses were confirmed and 161 plants were selected from 15 F_2 populations. From pedigree nursery 193 segregating progenies and 48 fixed lines were isolated. Thirty-six genotypes were selected from OT, eight genotypes were selected from PYT, six materials were selected from SYT and five genotypes were selected from RYT for promoting in ALART.

Investigators: M A Kader, T K Hore and T L Aditya

Development of rice varieties for favourable Boro environment. The major objective of the project was to develop improved genotypes with high yield potential (≥8.0 t/ha), earliness (130-135 days)

Fig. 3. Field RGA method at west byed, BRRI during the reporting period.

Table 3. Performance of the proposed line for premium quality rice, T. Aman 2017-18.

Genotype	Growth duration (day)	Plant height (cm)	Grain yield (t/ha)						Mean yield (t/ha)
			Raj	Ran	Dinj	Sher	Jash	Gaz	
BR8535-2-1-2	124	112	4.41	3.90	4.30	3.72	4.55	4.43	4.22
BRRI dhan34 (ck)	134	120	3.39	3.22	3.32	3.51	3.41	3.53	3.40

and acceptable grain quality for favourable irrigated ecosystem in Bangladesh. Thirty- one crosses were made. From RGA nurseries, 65,979 individual plants were selected from F_{2-} F_5 generations of 47 crosses. Seven of 43 genotypes were selected from OYT based on growth duration, yield and homogeneity in other morpho-agronomic traits. From PYT-1, 17 genotypes having 0.5-1.5 t/ha yield advantage over check varieties BRRI dhan28, BRRI dhan55 and BRRI dhan58. From PYT-2, 15 genotypes having 0.6-1.0 t/h yield advantage over check varieties BRRI dhan28, BRRI dhan29, BRRI dhan58 and BRRI dhan69. In AYT, in total three genotypes viz BR8904-28-1-2-2-2, BR9709-55-2-1 and KARJAT 5 had 0.8-0.9 t/ha yield advantage over the check varieties BRRI dhan28, BRRI dhan29 and BRRI dhan58. In RYT, four genotypes viz IR99061-B-B-7, IR09A235, IR14N126 and IR99056-B-B-15 had 0.7-1.3 t/ha yield advantage over the check varieties BRRI dhan28 and BRRI dhan58. In Boro 2016-17 the advanced line BR7358-5-3-2-1-HR2 (Com) was evaluated and showed similar yield and growth duration to BRRI dhan28 (Table 4). The advanced line was recommended as BRRI dhan81 by the National Technical Committee of the NSB meeting. In PVT, Boro 2017-18 the genotype BRRI dhan29-SC3-28-16-10-8-HR1 (Com) produced slightly higher yield than BRRI dhan28 with similar growth duration to BRRI dhan28 (Table 5). The promising low GI breeding line BRC266-5-1-2-1 waspromoted to PVT from ALART, Boro 2017-18.

Investigators: Md Anisuzzaman, M R A Sarker, Wazifa Afrin and T L Aditya

Development of cold tolerant rice. The major objective of the project is to develop high yielding (5.0-6.0 t/ha) rice varieties tolerant to cold stress at seedling (for northern district) and reproductive stage (*Haor* areas) to cold injury with short growth duration (130-135) days. Forty-five crosses were made. Eight crosses were confirmed as true F_1. In total, 60,795 individual plants were selected from 65 crosses of F_{2-} F_6 population by RGA system. Sixty-eight genotypes selected from Line Selection Stage (LST) based on phenotypic acceptability and disease infestation. Twenty-seven genotypes were selected from OYT based on growth duration, yield, and homogeneity in other morpho-agronomic traits and superiority in one or more traits over the check varieties. In PYT, seven genotypes viz. BR8910-B-6-3-CS1-5-CS2-P3-1-3, BR8909-B-12-2-CS1-4-CS2-P6-5-2, BR8909-B-12-2-CS1-4-CS2-P6-5-4, BR8909-B-12-2-CS1-4-CS2-P6-6-4, BR8909-B-12-2-CS1-4-CS2-P1-6-3, BR8909-B-12-2-CS1-4-CS2-P1-6-4 and BR8909-B-12-2-CS1-4-CS2-P2-1 had 0.7-0.9 t/ha yield advantage over the check varieties BRRI dhan28, BRRI dhan69 and BRRI dhan36. In AYT, two genotypes viz BR8562-11-2-6-1-1-2 and BR8564-32-1-1-6-1-1 had 0.5-0.7 t/ha yield advantage over the check varieties BRRI dhan28, BRRI dhan69 and BRRI dhan36. In *haor* areas, 58 genotypes were selected based on growth duration, yield and homogeneity in other morpho-agronomic traits.

Investigators: Md Anisuzzaman, M R A Sarker and Wazifa Afrin

Table 4. Performance of the variety BRRI dhan81 under PVT for favourable Boro rice, Boro 2016-17.

Designation	Plant height (cm)	Day to maturity	Grain yield (t/ha)*	Milling yield (%)	Head rice yield (%)	Grain characteristics			
						Length (mm)	L/B ratio	Size and shape	Amy-lose (%)
BRRI dhan81 (BR7358-5-3-2-1-HR2 (Com)	96	143	6.5	73.0	65.0	6.7	3.5	LS	25.0
BRRI dhan28 (ck)	95	142	5.9	71.0	68.0	5.8	3.2	MS	25.4

*Mean of nine locations.

Table 5. Performance of the proposed line in the PVT, Boro 2017-18.

Designation	Growth duration (day)	Yield (t/ha)	Milling yield (%)	Head rice yield (%)	Grain characteristics			
					Length (mm)	L/B ratio	Size and shape	Amy-lose (%)
BRRIdhan29-SC3-28-16-10-8-HR1(Com)	143	6.3	72	60	6.2	3.1	MS	25.0
BRRI dhan28 (ck)	141	6.1	72	60	6.3	3.1	MS	25.4

Development of zinc enriched rice. The project aims to develop high yielding rice varieties with improved nutritional quality in term of high zinc (Zn≥24 mg/kg) in polished grain as well as development of stress tolerant with zinc enriched rice varieties like submergence + zinc, drought + zinc, salinity + zinc with improved grain yield. The experiments were conducted in T. Aman and Boro seasons. Fifteen single and 30 pre breeding materials crosses were made in T. Aman, while at Boro season, 29 single crosses were made. A total of 11 crosses in T. Aman were selected and confirmed as true F_1 comparing with their parents and registered in the BR cross resister. A total of 15,510 individual progenies and 99 fixed lines in T. Aman season and 4,044 individual progenies and four fixed lines in Boro season were isolated from pedigree nurseries. From OT, 10 and 20 uniform genotypes were selected based on yield and growth duration considering significant difference in growth duration from the check variety during T. Aman and Boro seasons respectively. In T. Aman season, 10 genotypes from PYT-1 and PYT-2, 25 genotypes from SYT, three genotypes from RYT, one genotype from ALART were selected. In Boro season, five genotypes from PYT-1 and PYT-2, two genotypes from SYT and six genotypes from RYT were selected. The selected genotypes were better than the check varieties in terms of grain yield and other agronomic performances. A total of 150 kg and 700 kg nucleus seed of BRRI dhan62 and BRRI dhan72 were produced respectively in T. Aman season. On the other hand, Nucleus seed of BRRI dhan64, BRRI dhan74, BRRI dhan84 (Table 6) were produced 40 kg, 700 kg and 600 kg respectively in Boro season.

Investigators: M A Kader, Md Anisuzzaman and M M Haque

Disease resistant rice. Efforts were made for developing varieties resistant to bacterial blight (BB), rice tungro virus (RTV) and blast diseases. Seven crosses for BB and two for blast in T. Aman and 12 crosses for BB and nine for blast were made in Boro season. Eight crosses for BB and six for blast during T. Aman and nine crosses for BB and six for blast in Boro were confirmed as true F_1. A total of 29,988 progenies for BB and 16,170 progenies for blast were selected from RGA nursery (F_2 populations) in T. Aman season and 5,077 resistant progenies for BB and 3,425 progenies for blast were selected from F_2 populations of RGA nursery in Boro season. In total 7,546 progenies for BB and 2,002 progenies for blast were advanced from F_3 generations of RGA nursery in T. Aman season and 4,292 resistant progenies for BB and 1,113 progenies for blast were advanced from F_4 generations of RGA nursery in Boro season. One hundred seventy-three superior progenies for BB were selected from pedigree

Table 6. Performance of BRRI dhan84 under proposed variety trial, development of Zn enriched rice, Boro 2016-17.

Designation	Plant height (cm)*	Growth duration (day)*	Grain yield (t/ha)*	Grain characteristics					
				Head rice yield (%)	L/B ratio	Size and shape	Protein (%)	Amylose (%)	Zn content (mg/kg)
BRRI dhan84 (BR7831-59-1-1-4-5-1-9-P1)	96	141	6.57	53.0	3.3	LS	9.7	25.9	27.6
BRRI dhan28 (ck)	95	142	6.43	60.0	3.3	LS	8.9	27.5	15.3

*Mean of ten locations (Khulna; Dinajpur; Satkhira; Thakurgaon; Jashore; Rajshahi; Barishal; Rangpur; Habiganj and BRRI farm,Gazipur).

nursery (F_4-F_5 generations) were selected in T. Aman whereas, 805 progenies were selected for BB from F_3 generations and 166 superior progenies for BB were selected from F_4 generation during Boro season. Six genotypes for BB, eight for blast and three for RTV were selected from observational trial (OT) in T. Aman season while eight entries for BB during Boro season showed better yield potential and agronomic performance over the check varieties and tolerance to BB. In PYT#1, the advanced line BR10388-24-3-5 was selected based on growth duration, grain yield and BB score compared to the check varieties and two genotypes were selected for Blast from PYT#2 in T. Aman season and four genotypes for BB were selected in Boro season. From RYT trial, three genotypes in T. Aman season and two genotypes in Boro season were selected compared to yield, growth duration, BB resistance and better grain quality characters. The promising BB resistance line BR8938-19-4-3-1-1 was promoted to PVT from ALART, Boro 2017-18.
Investigators: M Khatun, M M Emam Ahmed and S Das

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). In T. Aman season, 34 crosses were made using 32 parents. Fifty-eight crosses were confirmed as true hybrid. A total of 275 superior individual plants were selected from 12 F_2 populations based on phenotypic performance of each cross. A total of 675 progenies and 78 fixed lines for BPH and GM were selected from pedigree nursery. Thirty lines from OYT and 16 lines from three PYTs were selected. Four lines out of nine from SYT were selected. Two genotypes were selected from RYT and it will advance to ALART for further evaluation. In Boro season, 35 crosses were made and 26 crosses were confirmed. From F_2 populations 353 progenies as well as 570 progenies for BPH were selected from pedigree nursery. Twelve genotypes from three PYT were selected showing moderately resistant (MR) to resistant (R) for BPH in Boro season. Two lines from RYT was selected out of nine entries for further trial. Besides this, eight F_3 population comprising 2,200 progenies were grown followed by RGA method and two thousand progenies were harvested as F_4.
Investigators: M Akhlasur Rahman, Nusrat Jahan and M Ruhul Quddus

Submergence and water stagnation tolerant rice varieties. The project was aimed to development of high yielding rice varieties tolerant to submergence (flash flooding) and medium stagnant water (MSW) stresses. Totally 1,416 F_1 seeds were obtained from single cross and 768 F_1 seeds were obtained from multiple cross. Panicles of 13,326 from F_3, 4,992 from F_4, 1,0238 from F_5, 6,753 from F_6 individuals were harvested at the time of maturity and preserved and processed with proper labels. The ranges of mortality percentage of different RGA generations are F_3 (6-71%), F_4 (32-53%), F_5 (30-68%) and F_6 (8-26%). In yield trial, 221 genotypes were tested out of which 77 genotypes were selected. In PYT, two experiments being conducted under controlled and natural flash flooding condition, IR13F450-5 showed the highest survival. PVS trials at Kulaghat, Mogholerhat, Darshona were submerged for 12, 8 and 11 days. Under flooded condition, average data over three locations (Mogholerhat, Kulaghat and Darshona) showed that IR13F441 produced the highest pooled grain yield 3.56 t/ha with 79% pooled survival percent. The pooled heritability obtained from grain yield of PVS trial conducted under flooding condition was 90%, indicating acceptable level of precision in this experiment.
Investigators: K M Iftekharuddaula, A K M Shalahuddin, Al Amin and T L Aditya

Drought tolerant rice. The project aimed at developing high yielding rice varieties tolerant to drought stresses at the reproductive stage in the rainfed lowland rice ecosystem in Bangladesh. In total, 10 crosses were made, 17 crosses were confirmed and 374 plants were selected from 28 F_2 populations. From pedigree nursery 715 segregating progenies and 58 fixed lines were isolated. In OYT, 32 genotypes performed better than the local and international check varieties in respect to yield under reproductive stage drought condition. From PYT, 16 genotypes were selected based on yield.
Investigators: M A Kader, T K Hore, M M Rahman and T L Aditya

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 transplanted under alternate wetting and drying (AWD) and aerobic conditions. In Boro

2017-18, 3,887 individuals of F_5 generation were advanced following single seed descent based field RGA technique. In OYT, 25 genotypes were selected out of 128 based on grain yield. Among them the highest grain yield was produced by IR16L1484 (7.38 t/ha) with growth duration 152 days. In comparison, BRRI dhan28, BRRI dhan29 and BRRI dhan58 produced 4.99, 5.84 and 5.99 t/ha grain yield with 144, 161 and 156 days growth duration, respectively. Whereas in AYT, the highest grain yield was produced by IR98814-11-1-3-1 (5.99 t/ha) with growth duration (154 days) which was around 1.0 ton higher than BRRI dhan58 with three days shorter growth duration.

Investigators: K M Iftekharuddaula, A K M Shalahuddin, Al Amin and T L Aditya

Green super rice (GSR). The project aims at developing of less input but high yield potential genotypes with tolerance to different stresses. In OYT, 122 advanced lines were selected from 360 tested entries based on earliness, grain quality and high yield potential for Boro season. One genotype was selected from SYT in T. Aman season. In SYT, two entries were selected for further yield trial. In RYT, two entries were selected from both T. Aman and Boro season. Two advanced genotypes HHZ12-SAL2-Y3-Y2 and HHZ5-DT20-DT2-DT1 were promoted to PVT from ALART, Boro 2017-18.

Investigators: H U Ahmed, M Khatun, M A Rahman, M M Emam Ahmed, F Akter, M R Islam, M Ibrahim, M Adil, M A Syed and S K Debsharma

Development of provitamin A enriched rice. The main objective of the project was to develop high yielding rice varieties with enhanced provitamin A content in polished rice grain. In T. Aman season, 7,718 BC_1F_1 seeds were produced from three backcrosses (BRRI dhan28*1/IR112062GR2E, BRRI dhan49*1/IR112062GR2E and BRRI dhan62*1/ IR112062GR2E). Totally 385 kg seeds of transgenic line (IR112060 GR2-E:2-7-63-2-96) produced as a seed multiplication activity for conducting MLT in next Boro 2017-18 season. In Boro season, totally, 2126 BC_2F_1 seeds were produced from three backcrosses (BRRI dhan28*2 /IR112062GR2E, BRRI dhan49*2/IR112062GR2E and BRRI dhan62*2/IR112062GR2E) and two plants were bulked. One GR2E line namely IR112060 GR2-E:2-7-63-2-96 was evaluated with standard check BRRI dhan29 in a confined field trial condition at five locations (Gazipur, Cumilla, Habiganj, Rajshahi, Barishal) under government approval. This line showed similar phenotypic appearance in almost all traits to non-transgenic BRRI dhan29. The crop condition of this entry was very uniform in phenotype particularly in flowering, plant height, and grain size and shape, with the majority of lines quite similar to the recipient parent in nearly all traits. Genotyping using event specific STS marker showed that all the transgenic plants were homozygous for transgene locus. The transgenic line yielded 7.08 t/ha to 9.11 t/ha with average of 8.0 ± 0.34 t/ha, while the non-transgenic BRRI dhan29 yielded 8.68 t/ha ranging from 7.33 to 9.56 t/ha. The total carotenoid content in milled rice after harvesting ranged from 13.7+17.4 mg/g with an average value of 16.0 ± 0.12 mg/g.

Investigators: M A Kader, T K Hore and M M Hoque

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. In T. Aman 2017, 67 genotypes were selected from International Rainfed Lowland Rice Observational Nursery (IRLON 2017), International Rice Soil Stress Tolerance Nursery (IRSSTN) - (Coastal salinity, wet season) 2017, International Rice Blast Nursery (IRBN), International Rice Bacterial Blight Nursery (IRBBN) and International Rice Brown Plant Hopper Nursery (IRBPHN). In Boro 2016, 47 genotypes were selected from International Irrigated Rice Observational Nursery (IIRON), International Rice Soil Stress Tolerance Nursery (IRSSTN) and International Rice Temperate Observational Nursery (IRTON).

Biotechnology Division

SUMMARY

Thirty-five experiments were conducted under eight projects during the reporting period. In total 21 doubled haploid plants were regenerated from hybrid anther of different crosses. A total of 99 homozygous lines were evaluated in different yield trials including OT, PYT, SYT, RYT, ALART and PVT. Among them, 31 promising lines were selected based on phenotypic appearance, growth duration and yield performance for further evaluation. In total, 890 EMS treated plants (M_1SC_2) were selected. A total of 39 plants and 18 homozygous lines were selected from 145 somaclonal lines of BRRI dhan48. Ten plants (SC3) and five homozygous lines were selected from 24 somaclonal lines of BRRI dhan47. On the other hand, 74 somaclonal antioxidant enriched plants were selected from 21 lines. Eighteen plants were regenerated through embryo rescue from four wide cross. In total 223 BC_2F_1 seeds were harvested from five wide crosses for future anther culture programme. Phenotypic data of QTL mapping F_2 population (BR11 × Sadamota acc. no. 1576) of 185 individual were collected. A total of 36 non-aromatic, one Basmati and 41 non-Basmati aromatic genotypes were differentiated using functional marker for fragrance. A total of 43 aromatic progenies were identified among 163 F_2 progenies of BRRI dhan28 and Kalizira by KOH. Bacterial blight (BB) gene pyramided three BRRI dhan29 rice lines having two BB resistant genes (*Xa4* and *Xa21*) were evaluated as ALART in Boro 2017-18. On the other hand, during Boro 2017-18, BB gene pyramided nine BRRI dhan28 rice lines having three BB resistant genes (*Xa4, xa13* and *Xa21*) were evaluated as PYT and five lines were selected for RYT. During T. Aman 2017, one advanced line BR(Bio)9786-BC2-132-1-3 was evaluated as PVT and the line was finally released as BRRI dhan87 for T. Aman season. On the other hand, during Boro 2017-18 another line, BR(Bio)9786-BC2-59-1-2 was evaluated as PVT with standard check BRRI dhan29. This line gave higher yield than BRRI dhan29 in all the locations tested. cDNA was synthesized from RNA of salt treated *P. coarctata* and amplified with vacuolar H+ ATPase (AVP1) primer and PCR product was clone into TOPO TA cloning vector. Positive clone were confirmed by colony PCR. Salt tolerant *GlyI and GlyII* genes were transferred into BRRI dhan29 through *Agrobacterium*-mediated genetic transformation and 12 putative transgenic BRRI dhan29 plants were obtained. Among them three plants were confirmed by both *GlyI* and *GlyII* gene specific primer. A total of 14 transgenic lines containing salt tolerant *PDH45* gene were evaluated against salinity at seedling stage in hydroponic culture and among them five transgenic lines were selected for reproductive stage characterization. Salt tolerant *AcMDHAR* gene containing MT24 rice genotype was crossed with five high yielding varieties to introgress *AcMDHAR* gene into them and 13 putative transgenic plants having *AcMDHAR* gene were confirmed by PCR analysis.

DEVELOPMENT OF DOUBLE HAPLOID RICE THROUGH ANTHER CULTURE

Low glycemic index (GI) rice variety

A total of 2,904 hybrid anthers of seven crosses were plated in N6 medium. The highest numbers (4) of calli were obtained from hybrid anthers of BR(Bio)9786-BC2-49-1-2/BR16 cross and three green plants (Table 1) were obtained. A total of 896 F_1 seeds were harvested from seven crosses for future anther culture programme. Ninety-one double haploid lines developed form six cross were grown in the field and among them six lines were bulked for further field evaluation.

Investigators. Jannatul Ferdous, Shahanaz Sultana, Md Enamul Hoque and Nilufar Yasmin Shaikh

Salt tolerant rice variety

A total of 19,332 hybrid anthers from six crosses were plated in M10 media. In total, 21 calli were obtained from them, but no green plants were regenerated. A total of 1,133 F_1 seeds were harvested from 11 crosses for future anther culture programme.

Investigators. Nilufar Yasmin Shaikh, Shahanaz Sultana, Md Enamul Hoque and Ripon Kumar Ray

Premium quality rice (Kalizira type) variety

A total of 8,774 hybrid anthers from three crosses were plated in M10 medium. In total 180 calli were obtained from them and only six green plants (Table 1) were regenerated from the cross of BRRI dhan38/Bashful (Fig. 1). In total, 503 F_1 seeds were harvested from seven crosses for future anther culture programme.

Table 1. Callus induction and green plantlet regeneration from hybrid anthers of different crosses.

Cross combination	No. of anther plated	No. of callus obtained	No. of green plant regenerated
	For low GI experiment		
BR(Bio)9786-BC2-49-1-2/BR16	933	4	3
	For premium quality experiment		
BRRI dhan38/ Bashful	1182	69	6
BRRI dhan38/ Kataribhog	3163	44	
BRRI dhan38/ Shakkorkhana	4429	67	
	For antioxidant enriched black rice experiment		
BRRI dhan28/Lansan	1250	26	4
BRRI dhan28/PadiKool	927	11	6
BRRI dhan28/PadiChelum	1102	3	2
Total	12986	224	21

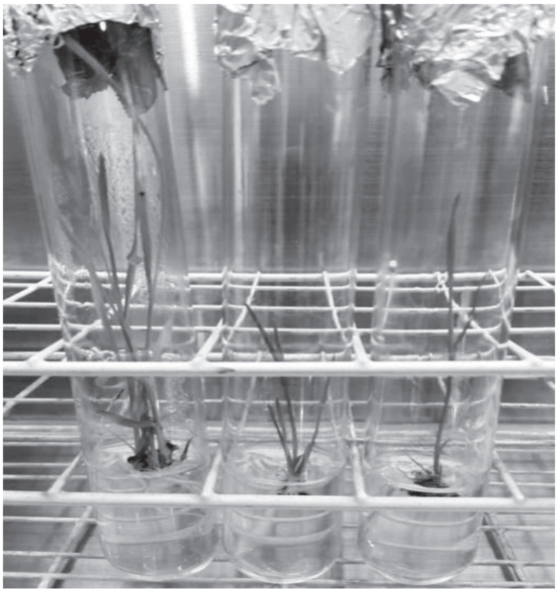


Fig. 1. *In vitro* regenerated plantlet from BRRI dhan38/ Bashful cross.

Aroma detection of 34 premium quality rice materials was done by a panel test. Among the tested sample, six local premium quality rice genotypes and 12 Kalizira type genotypes were found strongly aromatic. These aromatic materials will be used as parent in future anther culture programme for developing premium quality rice.

Investigators. Nilufar Yasmin Shaikh, Jannatul Ferdous, Md Enamul Hoque, Shahanaz Sultana and Ripon Kumar Ray

High yielding Aus rice variety

A total of 8,878 hybrid anthers of four crosses were plated in N6 and M10 media and 65 calli were obtained from them. The highest numbers of calli (24) were obtained from hybrid anthers of BRRI dhan48/Shaitta*² cross. No green plants were regenerated but 36 albino plants were obtained. In total 243 F_1 seeds were harvested for future anther culture programme.

Investigators. Shampa Dash Joya, Nilufar Yasmin Shaikh, Jannatul Ferdous and Md Enamul Hoque

Swarna type rice variety

A total of 13,543 hybrid anthers of 13 crosses were plated in N6 media. In total, 49 calli were obtained from six crosses in N_6 medium. No green plants were regenerated but six albino plants were regenerated. In total, 647 F_1 seeds were harvested from 11 crosses for future anther culture programme.

Investigators. Md Arafat Hossain, Shahanaz Sultana, Md Enamul and Jannatul Ferdous and Ripon Kumar Ray

Antioxidant enriched black rice variety

A total of 4,431 hybrid anthers from six crosses were plated in N6 media. In total, 12 green plants (Table 1 and Fig. 2) were regenerated. A total of 516 F_1 seeds were harvested from nine crosses for future anther culture programme.

Investigators. Jannatul Ferdous, Shahanaz Sultana and Md Enamul Hoque

DEVELOPMENT OF RICE VARIETY THROUGH SOMACLONAL VARIATION

Somaclone using EMS treated rice seed

During Aus and T. Aman 2017, a total of 88 and 299 EMS treated somaclonal plants (M_1SC_2) were selected from BR11 and BRRI dhan48 respectively.

Fig. 2. Double haploid plants from BRRI dhan28/Lansan cross.

On the other hand, during Boro 2017-18 season a total of 358, 61, 55 and 29 EMS treated somaclonal plants (M_1SC_2) were selected from BRRI dhan 86, BRRI dhan28, BRRI dhan29 and BR (BE)6158RWBC2, respectively.
Investigators. Shahanaz Sultana, Jannatul Ferdous Ripon Kumar Ray and Md Enamul Hoque

Somaclone of Aus variety
A total of 145 somaclone lines (SC_2) developed from BRRI dhan48 were evaluated during Aus season. From them, 39 plants and 18 homozygous lines were bulked for further evaluation.
Investigators. Shompa Das Joya, Jannatul Ferdous Md Enamul Hoque, Shahanaz Sultana and Ripon Kumar Ray

Somaclone of BRRI dhan47
In Boro 2017-18, sixteen BRRI dhan47 somaclonal lines (SC_3) were grown in observational trials (OT) with standard check BRRI dhan47. Among them five lines were selected. Moreover, 24 somaclonal lines (SC_3) developed from BRRI dhan47 were grown in pedigree line and among them 10 plants were selected.
Investigators. Nilufar Yasmin Shaikh, Jannatul Ferdous and Md Enamul Hoque, Shahanaz Sultana, Ripon Kumar Ray

Somaclone of antioxidant enriched black rice
SC_1 seeds were harvested from 40 SC_0 somaclonal plants developed from four black rice genotypes. On the other hand, 74 somaclonal plants (SC_2) were selected from 21 somaclonal lines.
Investigators. Jannatul Ferdous, Shahanaz Sultana and Md Enamul Hoque

DEVELOPMENT OF RICE VARIETY THROUGH WIDE HYBRIDIZATION

Wide hybridization followed by embryo rescue
In total, 18 plants were regenerated through embryo rescue technique from four wide cross (Table 2 and Fig. 3). Thirty-five F_1 seeds were collected from embryo rescued plants. These plants were backcrossed with high yielding rice variety. Moreover, BC_1F_3 seeds were harvested from BRRI dhan28/*O. nivara//*BRRI dhan28 cross.
Investigators. Nilufar Yasmin Shaikh, Shahanaz Sultana and Md Enamul Hoque

Wide hybridization followed by anther culture
BR11, BRRI dhan33, BRRI dhan39, BRRI dhan66 and BRRI dhan52 were used as recipient parent and two wild rices *O. rufipogon* (IRGC 103404) and *O. Officinalis* (IRGC 106174) were used as donor parent. Backcrossing was done for anther culture. In total, 223 BC_2F_1 seeds were harvested from five crosses for future anther culture programme.
Investigators. Ripon Kumar Ray, Janatul Ferdous, Nilufar Yasmin Shaikh, Shahanaz Sultana and Md Enamul Hoque

FIELD EVALUATION OF TISSUE CULTURE DERIVED LINES

Progeny selection
In T. Aman 2017, thirty-one homozygous lines were bulked from 183 pedigree lines for further evaluation. On the other hand, in Boro 2017-18, eighty-six plants were selected and 24 lines were bulked from 112 pedigree lines for further evaluation.
Investigators. Shahanaz Sultana, Jannatul Ferdous, Nilufar Yasmin Shaikh, Hisham Al-Rabbi, Md Arafat Hossain, Shampa Dash Joya and Md Enamul Hoque

Table 2. List of embryo rescued plants after wide hybridization.

Cross	No. of embryo rescued plants
BRRI dhan87/*O. glaberrima*	5 plants
BRRI dhan48/ *O. glaberrima*	7 plants
BR(Bio)8072-AC5-4-2-1-2-1/*O. glaberrima*	-
BRRI dhan86/*O. glaberrima*	-
BRRI dhan28/*O. glaberrima*	1 plants
BRRI dhan28/*O. nivara//* BRRI dhan28	5 plants
Total	18

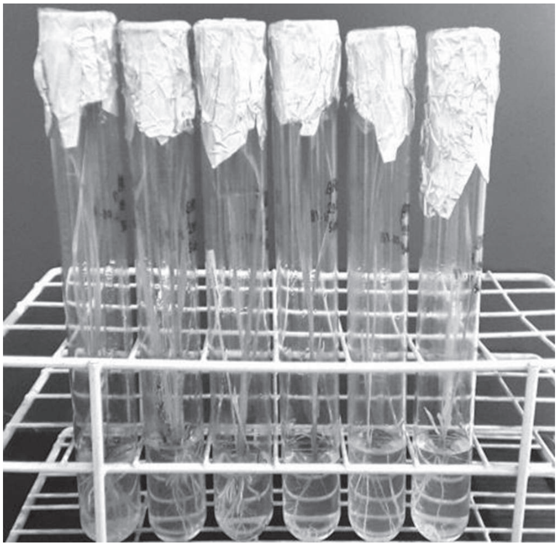


Fig. 3. Embryo rescued plantlets in nutrition solution for hardening.

Observational trial (OT)

In T. Aman 2017, forty-nine anther culture derived doubled haploid lines were evaluated in two OTs with standard checks to select agronomically desirable and high yield potential materials. Among them, 17 lines were selected depending on the duration and comparable yield with checks for further evaluation.

In Boro 2017-18, ten anther culture derived doubled haploid lines were evaluated in one OT with standard checks to select agronomically desirable and high yield potential materials. Among them four lines were selected depending on the duration and comparable yield with the checks for further evaluation.

Investigators: Jannatul Ferdous, Shahanaz Sultana, Nilufar Yasmin Shaikh, Hisham Al-Rabbi, Md Arafat Hossain, Shampa Dash Joya and Md Enamul Hoque

Preliminary yield trial (PYT)

During T. Aman 2017, six doubled haploid lines were evaluated with standard checks in a PYT, but none was selected.

Investigators: Jannatul Ferdous, Shahanaz Sultana, Nilufar Yasmin Shaikh, Hisham Al-Rabbi, Md Arafat Hossain, Shampa Dash Joya and Md Enamul Hoque

Regional yield trials (RYT)

In T. Aman 2017, four doubled haploid lines were evaluated at nine regional stations and among them two were selected for ALART.

Investigators. Jannatul Ferdous, Shahanaz Sultana, Nilufar Yasmin Shaikh, Hisham Al-Rabbi, Md Arafat Hossain and Md Enamul Hoque and Concernned regional Station scientists.

ALLELE MINING

Identification of yield enhancement QTLs

In the reporting period, advanced materials developed from yield enhancement QTLs were evaluated as PYT, SYT, RYT, ALART and PVT. In Aman 2017, three lines developed from QTL mapping population of BRRI dhan29*^{3}/*O. rufipogon* (IRGC 103404) were evaluated as PYT and all the three lines were selected. In Boro 2017-18, eight advanced lines were tested along with standard checks in two SYTs. Among them two lines were selected for RYT (Table 3). In Aus 2017, four advanced lines were evaluated at nine regional station and one line was selected ALART (Table 4). In Boro 2017-18 five lines were evaluated in an ALART with standard checks and one out of them was selected for PVT. In T. Aman 2017, one material BR(Bio)9786-BC2-132-1-3 developed for yield enhancement QTLs was evaluated as PVT at ten locations of the country and the line was finally released as a new variety, BRRI dhan87 for T. Aman season. In Boro 2017-18, another line BR(Bio)9786-BC2-59-1-2 (Table 5 and Fig. 4) was evaluated as PVT at ten locations of the country with standard check BRRI dhan29. This line gave higher yield than BRRI dhan29 in the all 10 locations and applied to NSB for releasing this line as a new rice varity for Boro season.

Investigators. Md Enamul Hoque, Jannatul Ferdous, Shahanaz Sultana, Nilufar Yasmin Shaikh, Hisham Al-Rabbi and Md Arafat Hossain

Identification of QTLs for salinity tolerance both at seedling and reproductive stage

In T. Aman 2017, seven lines were evaluated with standard checks in a PYT and two out of them were selected. In Boro 2017-18, seven lines were evaluated with standard checks in a SYT and two out of them were selected (Table 6). In the other

Table 3. Agronomic characteristics of three lines developed from QTL mapping population of BRRI dhan29*[3]/ *O. rufipogon* (IRGC 103404) cross during Boro 2016-17 (SYT).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)9786-BC2-80-1-1	106	160	7.96
BR(Bio)9786-BC2-65-1-1	106	159	8.65*
BR(Bio)9786-BC2-161-1-1	104	160	8.47*
BRRI dhan58	99	158	7.79
BRRI dhan29	101	166	8.71

Three lines were evaluated and two lines were selected. *=Selected.

Table 4. Agronomic characteristics of four lines developed from QTL mapping population of BRRI dhan28*[3]/ *O. rufipogon* (IRGC 105890) cross during Aus 2017 (RYT).

Designation	Plant height	Growth duration (day)	Yield (ton/ha)						
			Com	Son	Kus	Raj	Ran	Gaz	Avg
BR(Bio)9785-BC2-19-3-1	109	109	2.96	3.03	2.90	3.10	2.00	3.86	2.97
BR(Bio)9785-BC2-19-3-5	101	111	4.17	3.23	2.65	3.50	2.70	4.08	3.39
BR(Bio)9787-BC2-63-2-4	104	110	4.28	4.43	3.09	3.80	4.60	4.88	4.18*
BR(Bio)9785-BC2-120-2-1	110	109	3.99	3.14	3.67	3.70	3.00	4.80	3.72
BRRI dhan48(ck)	107	110	4.78	3.19	4.25	4.40	3.70	4.18	4.08

Table 5. Performance of the proposed line in PVT, Boro-2017-18.

Designation	Plant height (cm)*	Growth duration (day)*	Grain yield (t/ha)*	Grain characteristics						
				Head rice yield (%)	L-B ratio	Size and shape	Elongation ratio (ER)	Imbibition ratio (IR)	Protein (%)	Amylose (%)
BR(Bio)9786-BC2-59-1-2 (Proposed variety)	104	157	8.15	62.4	2.9	MB	1.4	3.5	7.0	28.5
BRRI dhan29 (Check variety)	101	160	7.45	60.0	3.1	MS	1.3	3.9	7.1	29.4

*Mean of ten locations.

Fig. 4. Field view of advanced line BR(Bio)9786-BC2-59-1-2 in PVT during Boro 2017-18 season.

hand, four lines developed from QTL mapping population of BRRI dhan29/IR4630-22-2-5-1-3 cross, were evaluated with standard checks in a RYT during Boro 2016-17 season (Table 7) and one line was selected from them for ALART.

Investigators. Jannatul Ferdous, Shahanaz Sultana, Md Arafat Hossain and Md Enamul Hoque

Identification of QTLs for taller seedling height

QTL mapping population was developed by crossing between BR11 and Shadamota (acc.no.1576). F_2 population (BR11 × Sadamota acc. no. 1576) were grown in T. Aman 2017 season. Phenotypic data were collected from F_2 population consisting of 185 individuals. Leaf samples were collected from F_2 population for DNA extraction.

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

Validation of a simple functional marker for fragrance in non-Basmati fragrant rice varieties

A total of 36 non-aromatic, one Basmati and 41 non-Basmati aromatic genotypes were differentiated using functional marker for fragrance. Different accessions of Kalijira and Chinigura were screened against functional marker (Fig. 5). Aroma detection was carried out with 163 F_2 progenies of BRRI

Table 6. Agronomic characteristics of seven lines developed from QTL mapping population of BRRI dhan29/IR4630-22-2-5-1-3 cross during Boro 2017-18 (SYT).

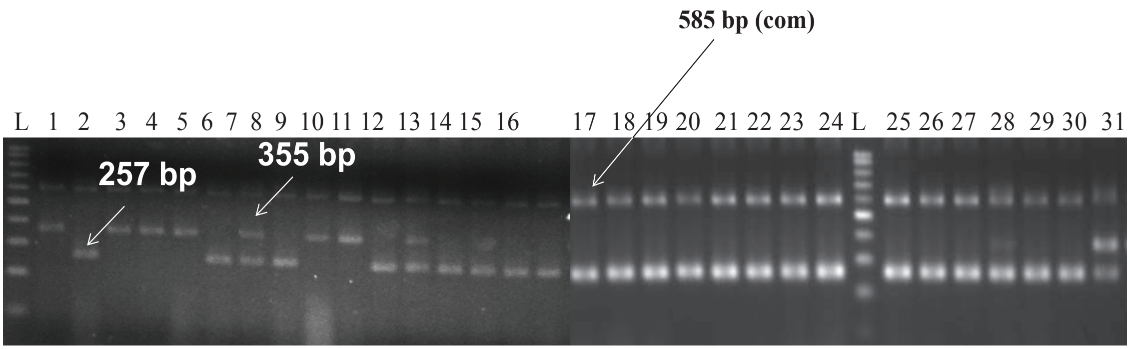
Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)9777-84-4-1-1	102	139	6.52
BR(Bio)9777-116-12-2-2	102	149	7.22
BR(Bio)9777-116-12-2-4	112	151	8.73*
BR(Bio)9777-117-4-5-3	107	153	7.98
BR(Bio)9777-123-4-6-1	106	154	8.25
BR(Bio)9777-116-12-2-5	109	150	8.81*
BR(Bio)9777-124-1-1-2	106	137	6.94
BRRI dhan58 (ck)	97	154	7.54

Seven lines were evaluated and two lines were selected.*=Selected.

Table 7. Agronomic characteristics of seven lines developed from QTL mapping population of BRRI dhan29/IR4630-22-2-5-1-3 cross during Boro 2017-18 (RYT).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)										
			Bha	Cum	Ran	Hab	Sat	Kus	Raj	Son	Bor	Gaz	Avg
BR(Bio)9777-26-4-3		159	5.94	8.49	5.93	7.21	4.85	7.58	6.22	6.58	8.64	7.38	6.88*
BR(Bio)9777-106-7-4		157	5.30	7.60	5.75	6.60	4.44	6.43	5.06	6.58	7.1	5.95	6.08
BR(Bio)9777-113-12-5		160	5.25	8.05	6.02	6.74	5.78	6.78	6.81	6.43	7.6	6.88	6.63
BR(Bio)9777-118-6-4		159	5.92	8.50	5.98	6.79	4.91	7.38	6.98	5.31	7.8	6.95	6.65*
BRRI dhan58 (ck)		156	5.23	6.26	6.08	6.40	4.63	6.73	5.27	6.58	7.07	5.33	5.95

Four lines were evaluated and two lines were selected. *=Selected.



Lane L= Marker 100bp, lane 1-6 –Chinigura, 7-31 –Kalizira accessions

Fig. 5. Validation of marker for fragrance gene (BADH2).

dhan28 and Kalizira cross by panel test. Among them, aroma was detected in 43 materials.

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

GENE PYRAMIDING

Gene pyramiding for resistance to bacterial blight in rice

Bacterial blight (BB) gene pyramided in three BRRI dhan29 rice lines having two BB resistant genes (*Xa4* and *Xa21*) were evaluated as ALART in Boro 2017-18 with standard checks. On the other hand, in Boro 2017-18, BB gene pyramided nine BRRI dhan28 rice lines having three BB resistant genes (*Xa4, xa13* and *Xa21*) were evaluated as PYT with standard checks. Depending on the yield and growth duration five lines were selected for RYT (Table 8 and Fig. 6).

Investigators. Jannatul Ferdous, Shahanaz Sultana, Ripon Kumar Ray and Md Enamul Hoque

Table 8. Agronomic characteristics of bacterial blight (BB) gene pyramided BRRI dhan28 lines having three BB resistant (*Xa4, Xa13, Xa21*) in Boro 2017-18 (PYT).

Designation	PH (cm)	GD (day)	BB score	Amylose (%)	Yield (t/ha)
BR(Bio)11447-1-28-1-1	103	142	1	23.5	5.96
BR(Bio)11447-1-28-4-6	107	141	1	25.5	5.83*
BR(Bio)11447-1-28-6-1	100	144	3	25.7	6.29
BR(Bio)11447-1-28-8-4	93	141	1	26.0	5.81
BR(Bio)11447-1-28-12-3	106	141	1		6.69*
BR(Bio)11447-1-28-14-1	112	141	1	25.0	6.35*
BR(Bio)11447-1-28-14-3	108	139	1	26.7	6.49*
BR(Bio)11447-3-10-7-1	108	137	1	26.0	6.53*
BR(Bio)11447-2-2-4-1	111	143	1	25.5	5.78
BRRI dhan28(Std. ck)	107	141	7	26.0	6.19
Purbachi (Sus. ck)	96	147	7	24.0	5.43
IRBB60 (Res. ck)	76	156	1	16.0	6.08

Nine lines were evaluated and five line were selected. *=Selected.

Fig. 6. Field performance of bacterial blight (BB) resistant gene pyramided BRRI dhan28 lines (PYT-1).

GENE CLONING

Isolation and cloning of salt and drought tolerant gene

cDNA was synthesized from RNA of treated *P. coarctata* and amplified with vascular H+ ATPase (AVP1) primer followed by sequence analysis. Then PCR product was clone into TOPO TA cloning vector. Positive clone were confirmed by colony PCR (Fig. 7).

Investigators. Shahanaz Sultana, Jannatul Ferdous, Md Enamul Hoque and Dr. Mahmuda

RICE GENETIC ENGINEERING

Development of salt tolerant transgenic rice

BRRI dhan29 was transformed with salt tolerant genes (*GlyI and GlyII*) and 12 putative transgenic BRRI dhan29 plants were obtained. Three plants were confirmed by both *GlyI* and *GlyII* gene specific primer.

Investigators. Shahanaz Sultana, Jannatul Ferdous, Md Enamul Hoque, Ripon Kumar Ray, Shompa Das Joya and Dr. Mahmuda

***PDH45* transgenic lines tested for salinity tolerance at seedling stage**

To characterize high-yielding rice varieties containing salt tolerant *PDH45* gene at seedling stage in a contained facility, 14 transgenic lines along with respective parents were tested for seedling stage salinity tolerance in the hydroponic culture (Fig. 7). IR58443 and IR154 were used as tolerant and sensitive check respectively. Considering their salinity tolerance at seedling stage, five transgenic

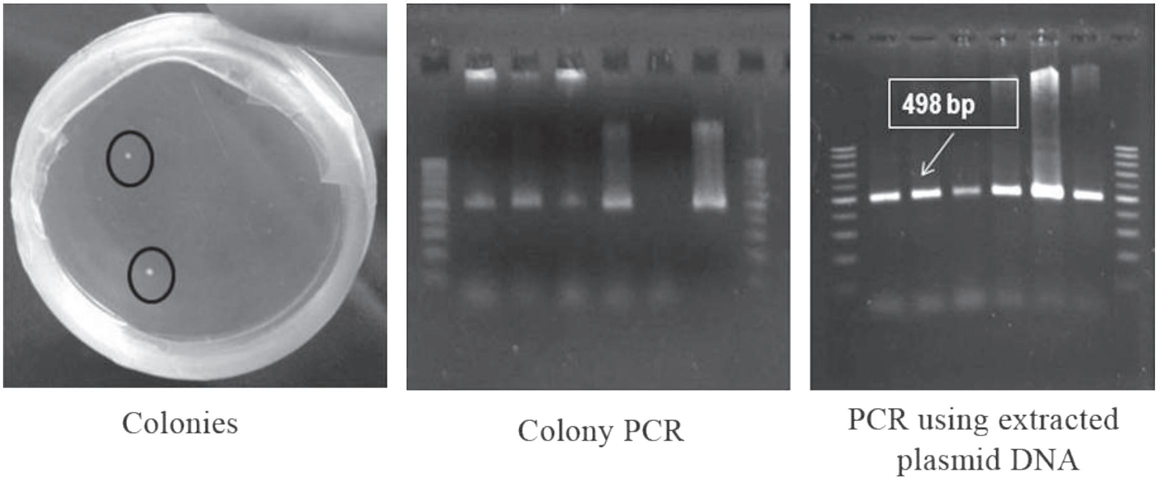


Fig. 7. PCR confirmation of salt tolerant gene AVP1 containing clone.

lines *PDH_BR47-1*, *PDH_BR47-2*, *PDH_BR29-2, PDH_BR28-3* and *PDH_BR36-2* were selected for reproductive stage characterization.

Investigators. Shahanaz Sultana, Md Enamul Hoque, Md. Shazzadur Rahman and Zeba Islam Sonaj

Introgression of salt tolerant mangrove gene

Salt tolerant *AcMDHAR (*from mangrove plant) gene containing MT24 rice genotype was crossed with BRRI dhan28, BRRI dhan29, BRRI dhan67, BRRI dhan86 and BINA dhan-10 to introgress *AcMDHAR* gene into them. Twenty-one plants from these cross were tested with *AcMDHAR* gene specific primer. Among them 13 plants were confirmed by PCR with gene specific primer.

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

Genetic Resources and Seed Division

SUMMARY

In total, 161 rice germplasm were collected from different districts including hilly areas of Bangladesh during 2017-18. Forty-nine germplasm accessions in T. Aus, 55 in T. Aman and 56 in Boro seasons were characterized against 53 morpho-agronomic traits. Rejuvenation of 2,040 accessions of which 591 accessions in Aus, 990 accessions in T. Aman 2017 and 459 accessions in Boro 2017-18 were completed. Rejuvenated Aus with T. Aman 2017 accessions were processed and stored in short term storage. Similarly, 335 and 105 accessions in Aus and 234 and 371 accessions in T. Aman were stored in medium and long term storages, respectively during the reporting year. Apart from this, 36 new germplasm were registered as new accessions (from accession number 8201 to 8236) in Genebank. Besides, 1,137 samples of rice germplasm and BRRI developed varieties were supplied to different users.

Ninety-five BRRI developed and recommended rice varieties were maintained and nucleus seeds of 63 varieties were produced. In total, 151.93 tons of breeder seed of which 37.20 tons from 42 varieties in T. Aman and 114.73 tons from 21 varieties in Boro seasons were produced during 2017-18. Among the total production, 140.33 tons were produced by GOB fund and 11.60 tons were produced by project fund *viz.* HarvestPlus, Transforming Rice Breeding (TRB) and Stress-Tolerant Rice for Africa and South Asia (STRASA). At the same time, 125.37 tons of breeder seed of which 93.47 tons from 21 varieties in Boro, 5.19 tons from 12 varieties in Aus and 26.71 tons from 36 varieties in T. Aman were distributed among the 879 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 161 rice germplasm of which 31 in Aus, 32 *Jhum* rice from hilly area, 91 in T. Aman and seven in Boro seasons were collected from different districts 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 single row of 5.4 m long per accession with a spacing of 20 × 20 cm 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 2,040 germplasm of which 591 accessions in Aus, 990 accessions in T. Aman 2017 and 459 accessions in Boro 2017-18 were rejuvenated in field for getting fresh seed and on average 500 g of seeds were produced per accession.

Morphological characterization of germplasm accessions. Three experiments were conducted to characterize rice germplasm using 53 morpho-agronomic traits. The experiments were conducted in BRRI HQ, Gazipur using a single row of 5.4 m long for each entry/accession with a spacing of 25 × 20 cm between rows and plants respectively. A total of 160 genotypes of which 49 in T. Aus, 55 in T. Aman and 56 in Boro were used for characterization. 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.

In Aus 2017, two genotypes had short (<100 days), 34 had medium (100-120 days) and 13 had long (>120 days) growth duration (Table 1). Eleven genotypes had short (<90 cm) and 38 genotypes were found with medium (90-125) plant height. Six genotypes were found with long (25.01-30 cm), 27 with medium (20-25 cm) and the rest 16 with short (<20) panicle length. Maximum 40 genotypes possessed intermediate (6-10) type effective tiller, whereas seven genotypes possessed low (<6) and two had many (>10) number of effective tillers. However, three genotypes possessed many (>110) number of filled grain per panicle. For 1000-grain weight (TGW), 19 genotypes had low (16-19), 16 with medium (20-23), 11 with high (24-27) and three with very high (>27) grain weight. Forty-eight genotypes had more than 10 g yield per hill.

The shortest growth duration (86 days) observed in Sada Dubjat Sona and the longest (135 days) in Gunda Dhan (Table 1). The shortest plant height (53.2 cm) was observed in Binni Longmona and the longest (123.2 cm) in Maloti Dhan. Again, the longest panicle (29.8 cm), the highest effective tillers (14) and the highest filled grain per panicle (139) were observed in Nerica-10, Tongte and Galong, respectively. Besides, the highest TGW (28.3 g) was observed in Sada Binni. Again, the highest yield per hill was observed in Boda Kushum (21.3 g).

In T. Aman 2017, six genotypes had short (<120 days) growth duration (Table 2). Six entry was found with long (26-30 cm) and 38 with 21-25 cm panicle length. Sixteen genotypes possessed many (>15) number of effective tillers. TGW of nine genotypes was found very low (≤15 g), eight was very high (>27). Twenty-three genotypes had higher (>10 g) yield/hill. Jira Sail gave the shortest growth duration (99 days). Mondol was the shortest plant (76.4 cm) and Gurunac the longest (134.2). Kela Mota possessed the longest panicle length (28.6 cm) and Monor possessed the highest number of tillers (20.2). The highest number of filled grain per panicle (171.8) was observed in Khama. Khoiya Mota had the highest (31.5 g) TGW and Satkata Binni the highest yield per hill (27.73).

Characterization of germplasm to discover new trait for changing climate. A total of 203 rice accessions were characterized with 53 morpho-agronomic traits (both quantitative and qualitative characters) at Genetic Resources and Seed Division using the Rice Germplasm Descriptors and Evaluation Form and UPOV convention. After detailed analysis, 20 superior germplasm were selected for better performance (Table 3).

Except Chini Atop, all of the selected varieties have modern structure ie phenotypic acceptance range is from 3 to 5. Chini Atop had the highest filled grain per panicle and lowest thousand grain weight which may be used for variety development. All of the varieties had short to medium duration considering days to flowering and maturity. Culm diameter is an alternative measure for lodging resistance and most of the selected germplasm got higher culm diameter. Most important is the filled grain number per panicle, which is higher in all of the selected germplasm with minimum unfilled grain (Table 3). Panicle length is also higher in most of the cases. Table 3 presents the maximum, minimum and mean value of the studied parameters for 203 germplasm. These superior germplasm against different traits need to be confirmed by another year characterization for further improvement by Plant Physiology and Plant Breeding Division.

Characterization of rice germplasm from saline areas of Bangladesh. Forty-five rice germplasm collected from the saline affected area and conserved in BRRI Genebank, were studied in both non-saline and saline areas, simultaneously in Boro 2017-18. The 45-day-old seedlings were transplanted from seedbed and hence they grown with proper management. Same procedure was followed both in the saline and non-saline areas. But in the saline area, among all germinated germplasm seven could not be transplanted in the main field due to their death at 5.8 ds/m. After three weeks all the plants were died due to high salinity and salinity ranged up to 18.2 ds/m.

Germplasm processing, registration and storage. In total 2,626 germplasm were processed to conserve with respective accession number in different storages of Genebank. The seeds were cleaned and dried with a seed moisture content of less than 9%.

In details, 591 accessions in Aus and 990 in T. Aman 2017-18 were processed and stored in short term storage. Similarly, 335 and 105 accessions in Aus and 234 and 371 accessions in T. Aman were stored in medium and long term storages respectively. On the other hand, 36 germplasm were registered in accession book as new accession (from acc. 8201 to 8236).

Viability testing, periodic evaluation and routine monitoring of stored germplasm. One hundred and ten accessions in Aus, 120 in T. Aman and 100 in Boro seasons were checked randomly for viability (germination %) test in short term storage during 2017-18. Five varieties namely Dharial (Acc. 649), Hashikalmi (3575), Purbachi (6207), Nizersail (1229) and Patnai-23 (52) were used as testers in the medium and long term storages and their viability were measured on six month interval each year usually in October and March to predict the viability status of germplasm in the respective storages. The seed viability was also monitored before storage of rice germplasm in the Genebank.

Among the randomly selected 330 stored germplasm, 217 had viability between 80-90% and 60 had above 90%. The germplasm accessions

Table 1. Some important features of characterized germplasm in T. Aus 2017.

Growth duration (day)		Plant height (cm)		Panicle length (cm)		No. of tiller		No. of effective 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
<100	2	<90	11	<20	16	<10	23	<6	7	<70	16	<15	0	<5	0
100-120	34	90-125	38	20-25	27	11-15	26	6-10	40	70-110	30	16-19	19	5-10	1
>120	13	>125	0	25.01-30	6	>15	0	>10	2	>110	3	20-23	16	>10	48
				>30	0							24-27	11		
												>27	3		
Shortest (86)	Sada Dubjatsona	Shortest (53.2)	Binni Longmona	Shortest (17)	Gunda Dhan	Lowest (5)	Memablack Binni Dhan	Lowest (4)	Memablack Binni Dhan	Lowest (31)	Koborok Dhan	Lowest (16.2)	Badiya Dhan	Lowest (9.9)	Chaparang Binni
Longest (135)	Gunda Dhan	Longest (123.2)	Maloti Dhan	Longest (29.8)	Nerica-10	Highest (14)	Tongte	Highest (11)	Tongte	Highest (139)	Galong	Highest (28.3)	Sada Binni	Highest (21.3)	Boda Kushum
Mean	113	98.7		21.7		10		8		77		21.6		15.0	
Std. Dev.	11.68	13.79		2.78		1.99		1.57		20.76		3.32		2.85	
CV	0.10	0.14		0.13		0.21		0.20		0.27		0.15		0.19	
LSD (5%)	3.24	3.86		0.78		0.56		0.44		5.81		0.93		0.80	

Table 2. Some important features of characterized germplasm in T. Aman 2017.

Growth duration (day)		Plant height (cm)		Panicle length (cm)		No. of tiller		No. of Filled grain/ panicle		Days to 50% flowering		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
<120	6	<110	24	≤20	11	<10	6	<100	42	<100	32	≤15	9	<5	5
120-130	32	110-130	27	21-25	38	10-15	33	100-150	10	110-125	20	16-19	13	5-10	27
>130	17	>130	4	26-30	6	>15	16	>150	3	>125	3	20-23	8	>10	23
				>30	0							24-27	17		
												>27	8		
Shortest (99)	Jira Sail (7591)	Shortest (76.4)	Mondol (7587)	Shortest (14.8)	Katlahi (7562)	Lowest (6)	Vaolo (7564)	Lowest (34.2)	Munsi Biruin (7576)	Shortest (72)	Jira Sail (7591)	Lowest (8.3)	Goarchoi (7574)	Lowest (2.73)	Matagarol (7592)
Longest (139)	Kala Biruin (7590)	Longest (134.2)	Gurunac (7598)	Longest (28.6)	Kela Mota (7613)	Highest (20.2)	Monor (7614)	Highest (171.8)	Khama (7583)	Longest (128)	Benikuchi (7594)	Highest (31.5)	Khoiya mota (7616)	Highest (27.73)	Satkata Binni (7578)
Mean	127.16	110.44		22.37		13.10		86.44		99.35		20.32		10.79	
Std. Dev.	6.77	14.22		2.81		3.54		28.77		8.74		6.02		5.35	
CV	6.64	14.38		11.22		20.61		22.71		15.28		29.58		53.06	
LSD	2.27	5.27		0.72		0.68		0.63		0.09		1.53		1.24	

Table 3. Performance of 20 selected rice germplasm from 203 local Genebank accession.

Acc. no.	Acc. name	Culm length (cm)	Effective till/hill	Days to maturity	Panicle length (cm)	Filled grain/ panicle	Unfilled grain/ panicle	Leaf length (cm)	Leaf width (mm)	TGW (g)	Culm diameter (mm)	Dry biomass (g, 5 Hill)	Grain length (mm)	Grain breadth (mm)	L/B ratio
5009	Innor Sail	112.4	8.8	106	25.4	196.0	54.4	55.6	17.0	18.27	5.24	27.88	7.44	2.44	3.05
5010	Boianga	118.4	10.4	104	23.2	205.8	27.2	60.4	17.8	18.47	6.64	30.29	7.45	2.62	2.84
5015	Pedi dhan	120.0	8.8	129	28.2	203.2	12.2	62.8	17.0	28.40	5.45	29.25	8.50	3.16	2.69
5060	Kajla IRRI	77.8	10.6	117	23.2	119.6	13.6	54.0	15.8	24.95	4.15	18.66	7.45	2.90	2.57
5062	Sharna	73.0	9.2	117	25.2	163.4	28.4	43.2	15.0	15.56	4.19	16.60	7.55	2.39	3.16
5076	Mala	114.2	13.6	110	25.8	166.2	50.2	54.4	13.8	18.36	4.45	29.01	7.79	2.52	3.09
5077	Dorna	74.0	8.8	124	25.2	138.6	24.8	37.4	12.0	17.67	4.16	16.32	7.55	2.49	3.03
5093	Chini Atop	121.2	7.6	115	24.0	223.2	47.6	47.6	9.8	10.32	3.63	32.78	7.6	1.73	4.39
5116	Sona	69.0	8.4	127	22.6	101.6	11.6	47.0	13.8	17.90	3.50	17.85	7.92	2.43	3.26
5216	Dud Ruchi	93.4	7.6	119	24.6	133.6	32.6	64.4	17.2	19.12	4.81	22.18	8.16	2.01	4.06
5230	Batarsar	101.0	7.4	102	26.2	122.2	13.2	60.2	11.2	26.09	5.08	27.47	9.39	2.10	4.47
5241	Bundamithi	106.0	8.4	112	22.8	120.6	19.4	45.0	11.0	19.22	3.91	30.10	8.88	2.79	3.18
5245	Bandail	109.0	10.0	122	27.6	122.2	27.0	60.8	13.4	20.29	4.23	24.00	6.70	2.59	2.59
5272	Bara Sail	114.6	7.8	124	27.4	98.2	4.2	64.6	12.2	24.26	5.46	25.88	8.52	2.86	2.98
5279	Sylhet IRRI	116.2	10.8	118	29.2	118.2	33.6	58.4	14.8	19.33	5.08	35.29	7.79	2.54	3.07
5282	23 Balam	91.2	7.4	141	27.0	158.4	15.8	47.0	15.8	23.58	4.72	32.43	8.32	2.58	3.22
5287	Rajshahi Balam	114.6	8.8	118	26.2	146.4	21.0	56.2	14.8	19.37	3.41	30.55	8.15	2.28	3.57
5292	IRRI -1010	80.2	10.0	135	22.0	150.8	31.2	39.0	11.0	19.58	3.31	24.21	6.98	3.05	2.29
5304	Beki Balam	97.8	6.4	134	28.4	198.2	30.4	55.8	18.2	29.11	5.50	31.93	9.49	2.78	3.41
5305	Asam Boro	99.4	8.0	133	30.0	153.8	27.6	57.4	12.4	20.95	5.21	29.79	8.02	2.53	3.17
Maximum*		161.0	15	151	31.6	223.2	119.6	84.0	18.2	36.83	6.78	44.02	12.36	3.78	5.52
Minimum		28.8	4.6	102	14.4	27.6	3.2	37.4	8.0	8.83	2.92	13.79	5.47	1.67	1.98
Mean		118.5	9.2	131	26.2	126.6	23.3	58.6	11.8	21.9	4.78	29.0	8.08	2.68	3.00
CV			21.5		5.46		45.42	12.23	7.91		19.32	29.23			
LSD			3.27		2.28		16.84	11.54	1.52		1.56	13.89			

*Rang, CV and LSD values were calculated form 203 rice germplasm accessions.

stored during 2017-18 in short term storage were also found with more than 90% germination. The germplasm that possessed less than 80% germination will be grown in the following season. On the other hand, the range of germination percentages of the five test samples/testers in the medium and long term storages conducted in October 2017 and March 2018 were 63-95% and 72-94% respectively, which indicate the viability condition of stored germplasm in medium and long term storages.

Germplasm distribution/exchange. A total of 1,137 samples were supplied to different users in the reporting year. Among the samples, 759 germplasm accessions were supplied for research purpose and 378 samples of BRRI developed rice varieties were supplied to Researchers, Department of Agricultural Extension (DAE) personnel and University students for research, demonstration as well as other purposes.

Documentation of germplasm. Two hundred accessions were entered into the database with collected available information of the accession during the reporting year. The information, which entered into the database, can be retrieved any time, if necessary.

SEED PRODUCTION AND VARIETY MAINTENANCE

Variety maintenance. Ninety-five BRRI developed and recommended rice varieties including 14 local improved varieties (LIV) were maintained using panicle to row method, implementing time isolation and performing thorough roguing (Table 4).

Nucleus seed production. A total of 63 BRRI developed rice varieties of which 42 in T. Aman and 21 in Boro were grown in panicle to row method to produce nucleus stock. The objective for nucleus seed production was to maintain genetic purity and homogeneity of morphological characteristics of a variety and subsequently breeder seed production. These nucleus seeds would be used for production of breeder seed in the following seasons.

‘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 stored in controlled temperature (20°C with 40% RH).

Breeder seed production and distribution. GRS Division, Farm Management Division and eight regional stations of BRRI were engaged in breeder seed (BS) production as per national demand during 2017-18. 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) for distribution.

A total of 151.93 tons of breeder seed of which 37.20 tons from 42 varieties in T. Aman and 114.73 tons from 21 varieties in Boro seasons were produced (Table 5 and 6). Among the total production, 140.33 tons were produced by GOB fund and 11.60 tons were produced by project fund viz. HarvestPlus, TRB and STRASA (Table 7). On the other hand, 125.37 tons of breeder seed of which 93.47 tons from 21 varieties in Boro, 5.19 tons from 12 varieties in Aus and 26.71 tons from 36 varieties in T. Aman were distributed among the ‘Rice Seed Network’ partners during 2017-18 (Tables 8, 9 and 10).

Monitoring seed production plots and farms. Breeder seed production plots of BRRI regional stations (RSs) *viz* Rangpur, Rajshahi, Habiganj, Cumilla, Sonagazi and Satkhira along with foundation seed production farms of BADC, Datta Nagar, Jashore and Auto Equipment ltd., Bogura were visited to observe the varietal purity and performances of breeder and foundation seeds. During the visit, no major insect-pest damage was noticed in the plots. Varietal purity (%) was observed as average of more than 99% in all the varieties. The crops were found almost free from weeds. In maximum cases, isolation distance was properly maintained. Foundation seed (FS) producers were advised to discard three meters boarder lines, where isolation distance was not maintained. Overall crop conditions and management was satisfactory. The seed producers were also advised for thorough roguing by themselves for one more time before harvesting.

Table 4. List of BRRI developed and recommended rice varieties maintained as nucleus stock.

Season	Type	Number	Variety name
T. Aman	MV	44	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
	LIV	8	Nizersail, Latisail, Rajasail, Kalijira, Kataribhog, Basmati-D, Patnai23, Tilockkachari
Boro	MV	37	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
	LIV	6	Hbj Boro II, Hbj Boro IV, Hbj Boro VI, Hbj Boro VIII, Purbachi, IR8

Table 5. Production (in kg) of breeder seed during T. Aman 2017.

Variety	Production (kg)									
	GRS Division	Farm Division	BRRI RS Rangpur	BRRI RS Rajshahi	BRRI RS Habiganj	BRRI RS Cumilla	BRRI RS Sonagazi	BRRI RS Barisal	BRRI RS Satkhira	Total
BR10	160	1200								1360
BR11	300			1720						2020
BR21	90									90
BR22	200					680				880
BR23	100							670		770
BR24	20									20
BR25	50									50
BRRI dhan30	170	1040								1210
BRRI dhan31	40									40
BRRI dhan32	210					1620				1830
BRRI dhan33	130									130
BRRI dhan34	140						950	2240		3330
BRRI dhan37	70									70
BRRI dhan38	40									40
BRRI dhan39	170	390								560
BRRI dhan40	40									40
BRRI dhan41	50							650		700
BRRI dhan42	50									50
BRRI dhan43	300									300
BRRI dhan44	60									60
BRRI dhan46	200									200
BRRI dhan48	40			1320	440	760				2560
BRRI dhan49	280	940				4200			1070	6490
BRRI dhan51	640									640
BRRI dhan52	370		340		260			1630		2600
BRRI dhan54	50									50
BRRI dhan56	190									190
BRRI dhan57	200									200
BRRI dhan62	120									120
BRRI dhan65	440									440

Table 5. Continued.

Variety	Production (kg)									
	GRS Division	Farm Division	BRRI RS Rangpur	BRRI RS Rajshahi	BRRI RS Habiganj	BRRI RS Cumilla	BRRI RS Sonagazi	BRRI RS Barisal	BRRI RS Satkhira	Total
BRRI dhan70	430									430
BRRI dhan71	190		670	680						1540
BRRI dhan72	1920					1160				3080
BRRI dhan73	130									130
BRRI dhan75	230					980				1210
BRRI dhan76	200							1220		1420
BRRI dhan77	70							1020		1090
BRRI dhan78	40									40
BRRI dhan79	100									100
BRRI dhan80	110									110
Nizersail	40									40
Sub total	8770	3570	1590	3720	700	9400	950	7430	1070	37,200

Table 6. Production (in kg) of breeder seed during Boro 2017-18.

Variety	Production (kg)										
	GRS Division	Farm Division	BRRI RS Rangpur	BRRI RS Rajshahi	BRRI RS Habiganj	BRRI RS Cumilla	BRRI RS Bhanga	BRRI RS Sonagazi	BRRI RS Barisal	BRRI RS Satkhira	Total
BR3	420										420
BR14	480										480
BR16	1130										1130
BR26	800				2160			2320	6090		11370
BRRI dhan28	220	3440		3080	5720	7100	7400	2570	4200	8220	41950
BRRI dhan29	40				5000	4340	5600	3260	3340		21580
BRRI dhan36	100										100
BRRI dhan45	40										40
BRRI dhan47	350										350
BRRI dhan50	320		700							3850	4870
BRRI dhan55	290										290
BRRI dhan58	570		4240		4080	3000					11890
BRRI dhan59	360										360
BRRI dhan60	450								1040		1490
BRRI dhan61	260								900		1160
BRRI dhan63	1700			1180							2880
BRRI dhan64	290										290
BRRI dhan67	1160								1130		2290
BRRI dhan68	490										490
BRRI dhan69	660					2300					2960
BRRI dhan74	4140					4200					8340
Total	14270	3440	4940	4260	16960	20940	13000	8150	16700	12070	114,730

Table 7. Production (in kg) of breeder seed under different projects of GRS Division.

Sl. No.	Variety	Project and quantity (in kg)			Total
		HarvestPlus	TRB	STRASA	
1	BRRI dhan66		270		270
2	BRRI dhan67			230	230
3	BRRI dhan70		290		290
4	BRRI dhan71			70	70
5	BRRI dhan72	2760			2760
6	BRRI dhan73			110	110
7	BRRI dhan74	7280	360		7640
8	BRRI dhan75		230		230
Grand total		10040	1150	410	11,600

Table 8. Distribution (in kg) of breeder seed in Boro 2017-18.

Type of the Organization	Number of the Organizations	Variety and quantity (in kg)																					Total
		BR3	BR14	BR16	BR26	BRRI dhan28	BRRI dhan29	BRRI dhan36	BRRI dhan45	BRRI dhan47	BRRI dhan50	BRRI dhan55	BRRI dhan58	BRRI dhan59	BRRI dhan60	BRRI dhan61	BRRI dhan63	BRRI dhan64	BRRI dhan67	BRRI dhan68	BRRI dhan69	BRRI dhan74	
GO	12	80	80	100	1000	17710	4460	0	0	340	580	40	1120	100	110	50	450	80	500	60	200	3900	30960
NGO	7	0	30	30	0	570	370	0	0		10	10	190	0	0	0	70	0	10	10	10	40	1350
PS	860	0	380	1030	3090	20540	16195	100	10	10	2061	140	10080	50	130	40	2320	40	630	240	420	3650	61156
Total	879	80	490	1160	4090	38820	21025	100	10	350	2651	190	11390	150	240	90	2840	120	1140	310	630	7590	93,466

Table 9. Distribution (in kg) of breeder seed in Aus 2018.

Type of the Organization	Number of the Organizations	Variety and quantity (in kg)												Total
		BR3	BR14	BR16	BR21	BR24	BR26	BRRI dhan27	BRRI dhan42	BRRI dhan43	BRRI dhan48	BRRI dhan55	BRRI dhan65	
GO	2	170	0	0	50	20	1940	0	50	200	2520	50	50	5050
PS	12	0	0	0	0	0	60	0	0	25	40	0	10	135
Total	15	170	0	0	50	20	2000	0	50	225	2560	50	60	5,185

Table 11. Distribution (in kg) of breeder seed (BS) in T. Aman 2018.

Type of the Organization	GO	NGO	PS	Total
Number of the Organizations	7	6	255	268
Variety and quantity (in kg)				
BR10	310	10	1000	1320
BR11	1000	40	970	2010
BR22	530	10	340	880
BR23	510		250	760
BR25	10		40	50
BRRI dhan30	1010		160	1170
BRRI dhan31	10			10
BRRI dhan32	310	10	1060	1380
BRRI dhan33	120		10	130
BRRI dhan34	935	80	2120	3135
BRRI dhan37	10		10	20
BRRI dhan38	10			10
BRRI dhan39	560			560
BRRI dhan40	20		60	80
BRRI dhan41	20	40	450	510
BRRI dhan44	30		60	90
BRRI dhan46	30		170	200
BRRI dhan49	3055	120	3360	6535
BRRI dhan51	430	10	170	610
BRRI dhan52	1610	40	910	2560
BRRI dhan54		40	10	50
BRRI dhan56	30	10	140	180
BRRI dhan57	60	10	50	120
BRRI dhan62	120			120
BRRI dhan66	190	10	15	215
BRRI dhan70	25			25
BRRI dhan71	290	20	140	450
BRRI dhan72	405	300	1012	1717
BRRI dhan73	40	30		70
BRRI dhan75	205	10	550	765
BRRI dhan76	480		20	500
BRRI dhan77	180		10	190
BRRI dhan78	30	10		40
BRRI dhan79	100			100
BRRI dhan80	70		40	110
Nizersail	40			40
Total	12785	800	13127	26712

EXPLORATORY AND GENETIC STUDIES

Selection criteria and genetic divergence of local rice germplasm. Sixty-one Binni accessions were grown under rainfed condition with three replications for diversity analysis with 12 agro-morphological characters. Mahalonobis (D^2) and Canonical Vector Analysis methods were used to group the genotypes.

D^2 analysis revealed that the genotypes were grouped into five clusters. Maximum 23 genotypes were clubbed into cluster IV and minimum (6) into cluster III (Table 11). Table 12 presented intra and Inter-cluster distances. All the inter-cluster distances were larger than the intra-cluster distance indicating the presence of wider diversity among the varieties of distance groups. The intra- and inter-cluster distances ranged from 0.91 to 1.20 and 3.23 to 10.16 respectively.

The highest panicle length (25.47 cm), plant height (133.9 cm), filled grains per panicle (138) and the lowest un-filled grains per panicle (21) with higher TGW (21.14 g) and grain yield (17.03 g/hill) (Table 13) were accumulated in cluster III. But the highest grain length (9.39 mm), grain width (1.87 mm) and LB ratio (5.08) along with lower plant height (121.93 cm) and TGW (20.72 g) were clubbed into cluster I, whereas the highest effective number of tillers hill^{-1} (8) and grain yield (17.18 g/hill) and the lowest TGW (20.55 g) were observed in cluster II. Moreover, the inter-cluster distance was higher between Cluster I and II (7.78) and the highest (10.16) between Cluster I and III. Therefore, the genotypes of cluster I, II and III can be used in hybridization programme to produce high yielding varieties along with other desirable traits.

Observational trial of popular rice germplasm of southern region. Seven out of 21 popular rice germplasm of which two from Balam (acc. 1011, 516), three from Jasho-Balam (2473, 2464, 2472), one each from Sada Mota (7888) and Lal Mota (7889) along with BRRI dhan49, BRRI dhan44 and BRRI dhan57 as standard checks were selected for Preliminary Yield Trial (PYT) for next T. Aman 2018 (Table 14). Physico-chemical characters of the germplasm will also be studied.

Table 11. Distribution of 61 Binni rice germplasm into five clusters.

Cluster	No. of variety	Name of the rice germplasm (acc. no.)
I	9	Kaisha Binni (206), Lal Binni (210), Kala Binni (236), Kaika Binni (1874), Pura Binni (4475), Lata Binni (4727), Binni Dhan / Chingnu (7253), Binni (7488), Lal Binni (7819)
II	15	Lal Binni (209), Garo Binni (4476), Chandan Binni (4481), Dudhmethi (4482), Atha Binni (4483), Atha Binni (4484), Gouhati Binni (4485), Chysa Binni (5954), Kala Binni (7258), Ranga Binni (7276), Binni (Red) (7487), Ayla Binni (7666), Patri Dhan (7747), Binni Langmeno (7767), Laxmi Binni (7781)
III	6	Kuichcha Binni (4474), Leda Binni (4478), Ranga Binni (4487), Nethabinni (4705), Sada Binni (4726), Horin Binni (7268)
IV	23	Kaisha Binni (204), Kaisha Binni (205), Kaisha Binni (207), Koha Binni (208), Netha Binni (1987), Aguinya Binni (4473), Binni (4477), Binni (4479), Kakoiya Binni (4480), Nedra Binni (4486), Sona Binni (4700), Kaisa Binni (4701), Binni (4707), Kaisa Binni (4720), Chidira Binni (7074), Kutkutta Binni (7261), Binni (Black) (7489), Ranga Binni (7693), Binni Sada (7730), Bak Binni (7768), Uscha Binni (7804), Binni Dhan (Redesh) (7832), Binni (Red) (7834)
V	8	Sail Binni (1974), Panga Binni (5032), Horina Binni (7493), Lal Binni (7691), Kangiri Binni Dhan (7738), Sada Binni (7746), Khoiya Binni (7784), Jhum Binni (7796)

Table 12. Intra-(bold) and inter-cluster distances (D^2) for 61 Binni rice germplasm.

Clusters	I	II	III	IV	V
I	**1.17**				
II	7.78	**0.91**			
III	10.16	3.23	**1.20**		
IV	4.50	3.73	6.30	**0.95**	
V	7.17	3.50	4.24	4.53	**1.18**

Table 13. Cluster means of 12 agro-morphological characters for 61 Binni rice germplasm.

Cluster	Flag leaf length (cm)	Flag leaf width (cm)	Effective tiller number per hill	Panicle length (cm)	Plant height (cm)	Filled grain number per panicle	Un-filled grain number per panicle	Grain length (mm)	Grain width (mm)	Grain LB ratio	1000-grain weight (g)	Grain yield per hill (g)
I	41.67	1.48	7	23.27	121.93	47	69	9.39	1.87	5.08	20.72	14.64
II	38.49	1.44	8	24.83	130.59	104	26	8.59	1.9	4.52	20.55	17.18
III	42.37	1.27	7	25.47	133.9	138	21	8.7	1.87	4.66	21.14	17.03
IV	39.29	1.34	8	23.32	120.4	73	33	8.89	1.93	4.64	21.83	16.21
V	43.28	1.48	7	22.6	119	124	54	8.51	1.91	4.48	20.79	13.81

Table 14. Mean data of 21 characterized germplasm during T. Aman 2017.

Variety	Acc. no.	Plant height (cm)	Effective tiller number	Panicle length (cm)	Growth duration	1000-grain weight (g)	Filled grain no.	Un-filled grain no.	Grain length (mm)	Grain width (mm)	LB ratio	Yield per hill (g)
Balam	4836	118.2	10	20.7	122	21.4	59	8	6.5	1.8	3.7	15.2
	1011	151.4	6	24.1	131	23.8	159	18	6.4	1.6	3.9	21.0
	516	152.0	8	25.7	128	12.4	170	34	5.6	1.4	4.0	17.8

Table 14. Continued.

Variety	Acc. no.	Plant height (cm)	Effective tiller number	Panicle length (cm)	Growth duration	1000-grain weight (g)	Filled grain no.	Un-filled grain no.	Grain length (mm)	Grain width (mm)	LB ratio	Yield per hill (g)
Jesho-Balam	2456	144.7	9	23.6	131	17.6	89	14	5.7	1.6	3.6	15.5
	2459	164.2	11	28.0	141	18.2	137	17	5.7	1.6	3.5	14.4
	2473	132.4	12	21.6	131	22.3	129	20	6.5	1.6	4.2	20.2
	2464	150.9	9	24.3	130	20.5	84	28	5.7	1.5	3.7	15.8
	2469	141.3	11	24.3	137	18.8	87	29	6.1	1.6	3.9	15.6
	2472	133.6	11	22.9	141	22.2	95	19	6.6	1.7	3.8	16.9
	2480	147.3	10	24.0	129	20.3	127	19	6.0	1.6	3.7	12.6
Sada Mota	1040	149.0	7	24.8	141	23.8	90	18	6.0	1.8	3.3	11.0
	1576	142.6	8	22.3	128	26.4	124	11	5.6	2.0	2.8	16.0
	7888	151.6	14	24.7	141	26.2	71	3	6.1	2.1	2.9	32.7
	7923	156.9	11	25.9	141	19.0	131	17	5.5	1.5	3.6	24.4
Lal Mota	1584	144.6	9	24.2	129	37.0	98	4	6.2	2.1	2.9	21.4
	1583	139.2	12	24.1	133	35.4	86	7	6.3	2.2	2.9	26.2
	7889	141.9	10	24.1	132	37.1	94	10	6.2	2.1	3.0	26.2
Khejur Chhori	4246	151.0	9	22.4	132	20.2	112	12	6.3	1.7	3.8	20.6
Khejur Jhupi	40	162.8	11	29.2	133	22.1	160	17	5.9	1.7	3.4	13.3
Bashful	4010	133.0	6	26.2	111	28.0	59	36	6.6	1.9	3.5	8.6
	3996	147.0	11	27.1	149	32.3	160	25	5.9	1.7	3.4	13.3
BR7	--	119.6	10	23.0	128	20.0	99	51	7.1	1.6	4.4	12.8
BR25	--	141.2	10	22.2	137	20.1	181	15	5.8	1.6	3.5	23.4
Minimum		118.2	6	20.7	111	12.4	59	3	5.5	1.4	2.8	8.6
Mean		144.2	10	24.3	133	23.7	113	19	6.1	1.7	3.5	18.0
Maximum		164.2	14	29.2	149	37.1	181	51	7.1	2.2	4.4	32.7
Std. Dev.		11.5	1.9	2.0	7.8	6.4	35.7	11.1	0.4	0.2	0.4	5.8
CV		8.0	19.3	8.4	5.9	27.2	31.6	59.0	6.3	12.7	12.3	32.0
LSD		4.05	0.67	0.72	2.75	2.27	12.56	3.90	0.14	0.08	0.15	2.03

Grain Quality and Nutrition Division

SUMMARY

On the basis of physicochemical and cooking properties, only 13 from 368 breeding lines are suggested for further research.

A total of 934 transforming breeding lines were evaluated for physicochemical and cooking properties for superior quality. Based on the performance of grain quality, we recommend 18 lines for further advancement. The highest milling outturn (73%) of BR3, BRRI dhan28 and BRRI dhan29 was found in Rangpur but the lowest milling outturn (69%) of BR3, BRRI dhan28 and BRRI dhan29 was found commonly in Sonagazi with other regions. The lowest amylose content of BR3, BRRI dhan28 and BRRI dhan29 was found in Barishal but the highest amylose content was found in Shatkhira. The lowest protein content of BR3, BRRI dhan28 and BRRI dhan29 was found in Kushtia but the highest protein content was found in Barishal.

Different varieties had different physicochemical properties. Higher dose of urea application on BRRI dhan29 increases higher protein content and higher yield but decreases amylose content. The lowest milling outturn and head rice recovery were found in Aus season. The lowest paddy length and 1000-grain wt were found in Aman season. The highest protein content (9.5%) was found in Boro season.

A total of 35 BRRI HYVs were selected to evaluate their vitamin profiling including thiamin and riboflavin minerals such as zinc, iron, phytic acid and molar ratio of phytate to respective minerals (PA/Zn and PA/Fe). BRRI dhan36 has the highest thiamin content of 1.15 mg100^{-1}g followed by BRRI dhan29 (1.14 mg100^{-1}g), BRRI dhan48 (1.12 mg100^{-1}g), BRRI dhan28 (1.09 mg100^{-1}g) and BRRI dhan43 (1.08 mg100^{-1}g). Both BRRI dhan43 (27.17 mgkg^{-1}) and BRRI dhan42 (27.12 mgkg^{-1}) have higher Zn content among all the tested BRRI rice varieties. Both BRRI dhan43 and BRRI dhan42 can be used as micronutrient enriched HYV for Aus season.

Heat treatment at 130-135°C for 2 hrs, was found suitable for stabilizing rice bran from increasing FFA% and lowering oil% for at least 28 days and it is expected that lipase activity might possibly inhibited or at least show down their activity by heat treatment even though we did not measure lipase activity in this experiment. We would like to recommend heat treatment as physical treatment, soon after harvesting bran from kernel in this regards. This particular physical treatment should be applied in auto rice mill premises just after harvesting fresh bran. In addition, it is necessary to explore biologically competitive inhibitor of lipase enzyme as an alternative approach, which yet to be done. So there is a huge scope in basic research in this regard. Since RBO industries are facing challenges with lack of fresh bran, high FFA% containing bran with lower oil content and artificial crisis of bran even at harvesting season, so our findings could assist these RBO industries to stabilize rice bran with attainable quality up to 28 days after harvesting bran at parboiled milling condition. Industrial waste such as bleaching earth might have good potential to use as alternate fueling as well as fertilizer in Bangladesh.

Noodles prepared from BRRI varieties were acceptable by the panelists. The cooking qualities including cooking loss and water absorption of the rice noodles were acceptable. This study showed the potential for commercial production of noodles.

In Bangladesh, rice based processed food items are available namely flattened, popped and puffed rice to meet local demand as traditional food items, we assume that there is a potential scope to enhance nutraceutical enriched rice based food considering malnutrition mitigation and humanitarian relief operation into account. In our study we have formulated energy dense nutraceutical enriched rice based food formulation specially cake and biscuits having energy density ranging from 5.0-5.5 100^{-1}g serving respectively. Rice based balanced and nutritious food intake may possibly reduce the amount of unprocessed whole rice consumption gradually. By attaining required dietary allowance, rice based food may help sustain food security in Bangladesh in a way to properly and effectively utilizing the rice grain. It will open diversified uses of rice and rice based food products in Bangladesh.

Puffed, popped and flattened rice were produced from 11 BRRI varieties to evaluate the quality products. Comparing few parameters (fully puffed rice, length and breadth increase percentage) with BR16 (Std), it was found that BRRI dhan59, BRRI dhan60, BRRI dhan62 and BRRI dhan66 are more or less suitable for making puffed rice. Considering physical parameters, BRRI dhan60, BRRI dhan62, BRRI dhan65, BRRI dhan66 and BRRI dhan67 varieties can be used commercially for popped rice production. Among the tested varieties, BRRI dhan62, BRRI dhan64, BRRI dhan65, BRRI dhan66 and BRRI dhan68 produce similar/better quality flattened rice comparing with BR16.

GRAIN QUALITY CHARACTERISTICS FOR VARIETY DEVELOPMENT

Determination of physicochemical and cooking properties of breeding lines

To ensure desirable qualities the physicochemical and cooking properties of 368 breeding lines from both the Plant Breeding and Biotechnology Division were analyzed. Most of the lines had satisfactory milling outturn. As many as 57 lines had 68-70% and 73 lines had more than 70% milling outturn. Only 12 lines had less than 68% milling outturn. Regarding chalkiness, kernels of more than 38% lines were translucent. Eighty-four lines had either white belly or white center. Size and shape of the grain are also important for the consumer. Out of the 142 breeding lines, 53 had long, 47 had medium and 42 short kernels.

Amylose content of rice starch is the major eating quality. It influences on volume expansion, water absorption, tenderness and stickiness of cooked rice. Out of 368 breeding lines, 79 had more than 25%, 189 had 20-25%, and only 100 had below 20% amylose content. Twelve lines had more than 9% protein content and 130 lines had it 7-9%. Among the breeding lines 27 had alkali spreading value ranging 6.0-7.0. In total, 114 had between 3.0 and 4.0. Grain with high gelatinization temperature is not desirable.

One hundred and eight lines had 15-20 and 25 lines had less than 15 minutes cooking time. The lines, having more than 20 minutes cooking time will give comparatively hard cooked rice.

The elongation ratio of 107 lines ranged from 1.3 to 1.5. Seventeen lines had more than 1.5 elongation ratio, which were desirable. Only 18 lines had less than 1.3 elongation ratio. The imbibition ratio of 62 lines ranged from 3.5 to 4.0. Eighty breeding lines had it more than 4.0. Some of promising lines were identified for high milling and head rice yield and acceptable other physicochemical properties (Table 1).

PI: MAS **CI:** MAH, SSD, NF, HBS and SH

Determination of physicochemical and cooking properties of transforming rice breeding (TRB) lines

Out of 934 advanced lines 406 had high (>70%) and 252 lines had intermediate (68.0-70.0%) milling yield. On the contrary, 511 lines had more than 57% head rice yield. Among them, around 180 lines had translucent grains. Four hundred eighty-six lines had long (>6.0mm), 442 had medium (5.0-6.0 mm) and only six had short (< 5.0 mm) grains. One hundred twenty lines had long slender grain. Out of 934 lines, 536 had high (>25%), 255 had intermediate (20-25%) and 143 had low (<20%) amylose content. Three hundred eighteen lines had

Table 1. Physicochemical properties of promising breeding lines.

Genotype	Milling outturn (%)	Amylose content (%)	Alkali spreading value	Protein (%)	Elongation ratio	Size and shape
BR10390-15-2-2	69.0	27.0	5.5	8.8	1.2	LS
BR10390-10-3-1	70.0	27.0	6.0	8.7	1.4	MS
BR10391-16-1-3	72.0	28.0	5.6	9.3	1.4	LS
BR10393-2-2-2	71.0	26.0	5.5	9.7	1.4	MB
GSR IR1-17-D6-Y1-D-1-11	70.5	25.5	7.0	9.0	1.3	LS
GSR IR1-5-D7-Y3-S-1	70.0	26.0	7.0	8.6	1.3	LS
BR (Bio) 11447-310-7-1	70.6	26.0	4.9	8.6	1.4	LS
BR (Bio) 11447-2-2-4-1	71.7	25.5	5.0	8.2	1.4	LS
IR 13F457	70.3	25.0	6.5	8.6	1.3	LS
IR13F352	70.2	25.0	4.9	8.0	1.3	LS
BR8841-38-1-2-1	73.0	26.0	4.9	8.1	1.5	MB
IR10F102	72.5	25.9	5.2	8.4	1.5	MB
BR8841-38-1-2-2	72.2	25.5	4.9	8.9	1.4	MB

high (9.0%) protein content, 613 had intermediate protein content (7.0-9.0%). Among the lines, 29 had low, 550 had intermediate and 99 had high gelatinization temperature. Twenty-three lines had high (>4.0) and 175 had intermediate (3.5-4.0) volume expansion ratio. Among 934 lines 99 had high (1.5), 785 had intermediate (1.3-1.5) and 50 had low (<1.3) elongation ratio. This study identified some of the promising lines for high milling and acceptable other physicochemical properties (Table 2).

PI: MAS **CI:** SSD

Study on the effect of physicochemical properties on the basis of regional variation in Boro 2016-2017

In case of BR3 (Tables 3 and 4), the highest milling outturn (73%) was found in Rangpur but the lowest milling outturn (69%) was found in Sonagazi. The highest head rice recovery (67%) of BR3 was found in Gazipur but the lowest head rice recovery (44%) was found in Rangpur. Among the regions, appearance of BR3 has shown good with medium bold (MB) type grain. Chalkiness of BR3 in all the regions was shown white belly grain with few white center. The highest thousand grain weight or TGW (30.0 g) of BR3 was found in Cumilla but the lowest thousand grain weight (26.2 g) was found in Shatkhira. Similar alkali spreading value (7) and imbibition ratio (3.4) of BR3 were found in all the regions. The range of elongation ratio varies from 1.4 to 1.5. Cooking time varies from 16.15 min to 17.50 min. The highest amylose content of BR3 was 27.1% in Shatkhira but the lowest amylose content was 24.1% in Barishal (Fig. 1). The highest protein content of BR3 was 10.1% in Barishal but the lowest protein content was 7.7% in Kushtia and Shatkhira (Fig. 2).

In case of BRRI dhan28 (Tables 3 and 4), the highest milling outturn (73%) of this variety was found in Rangpur but the lowest milling outturn (69%) was found in both Sonagazi and Habiganj. The highest head rice recovery (68%) of BRRI dhan28 was found in Gazipur but the lowest head rice recovery (48%) was found in Rangpur. Among the regions, appearance of BRRI dhan28 has shown good with medium slender (MS) type grain. Chalkiness of BRRI dhan28 in all the regions has shown translucent grain with few white belly, white center and opaque. The highest TGW (23.5g) of BRRI dhan28 was found in Cumilla but the lowest TGW (20.1g) was found in Sonagazi. The range of alkali spreading value varied from 5.7 to 6.2. Similar imbibition ratio (4.3) of BRRI dhan28 was found in all the regions. The range of elongation ratio varies from 1.4 to 1.5. Cooking time varies from 16.30 min to 17.30 min. The highest amylose content of BRRI dhan28 was 27.0% in Shatkhira but the

Table 2. Physicochemical properties of promising transforming breeding lines.

Genotype	Milling yield (%)	Size and shape	Amylose content (%)
IR93822-9-2-3-1	72.0	LS	25.2
IR 102860-5:7-B-B	72.3	LS	25.8
IR 101465-5:33	72.2	LS	27.1
IR 98867-19-1-1-1	72.9	LS	25.2
IR 91829-10-BAY 3-2-2-3	72.5	LS	27.9
IR 11N202	71.5	LS	26.7
IR90082-SUB-35-3-2-2	75.8	LS	26.6
IR92471-SUB-SUB-39-3-B	72.5	LS	26.7
IR92466-SUB-SUB-59-1-B	72.4	LS	25.5
IR92458-SUB-SUB-116-1-B	73.0	LS	25.5
BR8746-6-1-2-2-12	72.0	LS	25.2
BR7932-14-2-3-1-1-1-2	72.0	LS	27.1
IR91222-SUB-SUB-5-3-2	72.0	LS	26.3
IR13F478	75.7	LS	27.1
IR13F582	72.0	LS	25.6
IR9076-SUB-SUB-8-3-2-2	72.6	LS	25.2
BR8746-6-1-2-1-22	72.0	LS	24.5
IR13F457	72.2	LS	24.9

Table 3. Physical property of rice samples with regional variation in Boro season, 2016-2017.

Variety	Region	Milling outturn (%)	Head rice recovery (%)	Chalkiness	Milled rice length (L) mm	Milled rice breadth (B) mm	L/B ratio	Size and shape	TGW (g)
BR3	Barishal	72	47	Wb_1, (few Wc_5, c_9)	6.0	2.6	2.3	MB	26.7
BR3	Bhanga	72	66	Wb_1 (few Wc_9)	6.0	2.6	2.3	MB	29.9
BR3	Cumilla	71	46	Wb_1 (few Wc_9)	5.9	2.6	2.3	MB	30.0
BR3	Gazipur	71	67	Wb_1	5.9	2.6	2.3	MB	28.7
BR3	Habiganj	70	61	Wb_1	6.0	2.5	2.4	MB	29.2
BR3	Kushtia	70	64	Wb_1, (few Wb_5, Wc_9)	5.8	2.5	2.3	MB	28.3
BR3	Rajshahi	71	42	Wb_1 (few Wc_5)	5.8	2.5	2.3	MB	29.8
BR3	Rangpur	73	44	Wb_1	5.7	2.6	2.2	MB	29.5
BR3	Shatkhira	71	54	Wb_1 (few Wb_5)	5.8	2.4	2.4	MB	26.2
BR3	Sonagazi	69	62	Wb_1	5.9	2.5	2.4	MB	28.5
BRRI dhan28	Barishal	72	64	Tr	6.0	1.8	3.3	MS	21.4
BRRI dhan28	Bhanga	71	67	Tr (few Wb_5)	6.0	1.9	3.2	MS	20.3
BRRI dhan28	Cumilla	71	52	Tr (few Wc_5)	5.8	1.9	3.1	MS	23.5
BRRI dhan28	Gazipur	71	68	Tr (few Wc_5,Wc_9)	6.0	1.8	3.3	MS	22.2
BRRI dhan28	Habiganj	69	65	Tr (few Wc_9)	5.9	1.9	3.1	MS	20.6
BRRI dhan28	Kushtia	72	67	Tr (few Wb_1)	5.8	1.8	3.2	MS	21.1
BRRI dhan28	Rajshahi	70	67	Tr (few Wc_9)	5.9	1.8	3.3	MS	21.3
BRRI dhan28	Rangpur	73	48	Tr	6.0	1.8	3.3	MS	21.8
BRRI dhan28	Shatkhira	71	66	Tr (few Wc_1)	6.0	1.9	3.2	MS	21.4
BRRI dhan28	Sonagazi	69	62	Tr (few Opaque)	5.9	1.9	3.1	MS	20.1
BRRI dhan29	Barishal	71	66	Tr = Opaque	6.0	2.0	3.0	MB	19.8
BRRI dhan29	Bhanga	69	62	Tr = Opaque	6.0	2.0	3.0	MB	20.3
BRRI dhan29	Cumilla	70	67	Tr = Opaque	5.8	2.1	2.8	MB	21.7
BRRI dhan29	Gazipur	71	65	Tr = Opaque	6.0	2.1	2.9	MB	21.5
BRRI dhan29	Habiganj	70	66	Tr (few Opaque)	5.9	2.0	3.0	MB	20.3
BRRI dhan29	Kushtia	69	59	Wc_5 (few Tr)	6.0	2.0	3.0	MB	21.7
BRRI dhan29	Rajshahi	69	63	Tr (few Wc_9)	5.8	2.0	2.9	MB	22.6
BRRI dhan29	Rangpur	73	63	Tr (few Opaque)	5.9	2.0	3.0	MB	21.6
BRRI dhan29	Shatkhira	69	58	Tr (few Opaque)	6.0	2.0	3.0	MB	20.1
BRRI dhan29	Sonagazi	69	64	Tr = Wc_1	5.9	2.1	2.8	MB	20.7

lowest amylose content was 24.6% in Barishal and Habiganj (Fig. 1). The highest protein content of BRRI dhan28 was 9.7% in Barishal but the lowest protein content was 7.6% in Kushtia and Sonagazi (Fig. 2).

In case of BRRI dhan29 (Tables 3 and 4), the highest milling outturn (73%) was found in Rangpur but the lowest milling outturn (69%) was found in Bhanga, Kushtia, Rajshahi, Shatkhira and Sonagazi. The highest head rice recovery (67%) of BRRI dhan29 was found in Cumilla but the lowest head rice recovery (58%) was found in Shatkhira. Among the regions, appearance of BRRI dhan29 was good with medium bold (MB) type grain. BRRI dhan29 in all the regions had translucent grain with opaque and white center. The highest TGW (22.6g) of BRRI dhan29 was found in Rajshahi but the lowest TGW (19.8g) was found in Barishal. The range of alkali spreading value varied from 4.8 to 6.0. Similar imbibition ratio (4.4) of BRRI dhan29 has been found in all the regions. The range of elongation ratio varies from 1.3 to 1.4. Cooking time varies from 17.0 min to 18.40 min. The highest amylose content of BRRI dhan29 was 28.5% in Shatkhira and the lowest amylose content was 24.2% in Barishal (Fig. 1). The highest protein content of BRRI dhan29 was 7.9% in Barishal and the lowest protein content was 6.4% in Kushtia (Fig. 2).

PI: NF **CI:** MAS, MAH, SSD, HBS and SH

Table 4. Chemical and cooking properties of rice samples with regional variation in Boro season, 2016-2017.

Variety	Region	Alkali spreading value	Amylose content (%)	Protein content (%)	Cooking time (min.)	ER	IR
BR3	Barishal	7.0	24.1	10.1	17.40	1.4	3.4
BR3	Bhanga	7.0	26.6	8.2	16.15	1.4	3.4
BR3	Cumilla	7.0	26.1	7.9	17.00	1.5	3.4
BR3	Gazipur	7.0	26.3	9.5	17.50	1.4	3.4
BR3	Habiganj	7.0	25.7	9.4	17.00	1.5	3.4
BR3	Kushtia	7.0	25.7	7.7	16.40	1.5	3.4
BR3	Rajshahi	7.0	25.4	10	17.40	1.4	3.4
BR3	Rangpur	7.0	25.8	9.2	17.50	1.5	3.4
BR3	Shatkhira	7.0	27.1	7.7	16.40	1.5	3.4
BR3	Sonagazi	6.8	25.2	8.1	17.00	1.4	3.4
BRRI dhan28	Barishal	5.8	24.6	9.7	17.20	1.4	4.3
BRRI dhan28	Bhanga	5.8	25.2	8.2	17.30	1.4	4.3
BRRI dhan28	Cumilla	5.7	26.1	8.7	16.50	1.4	4.3
BRRI dhan28	Gazipur	6.1	26.4	8.5	16.50	1.5	4.3
BRRI dhan28	Habiganj	6.2	24.6	9.4	16.50	1.5	4.3
BRRI dhan28	Kushtia	5.7	26.0	7.6	16.30	1.4	4.3
BRRI dhan28	Rajshahi	6.0	25.8	9.0	16.50	1.4	4.3
BRRI dhan28	Rangpur	6.2	25.9	9.3	16.50	1.4	4.3
BRRI dhan28	Shatkhira	6.0	27.0	8.2	16.40	1.5	4.3
BRRI dhan28	Sonagazi	5.8	26.7	7.6	17.10	1.4	4.3
BRRI dhan29	Barishal	4.9	24.2	7.9	17.00	1.3	4.4
BRRI dhan29	Bhanga	5.1	25.5	7.6	17.30	1.3	4.4
BRRI dhan29	Cumilla	5.8	26.4	7.6	17.30	1.3	4.4
BRRI dhan29	Gazipur	6.0	26.5	7.5	17.40	1.3	4.4
BRRI dhan29	Habiganj	5.2	25.5	7.7	18.20	1.4	4.4
BRRI dhan29	Kushtia	5.2	26.5	6.4	18.10	1.4	4.4
BRRI dhan29	Rajshahi	5.6	26.8	7.9	18.40	1.3	4.4
BRRI dhan29	Rangpur	5.8	27.0	7.6	17.20	1.4	4.4
BRRI dhan29	Shatkhira	4.8	28.5	7.4	17.30	1.4	4.4
BRRI dhan29	Sonagazi	4.8	26.2	7.8	18.20	1.4	4.4

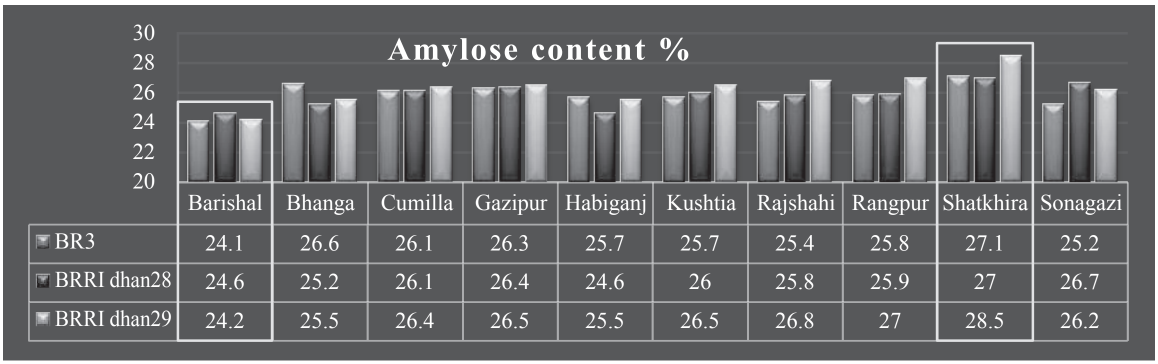


Fig. 1. Amylose content at different locations.

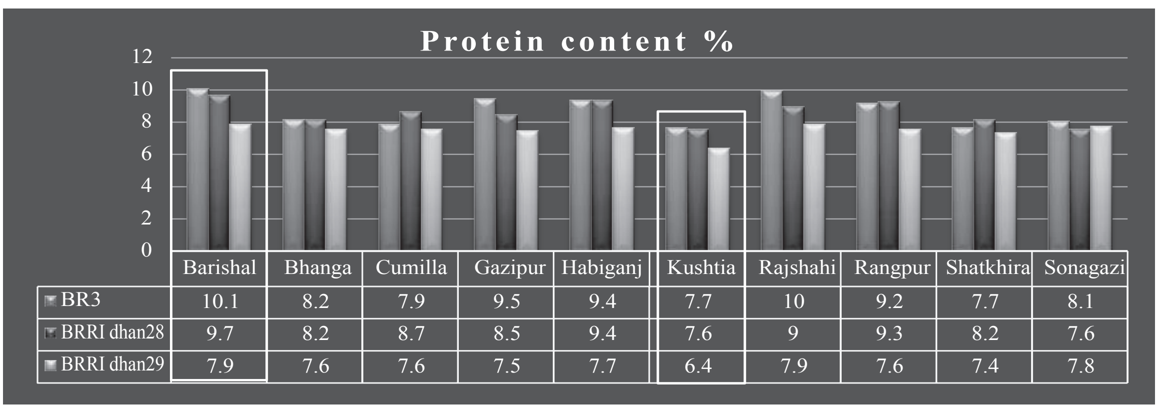


Fig. 2. Protein content at different locations.

Study on the effect of protein content on the basis of varietal difference in Boro season, 2016-2017

The variety BR3 is medium bold type good grain with white belly type chalkiness. Paddy length and breadth of this variety have 8.8 mm and 3.1 mm. Milling outturn, head rice recovery and TGW of that had 71%, 67% and 28.7g respectively with 12.5% moisture content. Alkali spreading value, ER and IR of this variety had 7.0, 1.4 and 3.4 with 17.50 minutes cooking time. If had 26.3% amylose content along with 9.5% protein content (Tables 5 and 6).

The variety BR16 has long bold type good grain with translucent and opaque type chalkiness. Its paddy length and breadth was 9.9 mm and 2.5 mm. Milling outturn, head rice recovery and TGW of that variety had 73%, 56% and 26.6g respectively with 13% moisture content. Alkali spreading value, ER and IR of that variety had 4.0, 1.3 and 3.7 with 18.40 min cooking time. Its amylose content and protein content was 27.9% and 8.6% (Tables 5 and 6).

The variety BRRI dhan28 had medium slender type good grain with translucent and white center type chalkiness. Paddy length and breadth of that variety had 9.2 mm and 2.3 mm. Its milling outturn, head rice recovery and TGW were 71%, 68% and 22.2 g respectively with 13% moisture content. Alkali spreading value, ER and IR of that variety had 6.1, 1.5 and 4.3 with 16.50 min cooking time. If had 26.4% amylose content and 8.5% protein content.

BRRI dhan29 had medium bold type good grain with translucent and opaque type chalkiness. Its milling outturn, head rice recovery and TGW were 71%, 65% and 21.5 g respectively with 13.1% moisture content. Alkali spreading value, ER and IR of that variety had 6.0, 1.3 and 4.4 with 17.40 min cooking time. If had 26.5% amylose content and 7.5% protein content (Tables 5 and 6).

PI: NF **CI:** MAS, MAH, SSD, HBS and SH

Study on the effect of protein content on the basis of different doses of urea application in Boro season 2016-2017 at BRRI farm, Gazipur

Five treatments based on different doses of urea application were applied on BRRI dhan29 at Gazipur station. Treatments were T_1=0g urea$10^{-1}m^2$, T_2=187.5g urea$10^{-1}m^2$, T_3=281.25g urea$10^{-1}m^2$, T_4= 375g urea$10^{-1}m^2$ and T_5=562.5g urea$10^{-1}m^2$. T_4= 375g urea$10^{-1}m^2$ was used as control. Milling outturn of all the treatments was 70% except T_1, which had it 69%. Head rice recovery of T_3 and T_4 had 64% but the others had it 65%. Appearance of all the treatments of those varieties were good with medium bold type grain. Translucent with opaque type chalkiness of this variety was observed among the treatments. TGW of this variety has shown gradually increasing trend but T_4 and T_5 have shown it similar (21.8g). The lowest yield (4 ton^{-1}ha) was obtained in T_1 and T_5 produced the highest yield (8.5 ton^{-1}ha). T_4 (control) had the second highest yield (8

Table 5. Physical properties of rice samples with varietal difference in Boro season, 2016-2017 at BRRI farm, Gazipur.

Variety	Milling outturn (%)	Head rice recovery (%)	Moisture content (%)	Appearance	Chalkiness	Paddy length (L) mm	Paddy breadth (B) mm	Size and shape	1000-grain wt (g)
BR3	71	67	12.5	Good	Wb_1	8.8	3.1	MB	28.7
BR16	73	56	13.0	Good	Tr (few Opaque)	9.9	2.5	LB	26.6
BRRI dhan28	71	68	13.0	Good	Tr (few Wc_5, Wc_9)	9.2	2.3	MS	22.2
BRRI dhan29	71	65	13.1	Good	Tr (Opaque)	8.7	2.7	MB	21.5

Table 6. Chemical and cooking properties of rice samples with varietal difference in Boro season, 2016-2017 at BRRI farm, Gazipur.

Variety	Alkali spreading value	Amylose (%)	Protein (%)	Cooking time (min)	ER	IR
BR3	7.0	26.3	9.5	17.50	1.4	3.4
BR16	4.0	27.9	8.6	18.40	1.3	3.7
BRRI dhan28	6.1	26.4	8.5	16.50	1.5	4.3
BRRI dhan29	6.0	26.5	7.5	17.40	1.3	4.4

ton^{-1}ha). Alkali spreading value varies from 4.8 to 5.3. Cooking time varies from 16.15 min to 17.50 min. Elongation ratio varies from 1.3 to 1.4 and imbibition ratio varies from 4.0 to 4.5. The highest amylose content (29.6%) was found in T_1 and the lowest amylose content (26.5%) was found in T_5. The lowest protein content (6.9%) was found in T_1 and the highest protein content (7.8%) was found in T_5. Alkali spreading value, amylose content, protein content, cooking time, imbibition ratio and yield of T_2 were higher than the T_3 (Tables 7 and 8).

PI: NF **CI:** MAS, MAH, SSD, HBS and SH

Study on the effect of protein content on the basis of seasonal variation in Boro, Aus and Aman 2017-2018

BR3 is a high yielding variety, which is commonly grown in Boro, Aus and Aman season. This variety was grown in Boro, Aus and Aman season at BRRI farm, Gazipur. It has shown the highest milling outturn (73%) in Aman season followed by Boro and Aus season. The lowest head rice recovery (60%) was found in Aus season but in Boro and Aman seasons it was almost similar (67%). Appearance of BR3 is good with medium bold type grain. The lowest paddy length (8.5 mm) was found in Aman season and it was the highest was found (8.8 mm) in Boro season. The highest TGW in Aus season followed by Boro and Aman seasons. There was no change of alkali spreading value, elongation ratio and imbibition ration among Boro, Aus and Aman seasons. Amylose content and cooking time was almost similar in Boro, Aus and Aman seasons. The highest protein content (9.5%) was found in Boro season followed by Aman and Aus seasons (Tables 9 and 10).

PI: NF **CI:** MAS, MAH, SSD, HBS and SH

NUTRITIONAL QUALITY ASSESSMENT OF RICE

Nutritional properties of BRRI HYV rice in Bangladesh

Rice is relatively a better source of vitamins, minerals, protein and starch among the cereals. In order to identify nutraceutically enriched HYV rice, we studied 35 BRRI released HYVs. We searched for

Table 7. Physical properties of rice samples with different doses of urea application in Boro season, 2016-2017.

Variety	Milling outturn (%)	Head rice (%)	Appearance	Chalkiness	Milled rice length (L) mm	Milled rice breadth (B) mm	L/B ratio	Size and Shape	1000 grain wt (g)	Yield (ton^{-1}ha)
BRRI dhan29-T_1 (0 dose)	69	65	Good	Tr (few Opaque)	5.8	2.0	2.9	MB	20.8	4
BRRI dhan29-T_2 (0.5 dose)	70	65	Good	Tr (few Opaque)	5.9	2.0	3.0	MB	21.0	7
BRRI dhan29-T_3 (0.75 dose)	70	64	Good	Tr (Opaque)	5.9	2.1	2.8	MB	21.6	6.9
BRRI dhan29-T_4 (Control, 1 dose)	70	64	Good	Tr (Opaque)	6.0	2.0	3.0	MB	21.8	8
BRRI dhan29-T_5 (1.5 dose)	70	65	Good	Tr (Opaque)	6.0	2.1	2.9	MB	21.8	8.5

Table 8. Chemical and cooking properties of rice samples with different doses of urea application in Boro season, 2016-2017 at BRRI farm, Gazipur.

Variety	Dose of urea (g10^{-1}m^2)	Alkali spreading value	Amylose content (%)	Protein content (%)	Cooking time (min)	ER	IR
BRRI dhan29-T_1	(0 dose =0 g)	4.8	29.6	6.9	16.15	1.4	4.0
BRRI dhan29-T_2	(0.5 dose =187.5 g)	5.3	27.5	7.7	17.30	1.4	4.4
BRRI dhan29-T_3	(0.75 dose = 281.25 g)	5.1	27.3	7.5	17.20	1.4	4.1
BRRI dhan29-T_4 (Cont)	(1 dose = 375 g)	5.3	27.6	7.7	17.40	1.4	4.5
BRRI dhan29-T_5	(1.5 dose = 562.5 g)	5.3	26.5	7.8	17.50	1.3	4.3

Table 9. Physical property of rice samples with seasonal variation for BR3.

Season	Milling outturn (%)	Head rice recovery (%)	Appearance	Chalkiness	Paddy length (L) mm	Paddy breadth (B) mm	Size and Shape	1000 grain wt. (g)
Boro 2016-17	71	67	Good	Wb_1	8.8	3.1	MB	28.7
Aus 2016-17	70	60	Good	Wb_1/few (Wc_5/Wc_9)	8.7	2.8	MB	29.4
Aman 2017-18	73	67	Good	Tr/Wb_5	8.5	3.1	MB	27.4

Table 10. Chemical and cooking properties of rice samples with seasonal variation for BR3.

Season	Alkali spreading value	Amylose (%)	Protein (%)	Cooking time (min.)	ER	IR
Boro 2016-17	7.0	26.3	9.5	17.50	1.4	3.4
Aus 2016-17	7.0	26.4	8.4	18.0	1.4	3.4
Aman 2017-18	7.0	26.4	9.0	18.0	1.4	3.4

water soluble vitamins such as thiamin and riboflavin along with physicochemical and cooking properties. In addition, some profound vitamin enriched HYVs were examined for mineral content such as zinc, iron, phytic acid (PA) and molar ratio of PA to minerals and those were evaluated over variation of degree of milling (DOM%) and polishing time (Seconds). Our data revealed that BRRI dhan36 had the highest thiamin content ($mg100^{-1}g$) of 1.15 followed by BRRI dhan29 (1.14), BRRI dhan48 (1.12), BRRI dhan28 (1.09) and BRRI dhan43 (1.08), BR16 (1.09), BR25 (0.93), BRRI dhan38 (0.93), BRRI dhan64 (0.89) and BRRI dhan42 (0.85) among all the tested 35 BRRI HYVs in Bangladesh (Table 12). Both BRRI dhan43 and BRRI dhan42 had higher Zn content (mg kg^{-1}) of 27.17 and 27.12 among all the tested BRRI HYVs rice varieties at 10% DOM (Fig. 3, Table 15). In addition, we had also observed that grain size and shape had significant impact on degree of milling (DOM) and mineral content trends to be decreased significantly over increasing the polishing time (Table 14). Considering all nutritional values such as water-soluble vitamins specially thiamin, protein, apparent amylose content, cooking time, elongation ratio, imbibition ratio, mineral contents such as Zn, Fe, PA and molar ratio of PA to minerals into account, BRRI dhan43 followed by BRRI dhan42 found suitable to treat as nutriceutically enriched HYV rice in Bangladesh among all the tested HYVs (Tables 11, 12, 13, 14 and 15). Consuming both BRRI dhan43 and BRRI dhan42 as nutraceutically enriched rice alternately, might impact on nutritionally challenged vulnerable portion of Bangladeshi population specially women and children under five years of age.

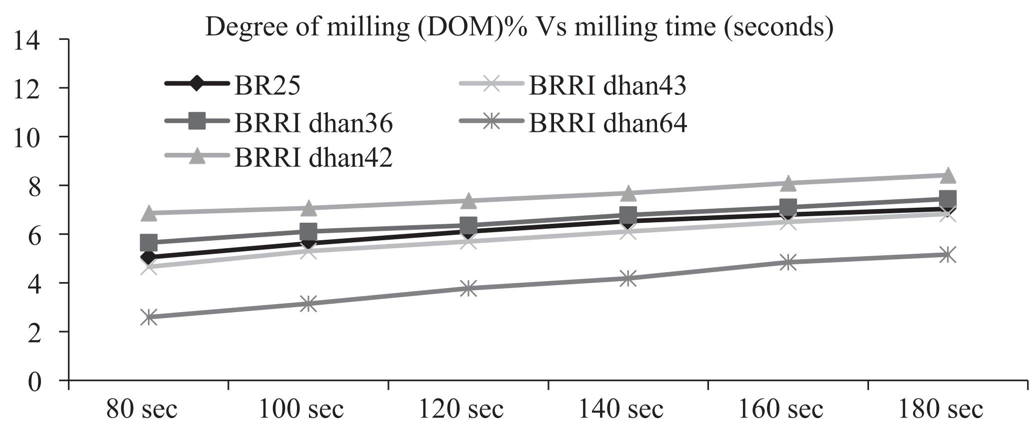


Fig. 3. Varietal differences of degree milling (DOM%) over polishing time (80 sec-180 sec at grainman rice polisher).

Table 11. Chemical and cooking properties of 35 BRRI HYVs.

Variety	Protein (%)	AAC (%)	Cooking time (Min)	ER ratio	IR ratio
BR3	8.1	26.2	17.0	1.4	3.4
BR5	9.0	26.0	14.0	1.6	3.4
BR6	7.1	26.0	17.0	1.4	3.6
BR7	8.1	22.3	16.0	1.3	3.5
BR10	8.3	26.0	16.0	1.3	3.7
BR11	8.2	26.0	17.0	1.4	3.6
BR14	7.5	27.1	18.0	1.4	3.6
BR16	7.4	27.0	18.0	1.4	3.5
BR17	7.0	27.0	20.0	1.4	3.7
BR18	8.2	27.0	21.0	1.3	3.7
BR19	7.5	26.2	18.0	1.3	3.6
BR21	8.8	25.1	15.0	1.4	3.4
BR22	7.3	26.0	18.0	1.5	3.8
BR23	7.8	27.2	17.0	1.4	3.4
BR25	9.1	25.9	19.0	1.4	4.0
BR26	8.4	22.6	19.5	1.3	4.1
BRRI dhan28	8.7	26.5	17.5	1.5	4.3
BRRI dhan29	7.0	27.0	18.5	1.4	4.4
BRRI dhan31	8.9	26.5	20.5	1.4	4.0
BRRI dhan34	10.2	23.0	13.0	1.4	4.0
BRRI dhan36	10.1	25.4	19.0	1.3	3.7
BRRI dhan37	10.4	23.8	20.0	1.2	3.7
BRRI dhan38	8.8	22.6	19.0	1.3	3.7
BRRI dhan39	8.4	26.6	19.5	1.3	3.7
BRRI dhan40	7.6	25.7	19.0	1.4	4.0
BRRI dhan41	6.4	24.6	17.5	1.4	4.0
BRRI dhan42	8.4	26.1	18.5	1.4	4.3
BRRI dhan43	7.5	26.7	15.5	1.4	4.4
BRRI dhan46	8.2	24.7	16.3	1.4	3.3
BRRI dhan47	6.6	26.1	22.0	1.4	3.6
BRRI dhan48	8.0	26.8	18.3	1.4	3.4
BRRI dhan49	8.7	24.8	20.0	1.4	3.6
BRRI dhan58	7.2	26.0	15.4	1.3	3.0
BRRI dhan61	7.1	20.0	16.0	1.3	3.5
BRRI dhan64	7.4	23.0	22.0	1.4	3.1
Mean± STD	8.1±1.0	25.4±1.7	17.9±2.1	1.4±0.1	3.7±0.3
Range	6.4-10.4	20.0-27.0	13.0-22.0	1.2-1.6	3.0-4.4

Table 12. Water soluble vitamins (thiamin and riboflavin) profiling of 35 BRRI HYVs.

Variety	Thiamin in $mg100^{-1}g$	Riboflavin in $mg100^{-1}g$
BR 3	0.46	0.056
BR 5	0.80	0.071
BR 6	0.56	0.019
BR 7	0.40	0.008
BR 10	0.55	0.069
BR 11	0.51	0.042
BR 14	0.59	0.095
BR 16	1.05	0.075
BR 17	0.45	0.039
BR 18	0.67	0.060
BR 19	0.62	0.045
BR 21	0.45	0.011

Table 12. Continued.

Variety	Thiamin in mg100^{-1}g	Riboflavin in mg100^{-1}g
BR 22	0.82	0.032
BR 23	0.83	0.014
BR25	0.93	0.080
BR 26	0.53	0.002
BRRI dhan28	1.09	0.045
BRRI dhan29	1.14	0.047
BRRI dhan31	0.84	0.044
BRRI dhan34	0.79	0.038
BRRI dhan36	1.15	0.019
BRRI dhan37	0.83	0.057
BRRI dhan38	0.93	0.080
BRRI dhan39	0.58	0.017
BRRI dhan40	0.83	0.058
BRRI dhan41	0.78	0.048
BRRI dhan42	0.84	0.030
BRRI dhan43	1.08	0.064
BRRI dhan46	0.75	0.016
BRRI dhan47	0.73	0.030
BRRI dhan48	1.12	0.023
BRRI dhan49	0.84	0.025
BRRI dhan58	1.09	0.046
BRRI dhan61	0.82	0.026
BRRI dhan64	0.89	0.045
Mean±STD	0.78±0.22	0.042±0.023
Ranges	0.41-1.15	0.002-0.095

Table 13. Mineral profiling of 10 selected BRRI HYVs (DOM at 10.20±0.22 %).

Variety	DOM%	Zn (ppm)	Fe (ppm)	PA (mg/g)	PA/Zn (M/R)	PA/Fe (M/R)
BR 16	10.20	16.49	5.16	ND	ND	ND
BR25	10.12	21.30	4.54	19	9.0	43.0
BRRI dhan28	10.43	15.21	8.17	ND	ND	ND
BRRI dhan29	10.30	16.02	7.78	ND	ND	ND
BRRI dhan36	10.38	20.43	10.12	15	6.0	13.0
BRRI dhan38	10.11	10.19	20.32	ND	ND	ND
BRRI dhan42	10.46	27.12	4.13	14	5.0	23.0
BRRI dhan43	10.43	27.17	10.09	14	3.0	4.0
BRRI dhan48	9.56	11.30	9.11	ND	ND	ND
BRRI dhan64	10.15	20.10	11.21	24	10.0	18.0

Mineral profiling of selected BRRI HYVs with thiamin (VitB1) level is ≥ 0.85 mg100^{-1}g. Phytic acid (PA) and molar ratio PA to minerals (Zn and Fe) were analyzed for BRRI HYVs with Zn level ≥ 20 ppm. ND=Not done, M/R=Molar Ratio.

Table 14. Variation of DOM% of 5 HYVs at different time points (80 sec, 140 sec and 180 sec).

HYVs	L (mm)	L/B ratio	Size and shape	DOM% at 80 sec	DOM% at 140 sec	DOM% at 180 sec
BR25	4.7	2.6	SB	8.65^{a}	10.12^{a}	10.62^{a}
BRRI dhan36	6.1	3.2	LS	9.24^{b}	10.38^{b}	11.04^{b}
BRRI dhan42	6.5	3.1	LS	10.46^{c}	11.28^{c}	12.02^{c}
BRRI dhan43	5.8	2.4	MB	8.25^{d}	9.30^{d}	10.43^{d}
BRRI dhan64	5.3	2.1	MB	6.19^{e}	7.78^{e}	10.15^{e}

L:Length; L/B ratio: Length /Breadth ration of polish rice: Size and shape; SM; Small and medium; LS; Long and slender; MB; Medium and Bold; DOM: Degree of milling; ppm:mg kg^{-1}. 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).

Table 15. Variation of Zn content (ppm or $mgKg^{-1}$) of 5 HYVs at different time points (80, 140, and 180 sec).

Polishing time (sec)	Variety				
	BR25	BRRI dhan36	BRRI dhan42	BRRI dhan43	BRRI dhan64
80	24.70^{a}	23.6^{a}	27.12^{a}	38.40^{a}	24.46^{a}
140	21.30^{b}	20.43^{b}	24.21^{b}	32.90^{b}	22.10^{b}
180	18.21^{c}	17.34^{c}	20.43^{c}	27.17^{c}	20.10^{c}

ppm: $mgKg^{-1}$. Any two means having common letter (s) are not statistically different at a $P< 0.05$, as measured by the DMRT.

In this study protein content of BRRI HYVs were found 8.1±1.0 % on average along with ranged from 6.4%-10.4%. According to HIES BBS, 2016 data of Bangladesh, per capita rice consumption is 367 (g $capita^{-1}day^{-1}$). Considering the amount into account, we are getting approximately 29.73 g (8.1*367 100^{-1}g) of protein from rice daily, where RDA of protein is 56g for an average 70 kg (Recommended amount is 0.8 g protein intake kg^{-1} body weight day^{-1}) weighted individual of Bangladeshi population. BRRI dhan34, BRRI dhan36 and BRRI dhan37 possess more than 10% of protein at brown rice condition. Apparent amylose content (AAC) is very important characteristic for varietal characterization and development. Since Bangladeshi population usually prefers non-sticky rice over sticky rice. Even though, there is no single trait responsible for significant correlation between AAC and stickiness of rice but others such as alpha amylase inhibitor, milling degree etc. BRRI usually prefers to release advanced lines whose AAC is preferably higher than 25% and it found at a range from 20 to 27% of ACC (Table 11). BRRI dhan43 and BRRI dhan42 has relatively high AAC value of 26.7 and 26.1% respectively. Cooking time is very important regarding fuel consumption assessment. Lower cooking time refers for lower fuel consumption. In this experiment, we found cooking time ranged from 13 to 22 minutes after attaining boiling temperature. Short grain HYVs such as BR5, BRRI dhan34 possess lower cooking times of 13 -14 minutes and bold types grain HYVs such as BRRI dhan47 and BRRI dhan64 possess higher cooking times of 22 minutes (Table 11). Elongation ratio (ER) and imbibition ratio (IR) of a rice variety indicates how much water can be uptaken by selective variety and it also gave us its indication of appearance as well. More IR score means particular HYV can uptake more water to produce more cooked rice. Both BRRI dhan29 and BRRI dhan43 possess IR score of 4.4 (Table 11), which means one kg of each individual can produce 4.4 kg of cooked rice. This is one of the reasons behind the popularity of BRRI dhan29 and BRRI dhan43 at Boro and Aus season respectively in Bangladesh.

Our data reveal that BRRI HYVs possess thiamin on average 0.78±0.22 $mg100^{-1}g$ with a range from 0.41 to 1.15 $mg100^{-1}g$ and riboflavin average 0.042±0.023 $mg100^{-1}g$ with a range from 0.002 to 0.095 $mg100^{-1}g$ at (8.0±0.50% polished) milled rice. BR16, BRRI dhan28, BRRI dhan29, BRRI dhan36, BRRI dhan43, BRRI dhan48 and BRRI dhan58 possess more than 1.0 $mg100^{-1}g$ of thiamin (Table 12). Since per capita rice consumption is 367 (g $capita^{-1}day^{-1}$) in Bangladesh so, considering the amount into account, we are getting approximately 3.67 mg (1.0*367 100^{-1}mg) of thiamin from rice daily where RDA of thiamin for adults is 1.2 mg day^{-1} for men and 1.1 mg day^{-1} for women. If we consider average thiamin content of 0.78±0.22 $mg100^{-1}g$ into account then we will get 2.87 mg (0.781*367 100^{-1}mg) of thiamin daily from rice intake only (Table 12). The median intake of thiamin from food in the United States is approximately 2 mg day^{-1}, and the ninety-fifth percentage of intake from both food and supplements was approximately 6.1 mg day^{-1}. Since thiamin is a water soluble vitamin so tolerable upper intake level (UL) for thiamin is not fixed yet [27] but deficiency is scared. Our BRRI HYVs are found very good source of thiamin. Regarding riboflavin, BRRI HYVs possess riboflavin on average 0.042±0.023 $mg100^{-1}g$ with a range from 0.002 to 0.095 $mg100^{-1}g$ at (8.0±0.50% polished) milled rice. We can get approximately 0.15 mg (0.042*367 100^{-1}mg) of thiamin from rice daily where RDA of riboflavin for adults is 1.3 mg $day^{-1}$for men and 1.1 mg $day^{-1}$for women [28]. So, it seems that rice is not a good source of riboflavin but BR14 showed the highest amount of riboflavin content (0.095 $mg100^{-1}g$). It could serve maximum of 0.35 mg (0.095*367 100^{-1}mg) riboflavin daily (Table 12). Selective mineral profiling of BRRI HYVs were analyzed and the selection criteria was set at the level of Thiamin (VitB1) is $\geq$ 0.85 mg100^{-1}g (Tables 12 and 13). Phytic Acid (PA) and molar ratio of PA to minerals (Zn and Fe) were also selectively analyzed and the selection criteria were set at the level of Zn is $\geq$ 20 mg kg^{-1}. In this regard, 10 BRRI HYVs were examined for mineral profiling such as Zn and Fe content and among them only five BRRI HYVs were also examined for PA and molar ratio of PA to minerals (Zn and Fe). Table 13 presents the all mineral data where DOM was approximately 10.2±0.22 g100^{-1}g. Zn content of both BRRI dhan43 (27.17 mg kg^{-1}) followed by BRRI dhan42 27.12 mg kg^{-1} were found higher in this study even at (10.20±0.22) g100^{-1}g DOM. Shozib *et al,* 2017 reported mineral profiling of 68 BRRI HYVs in Bangladesh but Zn content varied for these reported varieties because of variation in DOM percentage. Eighty seconds of polishing by Gainman polisher was applied for all tested varieties those gave around 8.5 g100^{-1}g of DOM as average. Grain size and shape also has a role in DOM so we tried to explore the explanation of zinc content variation over increasing DOM. Our data reveal that mineral content especially Zn content varied over increasing DOM and polishing time (Fig. 3 and Table 14). Lamberts *et al*, 2007 reported that the mineral content is the highest in bran (61.0 g100^{-1}g), followed by outer endosperm (23.7 g100^{-1}g), core endosperm (11.6 g100^{-1}g), and the lowest in the middle endosperm (3.7 g100^{-1}g). Proteins, minerals and starch were not uniformly distributed in the brown rice kernel. Bran (0 g100^{-1}g < DOM < 9 g100^{-1}g) contained most of the minerals (61.0 g100^{-1}g). We found variation in Zn content with increasing polishing time from 80 seconds to 180 seconds and DOM (Table 14). At 80 seconds of polishing, DOM variation ranged from 6.19 to 10.46 g100^{-1}g for five selected HYVs whose grain size and shape are also varied from small and medium grain, long and slender grain, medium and bold grain etc. Zn content of BR25, BRRI dhan36, BRRI dhan42, BRRI dhan43 and BRRI dhan64 were 24.70 mg kg^{-1}, 23.60 mg kg^{-1}, 27.12 mg kg^{-1}, 38.40 mg kg^{-1} and 24.46 mg kg^{-1} respectively at 80 seconds of polishing. Zn content of BR25, BRRI dhan36, BRRI dhan42, BRRI dhan43 and BRRI dhan64 were 21.30 mg kg^{-1}, 20.43 mg kg^{-1}, 24.21 mg kg^{-1}, 32.90 mg kg^{-1} and 22.10 mg kg^{-1} respectively at 140 seconds of polishing where DOM variation ranged from 7.78 to 11.28%. Finally Zn content of BR25, BRRI dhan36, BRRI dhan42, BRRI dhan43 and BRRI dhan64 were 18.21 mg kg^{-1}, 17.34 mg kg^{-1}, 20.43 mg kg^{-1}, 27.17 mg kg^{-1} and 20.10 mg kg^{-1} at 180 seconds of polishing where DOM variation ranged from 10.15 to 12.02 g100^{-1}g (Tables 14, 15). We have clearly demonstrated how Zn content and DOM g100^{-1}g of five different BRRI HYVs significantly varied at different polishing time ranged from 80 seconds to 180 seconds (Tables 14 and 15) considering grain size and shape into account.

PI: HBS **CI:** MAS

Post harvest loss minimization of rice bran for quality bran oil

The effect of physical and chemical treatments on the yields of oil, free fatty acid (FFA), peroxide value (PV), acid value, iodine value (IV), saponification value (SV), refractive index, relative density and fatty acid profiling in rice bran stabilization was examined. Rice bran oil percentage varied over varietal difference and mode of rice processing such as unparboiling and parboiling milling. In our experiment, we have used two HYVs such as BR16 and BRRI dhan28, and found that BRRI dhan28 HYV produces higher oil content g100^{-1}g and lesser FFA g100^{-1}g at parboiled condition than unparboiled. Since lipase activity of bran increases the FFA g100^{-1}g and decrease the oil g100^{-1}g of rice bran, so we had treated our experimental rice bran by three treatments such as untreated (control), heat treated (incubate at 130-135°C for two hours and chemically treated at the rate of 30ml HCl kg^{-1}. Our data clearly demonstrated that untreated rice bran at the 28 day of harvesting bran had grained the highest FFA g100^{-1}g and lowest oil g100^{-1}g compared to freshly harvested rice bran (Fig. 4). On the other hand, heat treated rice bran at the 28 day of harvesting bran had retained similar FFA g100^{-1}g and oil g100^{-1}g compared to freshly harvested rice bran (Fig. 5). But the chemically treated rice bran did not perform satisfactory in this regard (Fig. 6). Oil g100^{-1}g and FFA g100^{-1}g of parboiling milling processed rice bran showed higher value than unparboiled milling processed rice bran at three treatments such as untreated, heat treated and chemically treated (Figs. 7, 8, 9). Acid value (as KOH), mg g^{-1}, FFA as oleic g100^{-1}g, PV meq O_2^{-1}kg, and IV (Hanus method) and oil content

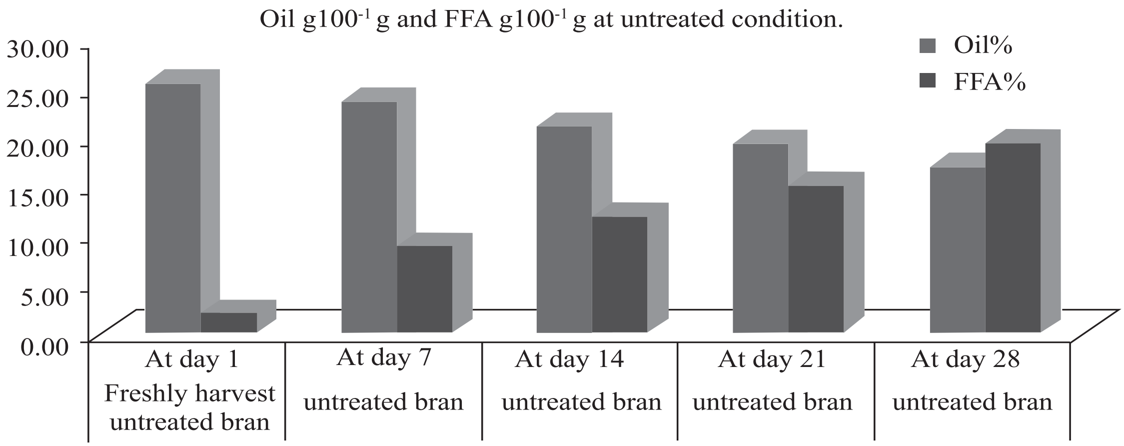


Fig. 4. Untreated BRRI dhan28 bran was used for extracting oil content $g100^{-1}g$ and measuring FFA $g100^{-1}g$ from freshly harvest to 28 days of storage at room temperature.

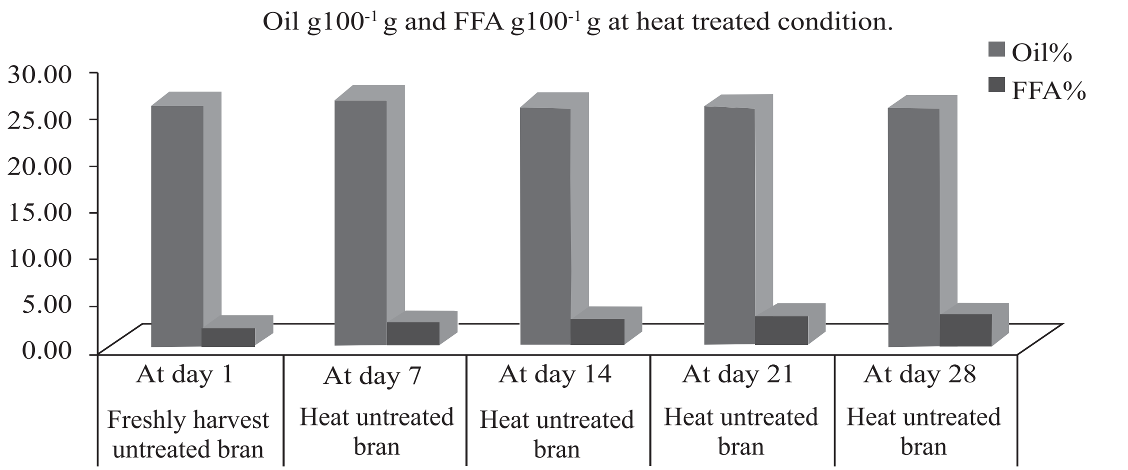


Fig. 5. Heat treated BRRI dhan28 bran was used for extracting oil content $g100^{-1}g$ and measuring FFA $g100^{-1}g$ from freshly harvest to 28 days of storage at room temperature.

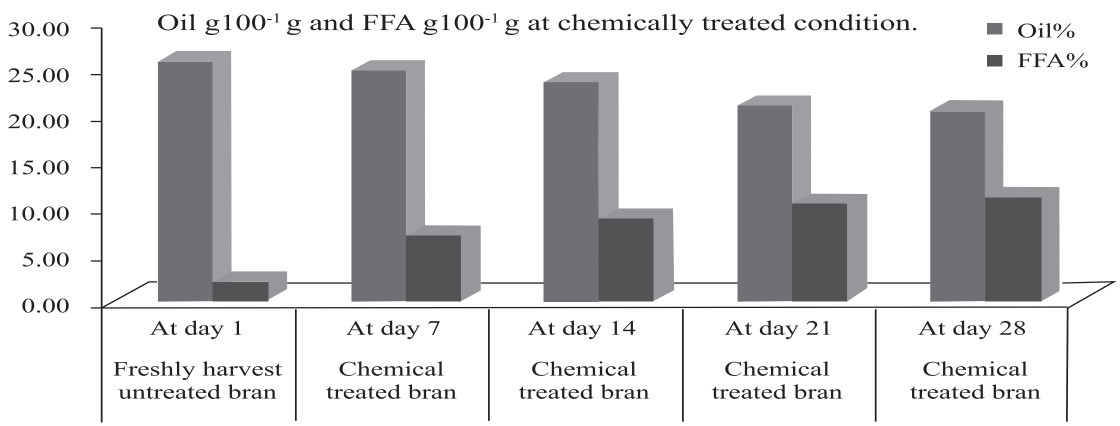


Fig. 6. Chemically treated BRRI dhan28 bran were used for extracting oil content $g100^{-1}g$ and measuring FFA $g100^{-1}g$ from freshly harvest to 28 days of storage at room temperature.

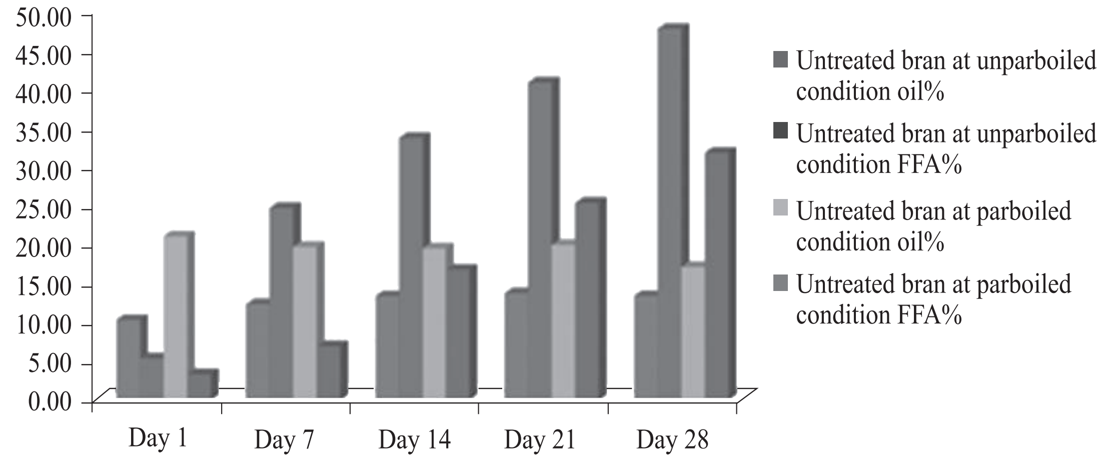


Fig. 7. Oil g100-1g and FFA g100-1g of untreated rice bran at both unparboiled and parboiled milling condition.

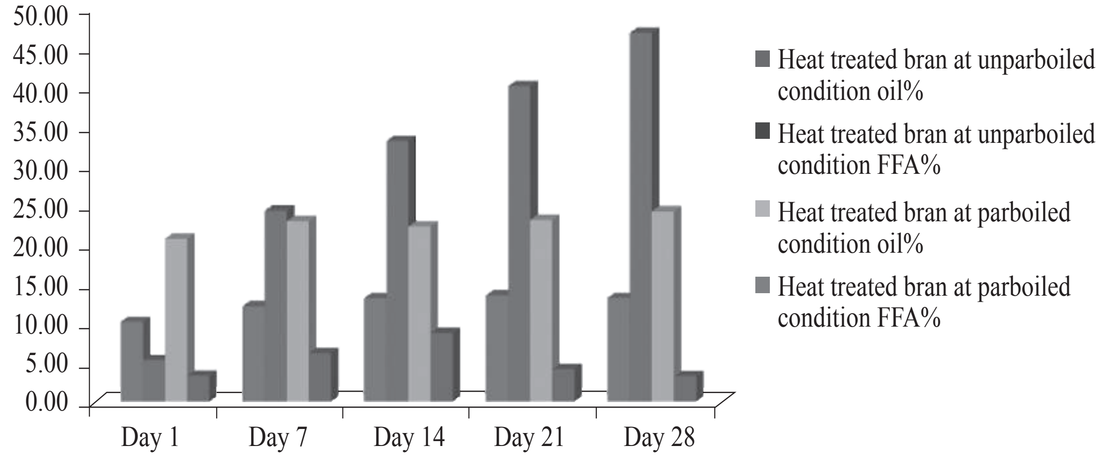


Fig. 8. Oil g100-1g and FFA g100-1g of heat treated rice bran at both unparboiled and parboiled milling condition.

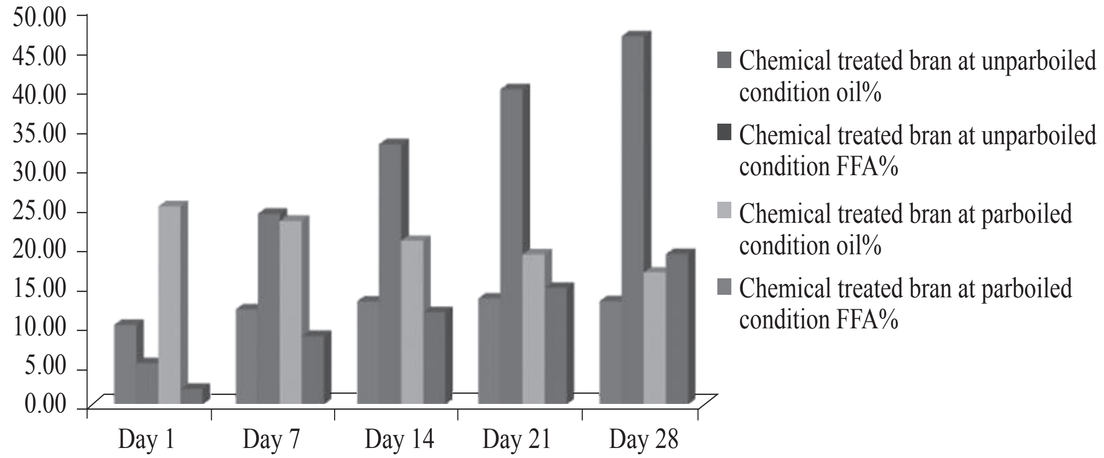


Fig. 9. Oil g100-1g and FFA g100-1g of chemically treated rice bran at both unparboiled and parboiled milling condition.

g100^{-1}g had significant variation among untreated, heat treated and chemically treated treatments at parboiled milling condition but SV, (as KOH) mg g^{-1}, refractive index at 40ºC and relative density at 300ºC did not show any difference (Table 16). Fatty acid profiling (FAP) of selected treated samples were found mostly with similar quality of saturated and unsaturated fatty acids composition between fresh and heat treated oils. It is further noticeable that heat treated rice bran could produce quality bran oil in respect to FAP and other tested oil chemistry parameters compared to freshly isolated rice bran even after 28 days (Table 17). In our experiment, we found RBO waste materials like as rice wax contained a reasonable portion of FFA as oleic g100^{-1}g ranges from 10.63 to 11.98 g100^{-1}g (Table 18). So, rice wax materials can be used in local soap industries (saponification) along with FFA and another is bleaching earth, which might become a source of alternate fueling in brick fields, boiler and potential source of organic matters in soil as volatile matter (g100^{-1}g w/w), ash content (g100^{-1}g w/w) and fixed carbon (g100^{-1}g w/w) were found at 41.48 g100^{-1}g, 48.47 g100^{-1}g and 5.32 g100^{-1}g respectively (Table 19).

PI: MAH **CI:** HBS

COMMERCIAL RICE BASED PRODUCTS

Physicochemical, cooking and sensory properties related to quality of rice noodles

Since rice is the staple and most important cereal of Bangladesh, value added production and diverse rice product is warranted. The laboratory analysis for the noodles quality evaluation was conducted at the Grain Quality and Nutrition Division at BRRI headquarters, Gazipur.

The moisture levels of all rice varieties varied between 11.44±0.68%-12.20±0.03%. The crude protein content was the highest for BRRI dhan28 (9.08%) followed by BRRI dhan29 and BR26 (8.72%). Fat content of rice ranged from 1.69-1.85% where 1.85±0.01% for BR26 and 1.69±0.02% in BRRI dhan28. The fiber percentages of all varieties were below 2.5%. BR26 had the highest fiber percentage (2.20%), followed by BRRI dhan29 (2.12%) and BRRI dhan28 (1.98%). BRRI dhan28 had the highest amount of ash (1.42%), followed by BRRI dhan29 (1.39%), and BR26 (1.35%). The carbohydrate content of all the varieties ranged from 73.68% to 74.39%. Food energy values were appreciably similar among all the rice varieties (Table 20). BRRI dhan28 provided the highest

Table 16. Quality parameters of rice bran oil (RBO) extracted from different treated rice brans (RB).

Test parameter	Crude oil (Parboiled condition) extracted from three different rice brans (RB)		
	Untreated as control (At day 28)	Heat treated (At day 28)	Chemical treated (At day 28)
Acid value, (as KOH), mg g^{-1}	38.90^a	6.60^b	22.08^c
Free fatty acid as oleic (FFA), g100^{-1}g	19.45^a	3.30^b	11.04^c
Peroxide value (PV), meq O_2 kg^{-1}	3.68^a	2.07^b	4.03^c
Iodine value (IV) (Hanus method)	97.00^a	90.00^b	105.00^c
Saponification value (SV) (as KOH), mg g^{-1}	181.00^a	182.00^b	180.00^c
Colour by lovibond	51.00^a	54.00^b	56.00^c
Refractive index at 40°C	1.46^a	1.47^a	1.46^a
Relative density at 30°C	0.90^a	0.91^a	0.91^a
Oil content %	17.08^a	25.38^b	20.34^c
Aflatoxins (B_1, B_2, G_1, G_2)	ND	ND	ND
Myristic acid g100^{-1}g	0.44^a	0.41^b	0.43^a
Palmitic acid g100^{-1}g	23.90^a	24.26^b	23.07^c
Stearic acid g100^{-1}g	1.32^a	1.32^a	1.23^b
Oleic acid g100^{-1}g	42.29^a	42.85^b	42.52^c
Linoleic acid g100^{-1}g	30.02^a	29.18^b	30.54^c
Linolenic acid g100^{-1}g	1.20^a	1.24^b	1.17^c
Arachidic acid g100^{-1}g	0.49^a	0.49^a	0.53^b
Ecosadoic acid g100^{-1}g	0.30^a	0.22^b	0.26^c

Any two means having common letter (s) are not statistically different at a $P< 0.05$, as measured by the DMRT. ND; Not detectable.

Table 17. Quality parameters of rice bran oil (RBO) extracted from rice bran (RB).

Test parameter	Crude oil (Parboiled condition) extracted from different rice bran (RB)	
	Untreated (Fresh)	Heat treated rice bran
Acid value, (as KOH), mg g^{-1}	4.00^{a}	6.60^{b}
Free fatty acid as oleic (FFA), g100^{-1}g	2.00^{a}	3.30^{b}
Peroxide value (PV), meq O_2 kg^{-1}	0.53^{a}	2.07^{b}
Iodine value (IV) (Hanus method)	91.00^{a}	90.00^{b}
Saponification value (SV) (as KOH), mg g^{-1}	182.00^{a}	182.00^{b}
Color by lovibond	47.00^{a}	54.00^{b}
Refractive index at 40°C	1.46^{a}	1.47^{a}
Relative density at 30°C	0.90^{a}	0.91^{a}
Oil content %	25.63^{a}	25.38^{a}
Aflatoxins (B_1, B_2, G_1, G_2)	ND	ND
Myristic acid g100^{-1}g	0.43^{a}	0.41^{a}
Palmitic acid g100^{-1}g	23.95^{a}	24.26^{b}
Stearic acid g100^{-1}g	1.36^{a}	1.32^{b}
Oleic acid g100^{-1}g	42.44^{a}	42.85^{a}
Linoleic acid g100^{-1}g	29.03^{a}	29.18^{a}
Linolenic acid g100^{-1}g	1.21^{a}	1.24^{a}
Arachidic acid g100^{-1}g	0.48^{a}	0.49^{a}
Ecosadoic acid g100^{-1}g	0.21^{a}	0.22^{a}

Any two means having common letter (s) are not statistically different at a P< 0.05, as measured by the DMRT. ND; Not detectable.

Table 18. Rice wax materials (byproduct of RBO) composition.

Parameter	Method/Instrument	Value
Acid value (as KOH), mg g^{-1}	IS 548-1964	15.08-16.99
Carbon (g100^{-1}g)	C H N S Analyzer	1.71-1.76
Hydrogen (g100^{-1}g)		6.97-7.31
Nitrogen (g100^{-1}g)		0.01-0.03
Sulpher (g100^{-1}g)		0%
Free fatty acid as oleic (FFA), g100^{-1}g	IS 548-1964	10.63-11.98
Melting point (°C)	BDS 908:2001	52-56

Table 19. Bleaching earth (waste materials of RBO) composition.

Parameter	Method/ Instrument	Value
Moisture content (g100^{-1}g w/w)	IP 2016-65	4.73
Ash content (g100^{-1}g w/w)	ASTM/IP4/58	48.47
Volatile matter (g100^{-1}g w/w)	Muffle furnace	41.48
Fixed carbon (g100^{-1}g w/w)	Physical	5.32
Higher calorific Value, kcal kg^{-1}	Bomb calorimeter	3411

energy among all the rice varieties analyzed (349.09 Kcal100^{-1}g) followed by BR26 (346.22 Kcal100^{-1}g) and BRRI dhan29 (346.01 Kcal100^{-1}g).

Table 21 presents the amylose content of tested varieties. BRRI dhan28 and BRRI dhan29 used in this study belong to high amylose (>25%) except BR26 that belongs to the intermediate amylose (20-25%). Significant differences (p<0.05) were observed among the amylose content of the rice varieties. All rice noodle samples showed a cooking time of 7-8 minutes. The highest value in water absorption rate was observed for BRRI dhan28 noodles (65.53%), followed by BRRI dhan29 (62.27%) and BR26 noodles (61.39%). The cooking loss of the noodles, found in that study, was between 4-7%. In indicates guarantee of quality in terms of water retention after being cooked.

Figure 10 presents the sensory attributes of rice noodles. The appearance of rice noodles was not significantly different among the noodles made out of different rice varieties. Noodles made from BR26 variety had higher values for taste and mouthfeel after chewing and were accepted by most of the panelists. There were no significant (p<0.05) difference observed for the surface and overall acceptability of rice noodles.

PI: SSD **CI:** MAS

Table 20. Proximate composition (%) and energy content (Kcal100^{-1}g) of prepared homemade rice noodles (dry weight basis).

Item	Moisture	Protein	Fat	Crude fiber	Ash	Carbohydrate	Energy
BR26	12.20±0.03	8.72±0.03	1.85±0.01	2.20±0.05	1.35±0.01	73.68±0.04	346.22±0.14
BRRI dhan28	11.44±0.68	9.08±0.02	1.69±0.02	1.98±0.03	1.42±0.00	74.39±0.65	349.09±2.78
BRRI dhan29	12.19±0.04	8.81±0.09	1.77±0.01	2.12±0.12	1.39±0.01	73.71±0.09	346.01±0.16
CD (P≤0.05)	1.37	0.20	0.05	0.12	0.02	1.32	5.58

Table 21. Chemical and cooking quality of prepared homemade rice noodles.

Rice variety	Amylose	ASV/ Gel temperature	Cooking time	Water absorption	Cooking loss	Rehydration ratio
BR26	22.73±0.12	4.0±0.02	7.0±0.03	61.39±0.01	5.63±0.01	1.60±0.01
BRRI dhan28	27.93±0.09	3.8±0.01	8.0±0.04	65.53±0.01	4.83±0.02	1.56±0.02
BRRI dhan29	29.20±0.06	3.1±0.01	8.0±0.04	62.27±0.02	6.69±0.04	1.48±0.01
CD(P≤0.05)	0.32	0.05	0.11	0.05	0.08	0.05

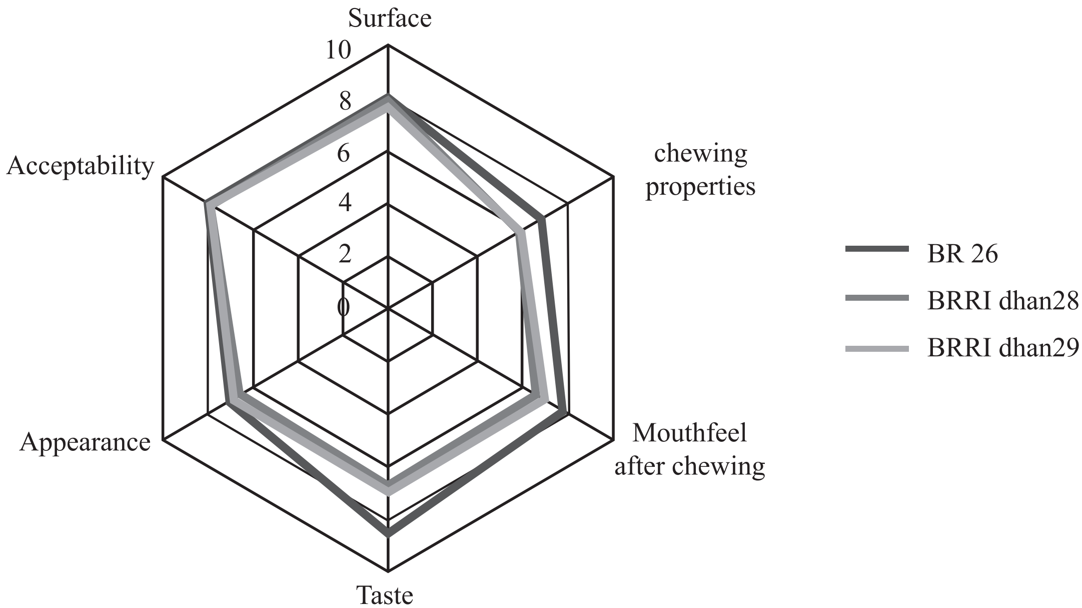


Fig. 10. Sensory evaluation of homemade rice noodles.

Value addition and standardization of nutritional level in selected food items to mitigate malnutrition

At present, total clean rice production of Bangladesh is about 34.8 MT, enough to satisfy the domestic requirement to feed more than 160 million people with the surplus of 2.06 MT. In contrast, there has been comparatively less progress on addressing the quality aspects of rice.

In this study, we selected 12 nutraceutical rice HYVs to prepare rice-based food formulation, i.e., as potential use of rice flour. All research activities were conducted at GQN Division of BRRI, Gazipur, Bangladesh. A total 12 nutraceutically enriched BRRI HYVs including B5, BR16, BRRI dhan31, BRRI dhan42, BRRI dhan43, BRRI dhan46, BRRI dhan62, BRRI dhan64, BRRI dhan69, BRRI dhan72, BRRI dhan74 and local landraces such as black rice (BK1) flours were used to prepare rice-based food items. Rice is a very good source of water soluble vitamins such as thiamine and riboflavin. BR5, BR16, BRRI dhan31, BRRI dhan43, BRRI dhan46 and BRRI dhan69 have thiamine (mg kg^{-1}) and riboflavin (mg kg^{-1}) levels of 8.0, 10.5, 8.4, 10.9, 7.5, 10.9 and 0.071, 0.075, 0.044, 0.064, 0.016, 0.060 respectively. In order to prepare rice-based food we have multiple options of choosing rice flour from the below mentioned nutraceutically enriched BRRI HYVs (Table 22). In rice based food formulation, customer's preference must be considered according to their necessity and demand. In Bangladesh, we do not have evidence based processed food. Since cancer is one of the fast growing non-communicable disease (NCD) at recent years in Bangladesh, anti-cancerous black rice based formulated foods might have immense potential (WHO, 2014). Considering the proximate analysis of rice (Table 23), among all tested HYVs in this study, it was found that black rice is the lowest carbohydrate (76%) containing rice variety. Cornejo *et al*, in 2015 reported that pre-germinated brown

Table 22. Selected nutraceutical BRRI HYVs for rice based food formulation.

Rice flour from selected HYVs	Special properties
Black rice	Anticancer property enriched.
BR16, BRRI dhan46 and BRRI dhan69	Antidiabetic property enriched.
PGBR BRRI dhan31(GABA enriched)	Anti-depressive property enriched.
BR5	Anti-oxidant property enriched.
BRRI dhan74 and BRRI dhan64	Zinc enriched.
BRRI dhan43 and BRRI dhan42	Micronutrient enriched both Zinc and iron.

rice flour has some added advantage over wheat flour as it is characterized as gluten-free, low GI, increasing amount of anti-oxidant activity, protein, GABA, phytase content and decreasing level of fat and carbohydrate. Hence, pre-germinated BRRI dhan31 (12 $mg100^{-1}g$ of GABA content) brown rice based food items has potential to make popular for a target population suffering from obesity, diabetis, hyperlipidemia, hypertension and Alzheimer's disease in Bangladesh. Nutraceuticaly enriched rice HYVs can be used to provide multiple options based on consumer's preference. For instance, micronutrient enriched (Zn and Fe) BRRI dhan43 and other reported Zn-enriched rice varieties might be suitable for preparing rice based products specially for malnourished population specially children under the age of five. In similar fashion, low GI indexed rice HYVs such as BR16 (52.4), BRRI dhan46 (53.1), and BRRI dhan69 (54.9) can be suitable as rice flour source to prepare rice-based food for diabetic patients in Bangladesh. A low GI diet has commonly been promoted as an effective way to help lose weight by controlling blood sugars and appetite. Considering the above situation into account, the low GI HYVs have potential to systematically combat non-communicable disease like diabetic in Bangladesh.

In this study, we have formulated energy dense rice biscuit (EDRB) and energy dense rice cake (EDRC) at ED 5.6 and 5.0 respectively (Tables 24 and 25). Earlier in 2015, Shozib *et al*, [32] reported few rice based food items such as rice ball (393 calories 100^{-1}g serving; ED 3.93), rice biscuit (479 calories 100^{-1}g serving; ED 4.79), rice plain cake (465 calories 100^{-1}g serving; ED 4.65) in an approach to create multiple options for diversified use of rice grain in Bangladesh. Since rice flour does not have gluten protein unlike wheat, so making dough seems difficult to get appropriate texture in reality. We tried several natural products to optimize its shape and texture such as sagu, a well-known lubricating agent, and dates; it enhances chewing properties rather than using xanthan gum (commercially available bacterial lyophilized powder).

Low cost, nutritious and balanced rice based food items can be distributed in emergency situations such as flood relief programme, earth quake disaster management, war engaged soldiers, refugee and social welfare related works such as improving health status of malnourished street children and climate change migrated population in Bangladesh. In the adverse situations, usually people suffer from inadequate intake of staples, and unavailability of fuel and cooking facilities. Hence, government as well as non-government organizations (GOs and NGOs) can distribute energy dense rice-based dry foods such as EDRC and EDRB to targeted

Table 23. Proximate analysis of few nutraceutical enriched BRRI HYVs.

Variety	*Protein	Moisture	Fat	Fiber	Ash	Carbohydrate
BR5	9.1	12.0	0.6	0.8	1.1	76.4
BR16	7.3	12.1	0.7	0.7	1.0	78.2
BRRI dhan31	8.9	11.8	0.6	0.8	1.1	76.8
BRRI dhan43	7.5	12.1	0.6	0.7	1.2	77.9
BRRI dhan46	8.1	12.3	0.6	0.8	1.0	77.2
BRRI dhan64	7.1	11.8	0.8	0.8	1.1	78.4
BRRI dhan69	8.0	12.0	0.7	0.7	1.0	77.6
BRRI dhan74	8.3	11.8	0.5	0.8	1.1	77.5
Black rice	9.5	12.2	0.6	0.7	1.0	76.0

Note: All parameters were analyzed at milled rice condition except protein.*Protein was estimated at brown rice condition.

Table 24. Energy dense rice biscuit (EDRB) formulated by GQN Division, BRRI. (Proximate analysis).

Nutritional fact sheet	EDRB per 100g
Zinc	1.50 mg
Iron	0.71 mg
Calcium	2.80 mg
Phosphate	8.5 mg
As	<0.1 ppm
Pb	<0.1 ppm
Cd	<0.1 ppm
Ni	<0.1 ppm
Carbohydrate	47.4g
Fat	36.0g
Protein	10.0g
Moisture	4.5g
Dietary fiber	2.0g
Energy	559 kcal
ED	5.6

Table 25. Energy dense rice cake (EDRC) formulated by GQN Division, BRRI. (Proximate Analysis).

Nutritional fact sheet	EDRC per 100g
Zinc	1.15 mg
Iron	0.51 mg
Calcium	2.04 mg
Phosphate	7.5 mg
As	<0.1 ppm
Pb	<0.1 ppm
Cd	<0.1 ppm
Ni	<0.1 ppm
Carbohydrate	48g
Fat	30.0g
Protein	10.0g
Moisture	11.0g
Dietary fiber	1.0g
Energy	500 kcal
ED	5.0

population to provide preliminary boost up feeding to mitigate malnutrition (Table 11).

PI: HBS CI: MAS

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

Puffed rice. Among the tested varieties, the fully puffed rice yield varied from 1.7-70.3% and partially puffed rice was 17.5-98.2% whereas the standard fully puffed rice yield was 79% (Table 26). The range of 1,000 puffed rice weight was 13.3-20.7g and the volume of 50g puffed rice was 357-555mL. Length and breadth increased 157-222% and 105.4-226% respectively comparing with milled rice. Compared with standard variety BR16, fully puffed rice, length and breadth increase percentage it can be concluded that BRRI dhan59, BRRI dhan60, BRRI dhan62 and BRRI dhan66 were more or less suitable for making puffed rice.

Popped rice. The range of fully and partially popped rice was 0.78-48.9% and 3.1-15.3% respectively (Table 27). Among the varieties, BRRI dhan62 and BRRI dhan67 showed higher quality of fully popped rice and BRRI dhan60, BRRI dhan65 and BRRI dhan66 demonstrated almost similar quality comparing with the standard (BR16). BRRI dhan60 and BRRI dhan64 showed almost similar weight compared with standard (BR16). The volume of 50g popped rice was the highest in BRRI dhan62. It might be concluded that BRRI dhan60, BRRI dhan62, BRRI dhan65, BRRI dhan66 and BRRI dhan67 varieties were suitable for popped rice production.

Flattened rice. Flattened rice of 12 varieties were produced by local commercial flattened rice producer. Total yield of flattened rice varied from 25.2 to 92.0%. The highest fully flattened (80.6%) quality was found in BRRI dhan64 and the lowest (25.2%) in BRRI dhan67 (Table 28). The weight of 1000 flattened rice was the highest in BRRI dhan68. The enlargement of length and breadth varied from 166.4 to 222.0% and from 140.0 to 194.1% respectively over the milled rice. Considering the above physical properties, BRRI dhan62, BRRI dhan64, BRRI dhan65, BRRI dhan66 and BRRI dhan68 can be used for commercial purpose to produce flattened rice.

PI: MAH **CI:** SH and MAS

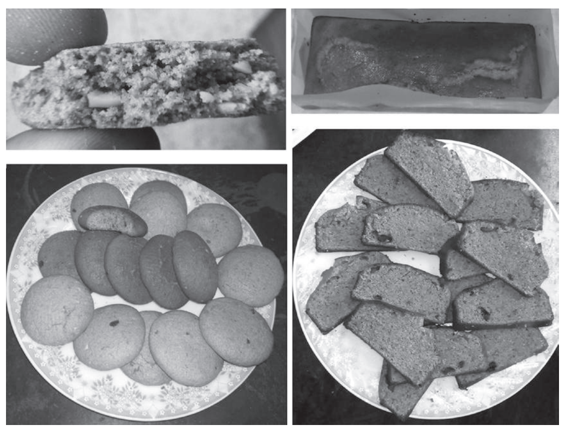


Fig 11. EDRB and EDRC HEBs formulated by GQN Division, BRRI.

Table 26. Physical properties of puffed rice of BRRI modern varieties.

Variety name	Fully puffed (%)	Broken (%)	Partial puffed (%)	Length increase (%)	Breadth increase (%)	1000 grain wt (g)	50 g volume (ml)
BR16 (std)	79.0	-	17.5	222.0	226.0	19.3	555
BRRI dhan59	51.8	-	34.4	157.0	107.0	17.1	410
BRRI dhan60	70.3	-	29.6	169.8	105.4	16.6	420
BRRI dhan61	10.4	-	94.0	173.2	150.0	13.3	433
BRRI dhan62	49.6	-	50.2	181.2	187.6	16.5	350
BRRI dhan63	35.2	-	64.7	191.6	195.2	14.3	500
BRRI dhan64	4.1	-	95.8	176.4	166.8	17.8	357
BRRI dhan65	1.7	-	98.2	170.1	177.0	14.6	479
BRRI dhan66	65.8	-	34.0	197.6	211.0	16.6	500
BRRI dhan67	17.6	-	82.2	196.7	178.0	15.5	483
BRRI dhan68	38.4	-	61.5	181.7	172.0	20.1	418
BRRI dhan69	11.4	-	88.4	193.7	157.5	20.7	410

Table 27. Physical properties of popped rice of BRRI modern varieties.

Variety name	Fully popped (%)	Broken (%)	Partial Popped (%)	Unpopped (%)	Hull (%)	Wastage (%)	Length increase (%)	Breadth increase (%)	1000 grain wt (g)	50 gvolume (ml)
BR16 (std)	45.7	2.2	10.2	2.2	22.5	6.2	217.0	151.0	20.0	690
BRRI dhan59	13.7	-	13.2	39.8	6.5	14.4	160.0	183.6	17.5	516
BRRI dhan60	40.2	1.3	9.7	19.7	14.0	3.6	199.0	194.5	19.2	680
BRRI dhan61	33.5	2.0	14.1	18.1	15.8	3.6	185.1	179.0	16.8	600
BRRI dhan62	48.9	4.7	3.1	8.6	19.1	3.2	226.0	217.0	18.6	940
BRRI dhan63	28.5	1.3	9.6	31.7	13.0	4.1	197.0	192.6	16.0	620
BRRI dhan64	3.3	-	15.3	5.5	5.8	6.1	160.9	173.2	19.8	461
BRRI dhan65	43.1	1.5	7.1	2.9	29.3	3.3	200.0	223.0	17.9	740
BRRI dhan66	44.7	0.4	9.6	14.1	16.3	4.3	196.9	204.0	18.0	690
BRRI dhan67	47.3	2.1	7.6	10.8	17.7	3.1	197.9	200.0	15.6	710
BRRI dhan68	0.78	-	11.5	58.6	4.2	11.6	176.0	177.0	11.2	500
BRRI dhan69	37.1	0.98	7.7	19.1	13.4	4.3	214.0	208.3	18.5	765

Table 28. Physical properties of flattened rice of BRRI modern varieties.

Variety name	Fully flattened (%)	Broken (%)	Partial flattened (%)	Length increase (%)	Breadth increase (%)	Thick ness (mm)	1000 grain wt (g)	50 gm volume (ml)
BR16 (std)	92.0	7.5	-	222.0	140.0	0.70	21.55	180
BRRI dhan59	29.8	69.2	1.82	177.3	169.0	0.75	18.45	105
BRRI dhan60	42.0	45.7	-	171.9	161.8	0.71	18.15	130
BRRI dhan61	39.3	59.2	-	208.9	174.5	0.62	16.3	150
BRRI dhan62	64.1	34.6	-	193.8	184.2	0.68	19.7	140
BRRI dhan63	30.3	68.8	-	166.4	154.2	0.77	15.8	95
BRRI dhan64	80.6	46.8	-	192.2	186.4	0.77	20.7	125
BRRI dhan65	69.7	18.7	1.0	183.6	156.0	0.8	18.8	135
BRRI dhan66	68.6	31.2	-	200.0	195.0	0.64	19.6	130
BRRI dhan67	25.2	72.0	6.0	205.6	194.0	0.82	17.1	130
BRRI dhan68	69.8	25.0	9.92	177.2	163.3	0.87	23.4	95
BRRI dhan69	39.7	56.2	8.98	202.5	194.1	0.74	20.8	135

Author's abbreviation: MAS=Muhammad Ali Siddiquee; MAH=Md Anwarul Haque; SSD=Sharifa Sultana Dipti; NF=Nilufa Ferdous; HBS= Habibul Bari Shozib; SH= Shakir Hosen.

Hybrid Rice Division

SUMMARY

Forty-eight test crosses and 215 (A × R) crosses were made from source nursery in T. Aman season 2017. A total of 184 test crosses (F_1s) were evaluated for their pollen fertility status of which nine entries have been found heterotic over check varieties. Pollen parents of those combinations were regarded as suspected restorers and selected for fertility restoration ability with other CMS lines in the next season. Twelve entries were found completely sterile and their corresponding male parents were regarded as suspected maintainer lines. Nineteen backcross generations were advanced as new CMS lines. Other backcross generations except for one BC_1 generation was found unstable in terms of pollen sterility and hence discarded. Fifty-nine CMS lines along with their respective maintainer lines were maintained by hand crossing.

A total of 60 test crosses and 417 (A × R) crosses were made using nine CMS lines in Boro season 2017-18. One hundred forty test crosses (F_1s) were evaluated for their pollen fertility status. Among them five entries showed complete sterility and immediately backcrossed with their corresponding male parents for conversion. On the other hand, six entries have been selected for their high yielding ability compared with check varieties. Four BC_6 generations were advanced as new CMS lines and shifted to CMS nursery. Other entries were advanced to the next generations except for four BC_1 generations. They were discarded due to instability in pollen fertility. Eighty-six CMS lines along with respective maintainer lines were maintained by hand crossing in CMS maintenance and evaluation nursery for their genetic purity.

In T. Aman, out of 261 test hybrids under observational trials ten hybrid combinations were selected based on yield, duration and grain type those produced more than 19-33% yield advantage over check variety BRRI dhan49, 10-22% over BRRI hybrid dhan4 and 2-13% over BRRI hybrid dhan6 but growth duration was two to four weeks earlier than check variety BRRI dhan49. Out of 303 test hybrids 16 hybrid combinations were selected based on yield, duration and grain type and showed yield advantage 4-20% over BRRI hybrid dhan5 with growth duration similar to BRRI dhan28 but one to two weeks earlier growth duration than BRRI dhan29. Under preliminary yield trials three hybrids out of twelve produced more growth duration than one ton yield advantage over BRRI dhan49 and exhibited yield advantage over BRRI hybrid dhan4 by 15-24% and BRRI hybrid dhan6 by 6-15% in T. Aman 2017. In Boro 2017-18, eighteen hybrids were evaluated along with two hybrid and two inbred checks and all the selected hybrids showed yield advantage ranging from 32-59% over BRRI dhan28 and 18-41% over BRRI dhan29. Three hybrid combinations had out yielded BRRI hybrid dhan3 and BRRI hybrid dhan5 by more than one ton. National hybrid rice yield trials were conducted through SCA in T. Aman 2017 and Boro 2017-18, which included eight and 36 hybrids. Results were compiled by SCA.

Seed yield of 476 kg/plot (1.4 t/ha), 364 kg/plot (1.3 t/ha), 456 kg/plot (1.2 t/ha), 192 kg/plot (1.2 t/ha) and 180 kg/plot (1.5 t/ha) were obtained from BRRI10A, BRRI11A, IR58025A, BRRI7A and IR79156A respectively in T. Aman 2017. On the other hand, in Boro 2017-18, CMS seed yields of 480 kg (2.2 t/ha), 370 kg (2.2 t/ha), 433 kg (2.3 t/ha), 240 kg (1.6 t/ha), 575 kg (2.4 t/ha) and 80 kg (2.4 t/ha) were obtained from BRRI7A, BRRI10A, BRRI11A, IR58025A, IR79156A and BRRI32A respectively. A total of 230 kg (1.3 t/ha) and 130 kg (1.3 t/ha) hybrid seeds were produced from BRRI hybrid dhan5 (BRRI7A/BRRI31R) and BRRI hybrid dhan6 (IR79156A/BRRI20R) respectively during T. Aman 2017. In Boro 2017-18 seasons, a total of 975 kg (2.6 t/ha) from BRRI hybrid dhan2, 1250 kg (2.5 t/ha) from BRRI hybrid dhan3, 938 kg (1.65 t/ha) from BRRI hybrid dhan4, 510 kg (1.8) t/ha) from BRRI hybrid dhan5 and 450 kg (1.9 t/ha) from BRRI hybrid dhan6 were obtained. A total of 52400 kg F_1 seeds were produced during Boro 2017-18 with the technical assistance of BRRI, which included BADC, 12 seed companies and regional stations of BRRI. In the reporting year, Hybrid Rice Division supplied 9,767 kg of parental lines and F_1 seeds to 80 farmers, 12 seed companies, scientists and staffs of BRRI.

DEVELOPMENT OF PARENTAL MATERIALS

Source nursery

Forty-eight test crosses and 215 (A x R) crosses were made using eight CMS lines in T. Aman 2017.

Sixty test crosses and 417 (A × R) crosses were made using nine CMS lines in Boro 2017-18.

Test cross nursery

In T. Aman 2017, out of 184 test crosses (F_1s), nine entries have been found heterotic over check varieties expressing 14-31% yield advantage over check BRRI dhan49 with two to three weeks earlier growth duration, 5-22% yield advantage over BRRI hybrid dhan4 having 1-17% yield advantage over BRRI hybrid dhan6 with more or less same growth duration. Twelve entries have been found completely sterile. Pollen parents of heterotic combinations were regarded as suspected restorers and pollen parents of completely sterile combinations were regarded as suspected maintainer lines. In Boro 2017-18, out of 140 test crosses (F_1s), five tested entries showed complete sterility and they were immediately backcrossed with their corresponding male parents for conversion. On the other hand, six entries have been selected for their high yielding ability compared with the check variety.

Back cross nursery

In T. Aman 2017, nineteen backcross generations were advanced as new CMS lines and shifted to CMS nursery for maintaining genetic purity through hand crossing (Table 1). Other entries were stable in terms of pollen sterility and advanced for next generation except for one BC_1 generation. It was discarded due to fluctuation in pollen fertility. In Boro 2017-18, four BC_6 generations were advanced

Table 1. List of backcross entries shifted to CMS nursery as a new CMS lines during T. Aman 2017.

BC gen	Designation	Sterility status	DFF	D50% F	DTM	Grain type	Base colour	Remark
BC_6	BRRI60A /EL140	CS	73	76	104	Slender	Green	Advanced ass new CMS line
BC_6	BRRI28A/EL140	CS	72	75	103	Slender	Green	Advanced as new CMS line
BC_6	BRRI60A/EL135	CS	69	73	99	Medium	Purple	Advanced as new CMS line
BC_6	IR77803A/EL135	CS	70	73	100	MB	Purple	Advanced as new CMS line
BC_6	BRRI60A/EL110	CS	79	83	110	Slender	Purple	Advanced as new CMS line
BC_6	PMS8A/EL30	CS	68	71	98	MB	Purple	Advanced as new CMS line
BC_6	BRRI7A/EL116	CS	77	81	109	Slender	Purple	Advanced as new CMS line
BC_6	BRRI7A/EL125	CS	75	78	107	Slender	Purple	Advanced as new CMS line
BC_6	BRRI7A/EL145	CS	78	82	110	Slender	Green	Advanced as new CMS line
BC_6	BRRI28A/EL256	CS	72	75	103	Slender	Purple	Advanced as new CMS line
BC6	BRRI71A/EL70	CS	77	81	108	Medium	Purple	Advanced as new CMS line
BC6	BRRI7A/EL211	CS	76	80	107	Slender	Purple	Advanced as new CMS line
BC6	BRRI7A/EL211	CS	72	75	103	Slender	Purple	Advanced as new CMS line
BC6	BRRI7A/EL210	CS	81	85	112	MS	Purple	Advanced as new CMS line
BC6	BRRI7A/EL207	CS	77	81	108	MS	Green	Advanced as new CMS line
BC6	BRRI7A/EL196	CS	79	82	110	MS	Green	Advanced as new CMS line
BC6	BRRI7A/EL50	CS	72	76	104	MS	Green	Advanced as new CMS line
BC6	BRRI7A/EL195	CS	80	83	111	Slender	Purple	Advanced as new CMS line
BC6	BRRI7A/EL23	CS	81	84	110	MS	Purple	Advanced as new CMS line

DS: P_1 = 5 Jul 2017; P_2/F_1= 8 Jul 2017 P_3 = 11 Jul 2017; DT: 30 Jul 2017; CS = completely sterile.

as new CMS lines and shifted to CMS nursery. Other entries were advanced to the next generations except four BC_1 generations those were unstable in pollen fertility.

CMS maintenance and evaluation nursery

Fifty-nine CMS lines were maintained by hand crossing for seed increase and genetic purity in T. Aman 2017 and in Boro 2017-18, 86 CMS lines were maintained through hand crossing for seed increase and genetic purity.

Development of BB resistance parental lines of hybrid rice

Six crosses were made in T. Aman season and matured F_1 seeds were properly collected and preserved those would be grown in next season. Matured BC_2F_1 seeds were also collected and preserved. On the other hand, DNA extraction was done of each combinations and molecular work is going on. In T. Aman 2017, fifty restorer and 55 maintainer lines were screened for bacterial blight resistant genes against 10 different isolates. In Boro 2017-18, out of six test crosses one entry (IR79156A/HRBB1) was found completely sterile against bacterial blight and immediately backcrossed for conversion and no entry was found heterotic over check variety.

EVALUATION OF PARENTAL LINES AND HYBRIDS

In T. Aman 2017, out of 261 hybrids ten hybrid combinations were selected based on yield, duration and grain type and produced more than 19-33% yield advantage over check variety BRRI dhan49, 10-22% over BRRI hybrid dhan4 and 2-13 % over BRRI hybrid dhan6 but growth duration two to four weeks earlier than check variety BRRI dhan49 (Table 2). 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 variety of BRRI. Out of 303 test hybrids, 16 hybrid combinations were selected based on yield, duration and grain type having yield advantage 4-20% over BRRI hybrid dhan5 with growth duration similar to BRRI dhan28 but one to two weeks earlier growth duration than BRRI dhan29 (Table 3).

Preliminary yield trials of promising hybrids

Under preliminary yield trials, three hybrids out of 12 gave more than one ton yield advantage over

Table 2. List of experimental hybrids found heterotic over check variety in T. Aman 2017.

Hybrid	PHT (cm)	E/T	SF (%)	DTM	Yield (t/ha)	Yield advantage over checks		
						Ck-1	Ck-2	Ck-3
BRRI7A/CHH-32R	104	9	78	102	6.02	19.3	9.5	3.03
BRRI7A/LPH47R	111.8	10	81	101	6.48	28.6	18.03	9.09
BRRI13A/BU507R	122.4	11	79	115	6.62	31.2	20.5	11.4
BRRI32A/BR1543-1-1-1-R	125.8	9	77	110	6.21	23.2	13.1	4.5
BRRI33A/R line7	141.2	11	81	112	6.10	21.07	11.1	2.7
BRRI33A/CHA-15R	116.4	12	82	109	6.57	30.3	19.7	10.6
BRRI35A/KasempurR	115.6	11	76	108	6.08	20.5	10.7	2.3
IR79156A/TejR	120.8	10	83	121	6.23	24.3	13.4	4.8
IR79156A/CHA-15R	128.8	12	78	110	6.17	22.3	12.3	3.8
IR79156A/ R line7	132.0	12	83	110	6.71	33.0	22.1	12.9
BRRI dhan49 (ck-1)	127.4	10	79	135	5.04			
BRRI hybrid dhan4 (ck-2)	114.2	11	79	112	5.49			
BRRI hybrid dhan6 (ck-3)	114.2	12	82	115	5.94			

DS: 8 Jul 2017; DT: 28 Jul 2017. PHT (cm)= Plant height; E/T = No. of effective tillers; SF(%) = Spikelet fertility; DTM = days to maturity.

Table 3. List of the hybrid combinations found heterotic from observational nursery in Boro season 2017-18.

Entry	Cross combination	E/T	PHT (cm)	PL (cm)	SF%	DTM	GT	Yield (t/ha)	Yield advantage over checks			
									Ck-1	Ck-2	Ck-3	Ck-4
OT14	BRRI7A/EL254R	10.0	92	24.2	92.2	137	MS	9.58	12.3	12.9	34.6	27.7
OT15	BRRI7A/EL255R	9.0	99	25.0	86.1	139	MB	9.54	11.8	12.5	33.9	27.2
OT58	BRRI13A/EL262R	11.0	112	32.8	88.8	139	MS	9.23	8.2	8.8	29.6	23.07
OT113	BRRI32A/Kashempur	11.2	103	33.2	87.8	141	MS	9.43	10.6	11.2	32.4	25.7
OT145	BRRI35A/EL108R	10.0	105	33.2	91.7	138	MB	9.12	6.9	7.5	28.09	21.6
OT147	BRRI35A/EL254R	10.0	104	21.2	88.1	139	MS	10.2	19.6	20.3	43.3	36.0
OT150	BRRI35A/EL262R	10.0	107	23.0	85.7	140	MB	9.71	13.8	14.5	36.4	29.5
OT156	BRRI35A/CHH32R	12.0	108	23.8	94.5	139	S	9.20	7.9	8.5	29.2	22.7
OT163	BRRI35A/EL224R	11.0	104	26.4	89.1	141	MB	9.64	13.01	13.7	35.4	28.5
OT171	BRRI35A/ KashempurR	10.2	115	24.2	88.5	143	MS	9.31	9.1	9.8	30.8	24.1
OT247	IR79156A/LPH14R	12.2	101	25.8	87.4	139	LS	9.62	12.8	13.4	35.1	28.3
OT251	IR79156A/CHH27R	10.6	106	25.6	84.1	139	LS	9.41	10.3	11.0	32.2	25.5
OT252	IR79156A/CHH32R	11.0	103	25.2	89.1	141	MS	9.13	7.03	7.7	28.2	21.7
OT253	IR79156A/LPH47R	9.8	108	25.4	85.8	144	LS	8.81	3.3	3.9	23.7	17.5
OT271	IR79156A/Basmati L	10.6	112	25.8	87.4	143	S	8.93	4.7	5.3	25.4	19.06
OT272	IR79156A/ BasmatiL-14	9.6	104	25.6	87.6	143	S	9.05	6.1	6.7	27.1	20.7
CK-1	BRRI Hybrid dhan3	9.0	105	25.0	90.6	144	MB	8.53				
CK-2	BRRI Hybrid dhan5	10.2	110	25.0	86.7	143	LB	8.48				
CK-3	BRRI dhan28	9.4	112	21.8	81.9	138	MS	7.12				
CK-4	BRRI dhan29	10.4	106	22.0	82.3	154	MS	7.50				
Mean		10.4	105.8	25.7	87.8	141.2		9.1				
CV (%)		8.3	4.9	13.5	3.5	2.6		8.0				
LSD (0.05%)		0.5	3.0	2.0	1.8	2.1		0.4				

Ds: 8 Dec 2017; DT: 8 Jan 2018. PHT (cm) = Plant height; E/T = No. of effective tillers; SF (%) = Spikelet fertility; PL (cm) = Panicle length; DTM = days to maturity; GT = Grain type; MB=Medium bold, S=Slender MS=Medium slender, LS=Long slender; LB = Long bold.

BRRI dhan49 and exhibited yield advantage over BRRI hybrid dhan4 by 15-24% and BRRI hybrid dhan6 by 6-15% in T. Aman 2017 (Table 4). In Boro 2017-18, eighteen hybrids were evaluated along with two hybrid and two inbred checks and all the selected hybrids showed yield advantage ranging from 32-59% over BRRI dhan28 and 18-41% over BRRI dhan29. Three hybrid combinations had out yielded BRRI hybrid dhan3 and BRRI hybrid dhan5 by more than one ton (Table 5).

SEED PRODUCTION OF PARENTAL LINES AND HYBRIDS

CMS line multiplication of released hybrids

Seed yield of 476 kg/plot (1.4 t/ha), 364 kg/plot (1.3 t/ha), 456 kg/plot (1.2 t/ha), 192 kg/plot (1.2 t/ha) and 180 kg/plot (1.5 t/ha) were obtained from BRRI10A, BRRI11A, IR58025A, BRRI7A and IR79156A respectively in T. Aman season 2017 (Table 6). On the other hand, in Boro 2017-18, CMS seed yields of 480 kg (2.2 t/ha), 370 kg (2.2 t/ha), 433 kg (2.3 t/ha), 240 kg (1.6 t/ha), 575 kg (2.4 t/ha) and 80 kg (2.4 t/ha) were obtained from BRRI7A, BRRI10A, BRRI11A, IR58025A, IR79156A and BRRI32A respectively (Table 7).

F_1 Hybrid seed production of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan4 in T. Aman 2017 and Boro 2017-18

A total of 230 kg (1.3 t/ha) and 130 kg (1.3 t/ha) hybrid seeds were produced from BRRI hybrid dhan5 (BRRI7A/BRRI31R) and BRRI hybrid dhan6 (IR79156A/BRRI20R) respectively during

Table 4. Results of preliminary yield trials in T. Aman 2017

Designation	PHT (cm)	E/T	SF%	GT	DTM	Yield (t/ha)	Yield advantage over Cks (%)		
							Ck-1	Ck-2	Ck-3
BRRI13A/EL108R	112	10	78	MS	109	6.75	42.8	24.4	14.7
BRRI28A/EL108R	114	11	76	MS	110	6.43	36.0	18.4	9.2
BRRI48A/EL253R	112	10	79	M	110	6.21	31.5	14.5	5.6
BRRI dhan49 (ck-1)	129	11	80	M	133	4.73			
BRRI hybrid dhan4 (ck-2)	113	12	79	S	117	5.43			
BRRI hybrid dhan6 (ck-3)	122	11	82	S	118	5.89			
CV (%)	6.0	6.9	2.5		7.8	12.4			
LSD (0.05%)	7.4	0.8	2.1		9.6	0.6			

DS: Jul 11 2017; DT: 3 Aug 2017; Plot size=30m^2; E/T = No. of effective tillers; SF% = Spikelet fertility; DTM = Days to maturity; GT= Grain type; S=Slender, M=Medium, MS=Medium slender.

Table 5. Results of preliminary yield trials in Boro 2017-18.

Entry	Designation	DTM	E/T	PHT (cm)	SF%	TGW	Yield	Ck-1	Ck-2	Ck-3	Ck-4
PYT6	BRRI13A/EL253R	142	11.7	99	88.3	26.1	10.3	22.6	27.2	58.5	41.1
PYT13	BRRI132A/EL254R	140	12.0	97	84.4	25.8	10.1	20.2	24.7	55.4	38.4
PYT7	BRRI32A/EL253R	144	11.6	100	85.3	27.6	9.7	15.5	19.8	49.2	32.9
PYT4	IR75608A/EL108R	136	9.3	97	82.7	24.3	9.0	7.1	11.1	38.5	23.3
PYT12	BRRI13A/EL254R	142	8.6	103	81.7	26.3	8.7	3.6	7.4	33.7	19.2
PYT3	BRRI48A/EL108R	138	9.3	102	85.0	26.4	8.6	2.4	6.2	32.3	17.8
CK-1	BRRI hybrid dhan3	139	9.3	104	83.3	24.9	8.4				
CK-2	BRRI hybrid dhan5	140	8.6	98	83.4	25.3	8.1				
CK-3	BRRI dhan28	142	10.4	105	80.3	22.6	6.5				
CK-4	BRRI dhan29	153	9.6	94	81.6	23.2	7.3				
Mean		141.6	10.04	99.9	83.6	25.25	8.67				
CV (%)		3.3	12.9	3.5	2.7	6.1	13.8				
LSD (0.05%)		3.8	1.1	2.9	1.9	1.3	1.0				

DS: 8 Dec 2017; DT: 8 Jan 2018. DTM = Days to maturity; E/T = No. of effective tillers; PHT (cm) = Plant height; SF (%) = Spikelet fertility; TGW (g) = Thousand grain weight.

Table 6. CMS lines multiplication of BRRI10A, BRRI11A, IR58025A, BRRI7A and IR79156A in T. Aman 2017.

Combination	Plant height (cm)		50% flowering (days)		PER (%)	OCR (%)	Yield		
	A line	B line	A line	B line	A line	A line	(kg/plot)	Area (m^2)	(t/ha)
BRRI10A/B	81	85	73	71	74	42	476	3400	1.4
BRRI11A/B	78	81	72	71	71	41	364	2800	1.3
IR58025A/B	86	91	89	86	72	37	456	3800	1.2
BRRI7A/B	93	96	84	86	70	42	192	1600	1.2
IR79156A/B	104	105	120	120	75	49	180	1200	1.5

DS: B_1=8 Jun 2017; A/B_2=11 Jun 2017; B_3=13 Jun 2017; DT: A/B= 4 Jul 2017. DS: B_1=9 Jun 2017, A/B_2=12 Jun 2017, B_3=14 Jun 2017; DT: A/B=7 Jul 2017. DS: B_1= 9 Jun 2017, A/B_2=12 Jun 2017, B_3=14 Jun 2017; DT: A/B=13 Jul 2017. DS: B_1=12 Jun 2017, A/B_2=15 Jun 2017, B_3=18 Jun 2017; DT: A/B=15 Jul 2017. DS: B_1=12 Jun 2017, A/B_2=15 Jun 2017, B_3=18 Jun 2017; DT: A/B=15 Jul 2017. PER=Panicle exertion rate, OCR= Out crossing rate.

Table 7. CMS lines multiplication of BRRI7A, BRRI10A, BRRI11A, IR58025A, IR79156A and BRRI32A during Boro 2017-18.

Combination	Plant height (cm)		50% flowering date		PER (%)	OCR (%)	Yield	
	A line	B line	A line	B line			kg/plot	(t/ha)
BRRI7A/B	98	100	115	117	78	56	480	2.2
BRRI10A/B	84	87	122	124	86	52	370	2.2
BRRI1A/B	86	88	125	126	88	58	433	2.3
IR58025A/B	86	88	122	123	80	43	240	1.6
IR79156A/B	80	82	120	122	76	54	575	2.4
BRRI32A/B	86	88	116	114	82	52	80	2.4

DS: B_1 = 2 Dec 2017; A/B_2 = 5 Dec 2017; B_3 = 8 Dec 2017; DT: A/B = 7Jan 2018. DS: B_1 =7 Dec 2017; A/B_2 = 10 Dec 2017; B_3 = 13 Dec 2017; DT: A/B = 13 Jan 2018. DS: B_1 =30 Nov 2017; A/B_2 = 3 Dec 2017; B_3 = 6 Dec 2017; DT: A/B = 3 Jan 2018. DS: B_1 =5 Dec 2017; A/B_2 = 8 Dec 2017; B_3 = 11Dec 2017; DT: A/B = 8 Jan 2018. DS: B_1 =10 Dec 2017; A/B_2 = 13 Dec 2017; B_3 = 16 Dec 2017; DT: A/B = 13 Jan 2018. DS: B_1 =12 Dec 2017; A/B_2 = 15 Dec 2017; B_3 = 18 Dec 2017; DT: A/B = 18 Jan 2018. PER=Panicle exertion rate, OCR= Out crossing rate.

T. Aman 2017 (Table 8). In Boro 2017-18, a total of 975 kg (2.6 t/ha) from BRRI hybrid dhan2, 1250 kg (2.5 t/ha) from BRRI hybrid dhan3, 938 kg (1.65 t/ha) from BRRI hybrid dhan4, 510 kg (1.8 t/ha) from BRRI hybrid dhan5 and 450 kg (1.9 t/ha) from BRRI hybrid dhan6 were obtained from BRRI HQ and production site of Barisal (Table 9).

Seed production of promising CMS lines and hybrids

Seed yields 7.8 kg/plot (1.5 t/ha), 8.0 kg/plot (1.1 t/ha), 3.6 kg/plot (1.2 t/ha), 2.3 kg/plot (1.8 t/ha), 3.5 kg/plot (0.9 t/ha), 17.0 kg/plot (1.1 t/ha). 16.0 kg/plot (1.06 t/ha), 13.0 kg/plot (0.87 t/ha), 14.5 kg/plot (0.97 t/ha) and 11.5 kg/plot (1.6 t/ha) were obtained from BRRI13A, BRRI25A, BRRI32A, BRRI35A, BRRI48A, BRRI50A, BRRI53A, BRRI72A, BRRI85A and IR78355A during T. Aman 2017 (Table 10). From 12 promising hybrid combinations seed yield were obtained ranging from 2.3 to 7 kg /plot equivalent to 0.46 to 1.4 t/ha (Table 11).

Table 8. F_1 seed production of BRRI hybrid dhan5 and BRRI hybrid dhan6 during T. Aman 2017.

Hybrid	PHT (cm)		D50% F		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg/plot)	Seed yield (t/ha)
	A Line	R line	A line	R line					
BRRI7A/BRRI31R (BHD5)	91	103	87	105	71.3	41.2	1800	230	1.3
IR79156A/BRRI20R (BHD6)	96	102	90	93	72.7	45.2	1000	130	1.3

DS: R_1 = 23Jun 2017; R_2 = 30 Jun 2017; A = 14 Jul 2017 DT: R = 27 Jul 2017; A = 10 Aug 2017. DS: R_1 = 18 Jun 2017; R_2 = 27 Jun 2017; A = 21 Jun 2017 DT: R/A = 10 Jul 2017. PER (%) = panicle exertion rate, OCR (%) = Out crossing rate.

Table 9. F_1 seed production of BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5 and BRRI hybrid dhan6 during Boro 2017-18.

Combination	Plant height (cm)		50% flowering date		PER (%)	OCR (%)	Yield	
	A line	R line	A line	R line			kg/plot	t/ha
BRRI 10A/BRRI10R	84	92	120	122	84	52	975	2.2
BRRI 11A/BRRI15R	84	91	122	126	80	50	1250	2.5
IR 58025A/BRRI10R	86	92	121	124	86	43	938	1.65
BRRI7A/BRRI31R	87	95	123	141	82	47	510	1.8
IR79156A/BRRI20R	90	97	124	130	83	48	450	1.9

DS: R_1 = 12 Dec 2017; R_2 = 18 Dec 2017; A = 15 Dec 2017; DT: R/A = 20 Jan 2018. DS: R_1 = 30 Nov 2017; R_2 = 8 Dec 2017; A = 04 Dec 2017; DT: R/A = 20 Jan 2018. DS: R_1 = 12 Dec 2017; R_2 = 18 Dec 2017; A = 15 Dec 2017; DT: R/A = 20 Jan 2018. DS: R_1 = 30 Nov 2017; R_2 = 7 Dec 2017; A = 24 Dec 2017; DT: R = 7 Jan 2018; A = 24 Jan 2018. DS: R_1 = 20 Dec 2017; R_2 = 29 Dec 2017; A = 23 Dec 2017; DT: R/A = 20 Jan 2018. PER (%) = panicle exertion rate, OCR (%) = Out crossing rate.

Table 10. Seed amount obtained from selected promising CMS lines in T. Aman 2017.

Designation	PHT (cm)		D50%F		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg /plot)	Seed yield (t/ha)
	A line	B line	A line	B line					
BRRI13A/B	89	90.3	81	80	72.3	53.2	50	7.8	1.560
BRRI25A/B	85.2	85.6	93	91	70.5	46.3	70	8.0	1.142
BRRI32A/B	87.0	87.0	85	84	76.2	52.2	30	3.6	1.200
BRRI35A/B	86.0	86.5	82	81	76.0	50.5	30	2.3	1.767
BRRI48A/B	93.0	93.2	87	85	69.7	44.3	40	3.5	0.875
BRRI50A/B	84.0	84.2	82	81	71.6	47.2	150	17.0	1.133
BRRI53A/B	93.0	95.0	84	83	72.3	44.7	150	16.0	1.066
BRRI72A/B	84.0	85.2	78	77	70.6	48.2	150	13.0	0.867
BRRI85A/B	87.0	88.5	84	83	69.5	41.6	150	14.5	0.967
IR78355A/B	81.0	83.0	91	90	70.4	45.4	70	11.5	1.642
Average	86.9	87.9	84.7	83.5	71.9	47.4		9.7	1.2
$Lsd_{(0.05)}$	3.2	3.2	3.7	3.5	2.0	3.0		3.4	0.3
CV (%)	4.4	4.5	5.4	5.2	3.3	7.8		56.0	26.4

Table 11. Seed amount obtained from promising hybrid rice combinations in T. Aman 2017.

Designation	PHT (cm)		D50%F		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg/plot)	Seed yield (t/ha)
	A line	R line	A line	R line					
BRRI7A/EL108R	95.5	101.3	85	88	68.2	40.2	50	6.0	1.2
BRRI33A/EL108R	89.0	102.0	80	83	67.0	38.6	50	4.0	0.8
BRRI28A/EL108R	92.5	101.5	79	86	72.0	37.2	50	5.0	1.0
BRRI13A/EL108R	96.3	102.2	80	85	74.5	42.2	50	7.0	1.4
BRRI7A/EL253R	96.0	105.2	86	89	70.1	38.0	50	4.0	0.8
BRRI33A/EL253R	90.0	104.3	81	85	68.2	37.2	50	4.2	0.84
BRRI28A/EL253R	93.0	104.2	80	83	71.3	36.5	50	4.5	0.9
BRRI13A/EL253R	97.2	105.6	81	87	73.6	39.6	50	5.0	1.0
BRRI7A/EL254R	95.2	101.3	85	90	69.8	37.4	50	4.5	0.9
BRRI33A/EL254R	90.2	100.7	81	86	68.2	36.2	50	2.3	0.46
BRRI28A/EL254R	92.4	102.0	78	83	71.6	36.5	50	3.1	0.62
BRRI13A/EL254R	96.0	101.5	81	87	73.0	41.0	50	4.6	0.92

DS: R_1= 7 Jul 2017, R_2=10 Jul 2017, R_3= 13 Jul 2017, A=10 Jul 2017 ; DT : R/A= 3 Aug 2017. In Boro 2017-18, seed yield 3.2 kg/plot (1.0 t/ha), 14.6 kg/plot (1.2 t/ha), 13.3 kg/plot (1.0 t/ha), 8.4 kg/plot (1.0 t/ha), 27.8 kg/plot (1.2 t/ha) and 3.9 kg/plot (0.8 t/ha) were obtained from promising CMS lines BRRI25A, BRRI50A, BRRI53A, BRRI72A, IR75608A and IR8355A respectively (Table 12).

Dissemination of hybrid rice technology

In the reporting year, Hybrid Rice Division supplied 9,767.0 kg of parental lines and F_1 seeds to 12 seed companies along with farmers, BRRI staffs, BRRI RSs and different projects (Table 13).

A total of 52,400 kg F_1 seed was produced in Boro 2017-18 with the technical assistance from BRRI under 13 seed companies and regional stations of BRRI (Table 14).

Table 12. Seed amount obtained from selected promising CMS lines in Boro 2017-18.

Designation	Plant height (cm)		D50% flowering		PER (%)	OCR (%)	Yield (kg/plot)	Seed yield (t/ha)
	A line	B line	A line	B line				
BRRI25A/B	100	101.3	117	115	70.0	51.3	3.2	1.0
BRRI50A/B	105	105.3	121	118	72.3	53.2	14.6	1.2
BRRI53A/B	103	104	116	113	68.5	46.3	13.3	1.0
BRRI72A/B	89.6	91.4	125	122	70.2	50.2	8.4	1.0
IR75608A/B	86.0	86.5	113	112	76.0	50.5	27.8	1.2
IR78355A/B	93.0	94.2	118	116	66.7	44.3	3.9	0.6
Average	96.1	97.1	118.3	116	70.6	49.3	11.9	1.0
$Lsd_{(0.05)}$	8.1	8.0	4.4	3.8	3.4	3.5	9.6	0.2
CV (%)	8.0	7.8	3.5	3.1	4.6	6.8	76.7	21.9

DS: B_1= 3 Dec 2017; B_2/A = 6 Dec 2017; B_3= 9 Dec 2017; DT: 7 Jan 2018; PER (%) = Panicle exertion rate, OCR (%) = Out crossing rate.

Table 13. Amount of parental line and hybrid seeds supplied to different organization.

Recipient	Nos.	F_1 (kg)	A line (kg)	B line (kg)	R line (kg)
Seed company	12	900.0	2,750.00	-	940.00
Farmer	80	2,800.0	293.00	-	131.00
BRRI scientist + staff	12	753.0	-	-	-
BRRI RS (5)+SPIRA	6	1,200.0	-	-	-
Total	110	5,653.00	3,043.00	0.00	1,071.00
Grand total			9,767.00		

Investigator: All staff of hybrid rice division.

Table 14. Seed production activities of BRRI developed hybrids during Boro seasons of 2017-18 both at private and public sectors.

Organization/person	Location	Variety	Area (acre)	Yield achieved (ton)	Remark
Sumaya seed	Kurigram	BHD3	2.0	2.3	Experienced
		BHD5	1.0	1.0	
Akkas Madubbar, Farmer	Mazikanda, Faridpur	BHD3	0.33	0.3	Experimental
S M Nasir, Farmer	Gopalganj	BHD4	0.33	0.3	Experimental
Modina Green Tech	Tangail	BHD4	2.0	2.0	Experienced
		BHD6	2.0	2.0	
Bhai Bhai Traders,	Lalmonirhat	BHD3	1.0	1.0	Experienced
M/S Hoque, Enter	Gaibandha	BHD2	10.0	10.0	Experienced
Nayan Seed	Shibganj, Bogura	BHD2	3.0	3.0	Experienced
		BHD3	7.0	8.0	
		BHD4	5.0	3.5	
		BHD5	3.0	2.5	
		BHD6	2.0	2.0	
BADC	Netrakona	BHD5	2.0	2.0	Experienced
Bangladesh seed company Ltd.	Naogaon	BHD3	1.0	1.0	Experimental
Aftab Bhumukhi Farms Ltd	Kishoreganj	BHD3	2.0	1.5	Experienced
Mr. Jalal Akand, Contract grower, HRD, BRRI	Barishal	BHD2	1.5	1.0	Experienced
		BHD3	1.0	1.3	
		BHD4	1.5	1.5	
		BHD5	1.0	0.8	
		BHD6	1.0	0.6	
BRRI RS, Barishal	Barishal	BHD3	0.33	0.2	Experienced
BRRI RS, Bhangha	Bhangha	BHD3	0.66	0.4	Experienced
		BHD4	0.66	0.3	
		BHD5	0.66	0.4	
Janani Biz Vander	Rangpur	BHD3	0.33	0.3	Experimental
Madina Seed Company	Mymensingh	BHD6	2.0	1.5	Experienced
ACI Limited	Gazipur	BHD6	0.33	0.3	Experienced
Hybrid Rice Div, BRRI, HQ	Gazipur, HQ	BHD2	0.33	0.4	Experienced
		BHD3	0.33	0.4	
		BHD4	0.33	0.2	
		BHD5	0.33	0.4	
Total			55.95	52.4	

Legend: BHD2 = BRRI hybrid dhan2, BHD3 = BRRI hybrid dhan3, BHD4 = BRRI hybrid dhan4. BHD5 = BRRI hybrid dhan5, BHD6 = BRRI hybrid dhan6.

Agronomy Division

SUMMARY

Salicylic acid @ 250 µM, 500 µM and 750 µM had nosignificant effect on shoot length, number of seedling per unit area and seedling strength when sprayed at 15 and 30 DAS respectively.wider row spacing of manual transplanting (30 × 13 cm), use of tender seedlings showed positive effect on the grain yield but that was not significant with other spacing by mechanical transplanter and hand transplanting compared to recommended transplanting. In T. Aus, NERICA10-7-PL2-B had lower growth duration and lower yield than the check variety BRRI dhan48. Both NERICA10-7-PL2-B and BRRI dhan48 gave higher yield at late planting situation. In T. Aman, RLR-2 lines- BR8204-5-3-2-5-2, IR11F190 and IR70213-10-CPA-4-2-2-2 gave higher yield than the check varieties BRRI dhan39 and BRRI dhan49 up to 2 August planting with similar growth duration. Salt tolerant lines, HHZ5-SAL12-DT3-Y2 and HHZ8-SAL12-Y2-DT1 gave higher grain yield than the check variety BRRI dhan73 up to 17 August planting with similar growth duration. In Boro, favourable Boro line- BRRI dhan29-SC3-28-16-10-8-HR1 (Com) produced higher grain yield but statistically similar to the check variety BRRI dhan28 up to 5 February planting with similar growth duration. Bacterial blight resistant entries- BR (Bio) 8333-BC5-1-20, BR (Bio) 8333-BC5-2-16 and BR (Bio) 8333-BC5-2-22 gave significantly higher grain yield (0.47 t ha^{-1}) than both the check IRBB60 and Purbachi up to 17 August planting. In BRRI dhan56, BRRI dhan62 and BRRI dhan71 all aged seedlings with M_1 (N-P-K-S: 70-11-41-11 kg ha^{-1} and N: 1/3rd as basal + 1/3rd at 10 DAT + 1/3rd at 25 DAT) gave comparatively higher yield than with M_2 (N-P-K-S: 120-11-41-11 kg ha^{-1} and N: 2/3rd as basal + 1/3rd at 25 DAT). In BRRI dhan75 the 20, 25 and 30-day-old seedlings with M_1 gave higher yield compared to M_2 but 35 and 40 days old seedlings with M_1 gave lower yield compared to M_2. Integrated crop management approach ($N_0 P_7 K_{28.5} S_9$ kg ha^{-1} as basal with 1st top dress N at 10 DAT @ 27.5 kg, 2nd top dress N at 30 DAT @ 16.5 kg and 3rd top dress N @ 11.0 + K @ 13.3 at 45 DAT) might be a good option to produce about 0.5 t ha^{-1} higher yield in Boro season than the existing researcher practice. Pretilachlor + Trisulfuron and Bensulfuran methyl + Bispyribac sodium effectively controlled most of the sedges and grasses in direct wet seeded rice in Aman season. Application of three hand weedings did not compete with herbicide treated plots in terms of grain yield due to phytotonic effect of herbicides on crop growth and development for sustained rice production.

At 24 January planting, BRRI dhan28 and BRRI dhan81 gave about 0.5 t ha^{-1} higher yield in Mg_2 (ICM) than Mg_1 (BRRI recommended management). Higher grain yield of 4.68 and 4.24 t ha^{-1} was observed in BRRI dhan75 and BRRI dhan70 respectively with 75% BRRI recommended fertilizer dose +25% N from PM BRRI dhan50 produced about 0.5 t ha^{-1} higher grain yield than BRRI dhan63 with integrated nutrient management (20% higher than BRRI recommended dose + 1.5 t ha^{-1} organic manure) and soil test based nutrient management (115-19-66-0-1.5 kg ha^{-1} N, P, K, S and Zn). Fertilizer management with 30% N at 15 DAT+35% N at active tillering (AT) + 35% N at PI+ PZnS (Basal)+K 50% basal+50% K at PI could be used for yield maximization in Boro rice.

SEEDS AND SEEDLINGS

Role of salicylic acid (SA) on raising of quality rice seedling in Boro season

The study was carried out at BRRI HQ, Gazipur and BRRI RS, Rangpur during Boro 2017-18. The experiment was laid out in a RCB design and replicated thrice. The conventional seed beds were prepared using 80 g m^{-2}. BRRI dhan29 was used as planting material. Seeds were sown in seed bed on 30 November. The treatments (SA) were: T_1= 250 µM, T_2= 500 µM, T_3= 750 µM, T_4=Control. SA sprayed at 15 and 30 days after seeding (DAS). Sampling was done at 40 DAS from 10×10 cm^2 area per treatment. Seedling strength was calculated as: shoot dry weight (mg)/Shoot length (cm). There were no significant differences in shoot length, number of plants per unit area, dry matter weight and seedling strength (Table 1).

Table 1. Effect of salicylic acid on quality seedling raising in Boro, 2017-18, BRRI HQ, Gazipur and BRRI RS, Rangpur.

Treatment	Gazipur			BRRI RS, Rangpur		
	Shoot length (cm)	No. of plants/100 cm^2	Seedling strength (mg cm^{-1})	Shoot length (cm)	No. of plants/100 cm^2	Seedling strength (mg cm^{-1})
T_1	20.23	58	3.27	15.5	57	2.59
T_2	19.06	49	3.21	15.3	54	2.11
T_3	20.80	62	3.00	15.2	63	2.24
T_4	18.31	56	3.13	15.7	56	2.61
CV (%)	3.05	5.03	13.50	2.04	5.10	12.95
LSD (0.05)		NS			NS	

PLANTING PRACTICES

Effect of plant spacing on growth and yield of mechanically transplanted rice

Machine transplanting is gaining attention to the Bangladeshi farmers as it saves 53-55% labour in transplanting operation and ensures faster operation. The hypothesis of the study was growth and yield of rice would not differ in different plant spacings kept by mechanical rice transplanter. The objective of the study was to compare the growth and yield of mechanical transplanted rice as affected by hill-row spacing. The experiment was conducted at BRRI farm Gazipur during Boro season 2018 to observe the production potential and growth of mechanically transplanted rice with different plant spacings. The treatment of the experiment was as follows. Mechanical transplanter with 25-day-old seedlings with 30 × 13 cm, 30 × 15 cm and 30 × 17 cm spacing. Hand transplanting with same seedling age and spacing and traditional transplanting with seedling age of 45 days with 20 × 20 cm spacing. BRRI dhan58 were used as variety. The experiment was conducted following RCB design with three replications. No significant difference was observed among the treatments regarding tiller production, dry matter production and crop growth rate (Fig. 1). Leaf area index at booting stage varied in different treatments from 3.23 to 3.76, but it was not significant among the treatments (Fig. 2). It was observed that yield was slightly increased with 30 × 13 cm spacing with manual transplanting. But that was insignificant to other treatments. Panicle m^{-2}, grains panicle and 1000 grain weight was also insignificant among the treatments (Table 2). Straw yield, biological yield and harvest index did not differ significantly with the variation of plant spacing. But pearson correlation matrix of grain yield, yield character, straw yield, harvest index and biological yield as affected by different spacings significantly and positively correlated with grain yield (Table 3). So, wider row spacing

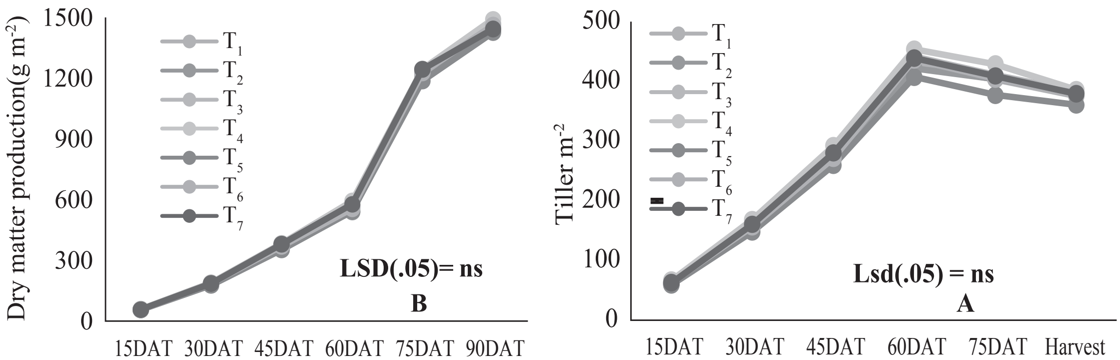
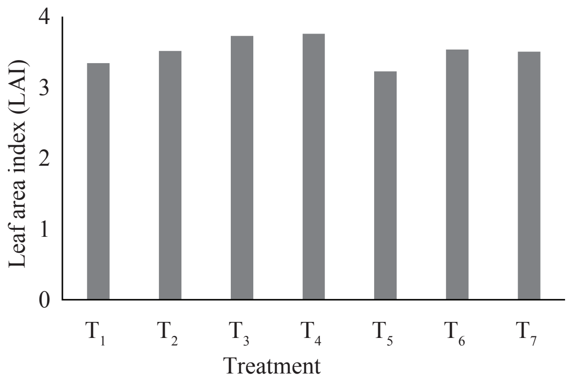


Fig. 1. Tillering pattern and dry matter production over time as affected by different plant spacing.



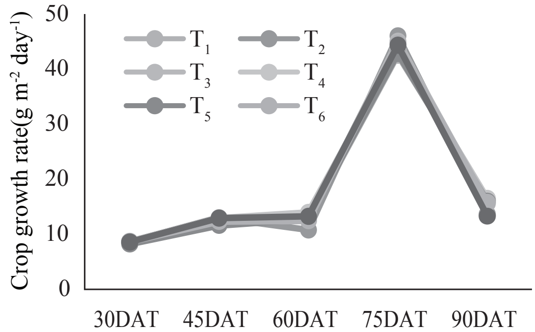


Fig. 2. Leaf area index at booting stage and crop growth rate over time as affected by different plant spacings.

Table 2. Yield and yield character, straw yield, biological yield and harvest index.

Treatment	Panicle m^{-2}	Grains $panicle^{-1}$	1000 GW	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index
T1	277	97	22.91	6.67	6.15	12.81	0.52
T2	267	93	22.82	6.51	6.15	12.66	0.51
T3	297	105	23.23	6.76	6.12	12.88	0.52
T4	313	114	23.47	7.20	6.75	13.95	0.52
T5	273	91	22.27	6.48	6.07	12.55	0.52
T6	293	102	23.02	6.75	6.14	12.89	0.52
T7	271	95	22.96	6.64	6.47	13.11	0.51
LSD (.05)	ns	ns	ns	ns	ns	ns	ns
CV (%)	8.4	8.1	1.7	11.2	8.0	9.4	2.5

Table 3. Correlation matrix among yield and yield characters, straw yield, biological yield and harvest index.

	GY	Pm-2	G /p	1000 GW	SY	BY
Pm-20.919						
	0.003					
G /p	0.966	0.973				
	0.000	0.000				
1000GW	0.849	0.771	0.886			
	0.016	0.043	0.008			
SY	0.787	0.522	0.635	0.635		
	0.036	0.230	0.125	0.125		
BY	0.942	0.758	0.843	0.782	0.948	
	0.002	0.048	0.017	0.038	0.001	
HI	0.402	0.623	0.473	0.118	-0.124	0.138
	0.372	0.135	0.283	0.801	0.791	0.768

Cell Contents: Pearson correlation. P-Value, GY= Grain yield, pm-2= Paniclem-2, G/P= Grain/Panicle, SY= Straw yield, BY= Biological yield.

of manual transplanting (30 × 13 cm) and use of tender seedlings showed positive effect on the grain yield but that was not significant with other spacing by mechanical transplanter and hand transplanting compared to recommended transplanting.

Effect of planting time on growth and yield of advanced lines in T. Aus

Planting time is one of the key factors to release a variety and considering this a trial was conducted at the BRRI farm, Gazipur in Aus 2017 to select the best promising lines. Promising line NERICA10-7-PL2-B was compared to BRRI dhan48 (ck). Entries were planted from 15 July to 14 September with 15 days intervals. Twenty-four-day-old seedling was transplanted with 20 × 20 cm spacing. The treatments were distributed in a split-plot design, placing planting date in the main plot and varieties in the sub-plot with three replications. Fertilizers were applied @ 74-10.5-41.5 kg ha^{-1} N-P-K respectively and 1/3 nitrogen and all fertilizers were applied as basal during final land preparation. The rest 2/3 nitrogen was applied as top dress in two equal splits at 10 and 20 DAT (days after transplanting). Flowering of NERICA10-7-PL2-B was completed within 7-8 days and flowering was almost homogenous. Yield of NERICA10-7-PL2-B was 3.50-4.50 t ha^{-1} and BRRI dhan48 3.63-4.78 t ha^{-1} having growth duration 102-106 days and 105-110 days respectively. NERICA10-7-PL2-B matured 2-3 days earlier than the check BRRI dhan48. Both the test entry gave higher yield on 2 June planting (Table 4).

Effect of planting time on growth and yield of advanced lines in T. Aman season

Seven field trials were conducted at BRRI farm, Gazipur in T. Aman 2017 to find out suitable planting time for higher yield under rainfed lowland rice ecosystem -RLR-1 (BR8192-10-1-2-3-4 and BRRI dhan29-SC3-28-16-15-HR2(Com) including check BRRI dhan39 and BRRI dhan49), RLR-2 (BR8204-5-3-2-5-2, IR11F190 and IR70213-10-CPA-4-2-2-2 including check BRRI dhan39 and BRRI dhan49), RLR-3 (BR8492-9-5-3-2 and BR8210-10-3-1-2 including check BRRI dhan39 and BRRI dhan49), RLR- 4 (BR8189-10-2-3-1-5 and BR8189-10-2-3-1-6 including check BR11), Disease resistant rice, DRR- 5 (BR7959-14-2-1 including check BR11 and BRRI dhan49), Salt tolerant rice, SLR-6 (HHZ5-SAL12-DT3-Y2 and HHZ8-SAL12-Y2-DT1 including check BRRI dhan73) and Drought tolerant rice, DTR-7 (HHZ5-DT20-DT3-Y2, HHZ5-SAL10-DT3-Y2 and HHZ5-DT16-DT1-DT1 including check BRRI dhan71). Twenty-five-day-old seedling was transplanted with 20×20 cm spacing. The trial was conducted in spilt-plot design, where planting date was in main plots and the advanced lines were in sub-plots. Fertilizers were applied @ 68-10-41-11 kg ha^{-1} N-P-K-S respectively. All fertilizers except N were applied during final land preparation. Nitrogen was applied in equal splits at 15, 30 and 45 DAT (days after transplanting). None of the promising lines from RLR-1, RLR-3 and RLR-4 gave higher grain yield than the check varieties BRRI dhan39, BRRI dhan49 and BRRI dhan11. All RLR-2 tested entries gave higher grain yield than the check varieties BRRI dhan39 and BRRI dhan49 up to 2 August planting with similar growth duration but it was statistically insignificant (Table 5). Entries from DRR line and DTR line gave significantly lower grain yield than the check varieties BR11, BRRI dhan49 and BRRI dhan71 at all planting dates. The advanced lines, HHZ5-SAL12-DT3-Y2 and HHZ8-SAL12-Y2-

Table 4. Effect of planting time on yield and yield components of advanced lines/varieties in Aus 2017, BRRI, Gazipur.

Planting date	Yield (t ha^{-1})		Growth duration (day)		Panicle m^{-2}		Grain $panicle^{-1}$		1000 seed weight (g)	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
23 May	3.50	3.63	102	105	167	194	72	77	26.2	25.8
02 June	4.50	4.78	106	108	211	218	87	91	25.8	25.6
12 June	3.95	4.72	108	110	204	221	80	84	25.9	25.8
CV (%)	7.4				21.3		9.6		1.1	
$LSD_{(0.05)}$	0.62				18.3		14.2		0.27	

V_1= NERICA10-7-PL2-B, V_2= BRRI dhan48.

Table 5. Effect of planting time on yield and growth duration (in parenthesis) of RLR-2 lines in T. Aman 2017, BRRI, Gazipur.

Advanced lines/varieties	Yield (t ha^{-1})		
	19 July	2 Aug	17 Aug
BR8204-5-3-2-5-2	4.85 (118)	5.32(120)	2.95(120)
IR11F190	5.07(130)	4.87 (130)	3.89(131)
IR70213-10-CPA-4-2-2-2	4.92(122)	4.68(123)	3.11(124)
BRRI dhan39 (ck)	4.34(120)	4.60 (121)	3.65(121)
BRRI dhan49 (ck)	4.39(138)	4.35(139)	3.86(139)
CV (%)		4.50	
$LSD_{(0.05)}$		NS	

DT1 gave highergrain yield than the check variety BRRI dhan73 at all plantings with similar growth durationbut it was statistically similar (Table 6).

Effect of planting time on growth and yield of advanced lines in Boro season

Six trials were conducted at the BRRI farm, Gazipur during Boro 2017-18 to find out the optimum planting time of potential promising lines. The promising lines of ALART-1 (Favourable Boro) were: BRRI dhan29-SC3-28-16-10-8-HR1 (Com) and check variety was BRRI dhan28; In case of ALART-2 (Disease resistant rice)-, BR8938-19-4-3-1-1 and the check variety was BRRI dhan28 (Std. ck); for ALART-3, green super rice (GSR)- HHZ12-SAL2-Y3-Y2, HHZ5-DT20-DT2-DT1 and check varieties were BRRI dhan28 (Sus. ck) and BRRI dhan67 (Std. ck); for ALART-6, Zn enriched rice (ZER)- BR8631-12-3-5-P2, BR8631-12-3-6-P3 and check varieties were BRRI dhan28 (ck) and BRRI dhan74 (ck); for ALART-1 (Bacterial blight resistant)-BR(Bio)8333-BC5-1-20, BR(Bio)8333-BC5-2-16, BR (Bio) 8333-BC5-2-22 and check varieties were IRBB60 (R. ck) and Purbachi (S. ck), BRRI dhan29 (Standard ck); for ALART-2 (Favourable Boro-short duration)-BR (Bio) 9785-BC2-6-2-2, BR (Bio) 9785-BC2-20-1-3 and the check variety was BRRI dhan28. Thirty-five-days old seedlings were transplanted on 6 January to 20 February 2018 with a spacing of 20- × 20-cm using one seedling $hill^{-1}$. The treatments were assigned in split-plot design, providing planting date in the main plots and promising lines/varieties in the sub-plots with three replications. Fertilizers were applied @ 120-18-75-18-4 kg ha^{-1}N-P-K-S-Zn respectively. All fertilizers except urea were applied during final land preparation. Urea was applied as top dress in three equal splits, at 20, 35 and 50 DAT. The promising line BRRI dhan29-SC3-28-16-10-8-HR1 (Com) produced higher grain yield but statistically similar to check variety BRRI dhan28 up to 5 February planting with similar growth duration (Table 7). None of the promising lines from disease resistant rice, green super rice, Zn enriched rice and favourable Boro-short duration line gave higher yield than the check variety. All BBR tested entries gave significantly the highest grain yield (0.47 t ha^{-1}) than both the checks IRBB60 and Purbachi at all plantings. The BBR entries gave statistically similar grain yield with check variety BRRI dhan29 at all plantings with similar growth duration (Table 8).

Table 6. Effect of planting time on yield and growth duration (in parenthesis) of SLR-6 lines in T. Aman 2017, BRRI, Gazipur.

Advanced lines/varieties	Yield (t ha^{-1})		
	19 July	2 Aug	17 Aug
HHZ5-SAL12-DT3-Y2	3.66 (115)	4.32 (116)	3.56 (116)
HHZ8-SAL12-Y2-DT1	3.88 (117)	4.27 (116)	3.95 (116)
BRRI dhan73	3.13 (116)	3.91 (117)	3.48 (117)
CV (%)		4.50	
$LSD_{(0.05)}$		NS	

Table 7. Effect of planting time on yield and growth duration (in parenthesis) of advanced lines ALART-1 (FB) in Boro 2017-18, BRRI, Gazipur.

Advanced line/variety	Grain yield (t ha^{-1})			
	6 Jan	21 Jan	5 Feb	20 Feb
BRRI dhan29-SC3-28-16-10-8-HR1 (Com)	6.13 (146)	5.95 (144)	5.49 (138)	5.11 (130)
BRRI dhan28 (ck)	5.95 (146)	5.84 (144)	5.38 (138)	4.49 (130)
CV (%)	2.7			
$LSD_{0.05}$	0.28			

*Early harvesting (75% maturity) because of lodging caused by heavy rainfall.

Table 8. Effect of planting time on yield and growth duration (in parenthesis) of advanced lines ALART-1 (BBR) in Boro 2017-18, BRRI, Gazipur.

Advanced line/variety	Grain yield (t ha^{-1})			
	6 Jan	21 Jan	5 Feb	20 Feb
BR (Bio) 8333-BC5-1-20	6.26 (164)	6.07 (160)	5.56 (156)	4.52 (147)
BR (Bio) 8333-BC5-2-16	6.11 (164)	5.99 (160)	5.67 (156)	4.79 (147)
BR (Bio) 8333-BC5-2-22	6.04 (164)	5.96 (160)	5.56 (156)	4.88 (147)
IRBB60 (R. ck)	5.79 (159)	5.64 (1600)	5.15 (156)	4.26 (147)
Purbachi (S. ck)	5.64 (164)	5.56 (154)	5.48 (148)	3.82 (139)
BRRI dhan29 (Std. ck)	6.24 (164)	6.06 (160)	5.68 (156)	4.86 (147)
CV (%)	3.4			
$LSD_{0.05}$	0.30			

FERTILIZER MANAGEMENT

Influence of N and K management options on growth and yield of Swarna5 cultivar at variable planting time

The experiment was conducted in T. Aman 2017 at BRRI farm Gazipur to determine optimum planting time and proper agronomic management for achieving higher yield of Swarna5. Table 9 presents detailed fertilizer management for each treatment. The experiment was laid out in split plot design with three replications. Twenty-five-day-old seedling (Soaking – TP) was transplanted at a spacing of 20 × 20 cm with two seedlings per hill. Check variety was BRRI dhan49. Initial soil status of the experimental field was pH = 6.2, N = 0.12%, P = 8.77 ppm and K = 0.26 me/100g.

Swarna5 produced more number of panicles with Mg_2 irrespective of planting date but BRRI dhan49 produced more number of panicles with Mg_1. Swarna5 produced more number of panicles on 15 August planting (Table 10). Swarna5 and BRRI dhan49 produced higher yield at 15 July and 15 August planting. Irrespective of planting date, Swarna5 produced more than 5.0 t ha^{-1} grain yield with Mg_2 and Mg_3 but Mg_2 is suitable for Swarna5 because plant becomes taller with Mg_3 which is prone to lodging (Table 10). All varieties produced lower yield at 30 July planting `due to heavy rainfall up to 45 DAT (586 mm/32d).

Nitrogen management for short duration T. Aman rice with aged seedlings

The experiment was conducted in Aman 2017 at BRRI farm, Gazipur to find out suitable nitrogen management practice for aged seedlings. BRRI dhan56, BRRI dhan62, BRRI dhan71 and BRRI dhan75 were selected for the experiment. The experiment was laid out in split plot design with three replications. The main plot treatments were fertilizer management options: M_1 = N-P-K-S: 70-11-41-11 kg/ha and N: $1/3^{rd}$ as basal + $1/3^{rd}$ at 10 DAT + $1/3^{rd}$ at 25 DAT, M_2= N-P-K-S: 120-11-41-11 kg/ha and N: $2/3^{rd}$ as basal + $1/3^{rd}$ at 25 DAT. The sub plot treatments included seedling age: S_1 = 20 days, S_2 = 25 days, S_3 = 30 days, S_4 = 35 days and S_5 = 40 days. Seedlings were transplanted on 31 July 2017 at a spacing of 20 × 20 cm using

Table 9. Detailed fertilizer management for each treatment, T. Aman 2017, BRRI, Gazipur.

Treatment	Basal (kg ha^{-1})				Top dress (kg ha^{-1})		
	N	P	K	S	1st N at 10 DAT	2nd N at 30 DAT	3rd N + K at 45 DAT
Mg_1 (BRRI)	-	7.0	38.0	9.0	18.3	18.3	18.3 + 0
Mg_2	-	7.0	28.5	9.0	27.5	16.5	11.0 + 13.3
Mg_3	11.0	7.0	28.5	9.0	22.0	16.5	11.0 + 13.3

Table 10. Panicle number, grain yield and growth duration (day) of tested varieties under different N and K management options, T. Aman 2017, BRRI, Gazipur.

Treatment			Panicle m^{-2}			Grain yield (t ha^{-1})		
			15 July	30 July	15 August	15 July	30 July	15 August
Swarna5	x	Mg_1	227	195	230	5.16 (137)	4.26 (128)	5.04 (128)
Swarna5	x	Mg_2	228	201	237	5.28 (135)	4.48 (126)	5.53 (126)
Swarna5	x	Mg_3	224	217	226	5.30 (135)	4.71 (126)	5.31 (126)
BRRI dhan49	x	Mg_1	255	214	235	5.34 (134)	4.30 (125)	4.73 (125)
BRRI dhan49	x	Mg_2	252	214	220	5.01 (133)	4.37 (124)	4.84 (124)
BRRI dhan49	x	Mg_3	245	224	227	4.85 (133)	4.40 (124)	4.87 (124)
$LSD_{(0.05)}$				34.8			0.73	

one seedling per hill. The full doses of PKSZn were applied during final land preparation. BRRI dhan75 produced significantly higher yield (4.31 t ha^{-1}) than BRRI dhan56 with N: 70 kg ha^{-1} (N: 1/3rd as basal + 1/3rd at 10 DAT + 1/3rd at 25 DAT) and 20 days old seedling, whereas BRRI dhan71 gave higher yield (4.19 t ha^{-1}) than BRRI dhan62 with N: 70 kg ha^{-1} (N: 1/3rd as basal + 1/3rd at 10 DAT + 1/3rd at 25 DAT) and 25-day-old seedling. In panicle m^{-2}, grains panicle^{-1} and yield there was significant difference among the treatments. Although, 1000-grains weight were not influenced by N application in any tested entries, number of panicle production was significantly higher in BRRI dhan62 than BRRI dhan75. In BRRI dhan56, BRRI dhan62 and BRRI dhan71 all aged seedlings with M_1 gave comparatively higher yield than with M_2. In BRRI dhan75 the 20, 25 and 30 days old seedlings with M_1 gave higher yield compared to M_2 but 35 and 40-day-old seedlings with M_1 gave lower yield compared to M_2.

WEED MANAGEMENT

Weed persistence, crop resistance and phytotonic effects of new molecule herbicides in transplanted rice

Herbicides are used to control weeds in crop as pre or post emergence application, which reduces the population of weeds significantly resulting in higher yield and profit. The present investigation was undertaken to identify the phytotonic effect of herbicides on crop growth for sustained production in transplanted rice. With this the hypothesis of the experiment was integration of new molecule pre and post emergence herbicide have phytotonic effects on crop growth and development. The experiment was conducted during Boro season of 2018 at BRRI farm Gazipur. The treatments of the experiments were different combination of herbicides T_1= Mefeneset+ bensulfuron methyl (Pre emergence) fb cyhalofopbutyl (post emergence), T_2=Mefeneset+ bensulfuron methyl (Pre emergence) fb bispyribac sodium (post emergence), T_3= Bensulfuron methyl+ acetachlor (Pre emergence) fb ethoxysulfuron (post emergence), T_4=Pretilachlor+ trisulfuron 2% (Pre emergence) fb penoxlum (post emergence), T_5= Weedy check (Unweeded) and T_6= Weed free by 3 HW.

The experiment were conducted following RCB design with three replications. Thirty-five-days old seedlings of BRRI dhan58 was transplanted at 16 January maintaining 20 × 20 cm spacing. Different agronomic efficiencies were evaluated for calculation of weed vegetation analysis. Results indicated that the herbicide Mefeneset+ bensulfuron methyl (Pre emergence) fb bispyribac sodium (post emergence) produced the lowest weed number and biomass and higher weed control efficiency (93%).

The treatment Mefeneset+ bensulfuron methyl (Pre emergence) fb bispyribac sodium (post emergence) had higher value of (Herbicide efficiency index), (Crop resistance index) and lower value of (Weed persistance index) and (Weed management index) than the other weed management treatments. Higher weed index was observed in unweeded plots. Among the treatments Mefeneset+ bensulfuron methyl (Pre emergence) fb bispyribac sodium (post emergence) produced the highest panicle numbers, grains per panicle and higher thousand weight than the others. The highest grain yield was achieved in the treatment Mefeneset+ bensulfuron methyl (Pre emergence) fb bispyribac sodium (post emergence) followed by Bensulfuron methyl+ acetachlor (Pre emergence) fb ethoxysulfuron (post emergence) treatment. Herbicide treatment strongly influenced grain yield as they produced 302-331% higher yield than in the season long unweeded check.

The above ground biomass of rice (DMP) and crop resistance index was closely related to each other. Higher the biomass, higher the CRI and lower the biomass, lower the CRI. With the increase in rice biomass corresponding crop resistance index increased. A positive linear correlation was observed in CRI and dry matter production of rice. The relationship of grain yield with weed biomass and weed index indicating significant negative correlation with grain yield. The results of our regression analysis revealed that every 1 kg increase in weed biomass at 50 DAT resulted in decrease 7.8 kg of grain yield. Mefeneset+ bensulfuron methyl (Pre emergence) fb bispyribac sodium (post emergence) proved to be the best broad-spectrum herbicide when applied as pre and post emergence application. Application of three hand weeding did not compete with herbicide treated plots in terms of grain yield may be phytotonic effect of herbicides on crop growth and development for sustained rice production.

Mixed weed flora management by new molecule herbicides in transplanted and direct seeded rice

The experiment was conducted at BRRI, Gazipur in Aman 2017 to determine efficiency of these herbicides to control weeds in transplanted and wet direct seeded rice cultivation. In Aman, sprouted seeds of BRRI dhan56 were directly sown in line (line distance 20 cm) and 25-days old seedling of same variety were transplanted on 30 July. The treatments were; i) Pre planting herbicide (Sulfentrazone- 200ml ha^{-1}) + 1 HW, ii) Pre emergence herbicide (Bensulfuron methyl + Acetachlor-750g ha^{-1}) + 1 HW, iii) Early post emergence herbicide (Pretilachlor + Trisulfuron @750g ha^{-1}) + 1 HW, iv) Post emergence herbicide (Metsulfuron methyl+Chlorimuron ethyl @20g ha^{-1}) + 1 HW, v) Post emergence herbicide (Bensulfuran methyl + Bispyribac sodium @144g ha^{-1}) + 1 HW, vi) Post emergence herbicide (2,4-D Amine @1L ha^{-1}) + 1 HW, vii) Three hand weeding (3 HW) and viii) control (no weeding). Pre-planting herbicide was applied at three days before direct seeding and transplanting. The pre-emergence herbicide was applied at four days after seeding (DAS) in direct seeding and at 4 DAT in transplanting method. Early post emergence herbicide applied at 6 DAS in direct seeding and at 6 DAT in transplanting method. Post-emergence herbicide applied at 8 DAS in direct seeding and at 8 DAT in transplanting method. The treatments were distributed in RCB factorial design with three replications. BRRI recommended fertilizers N-P-K-S=C 68-11-41-10 kg ha^{-1} were applied. Weed sampling was done at 30 DAS and 30 DAT. *Echinochloa crus-galli*, *Cyperus difformis* and *Scirpus maritimus* were effectively controlled by Sulfentrazone and Bensulfuron methyl + Acetachlor with one HW more than 80%, whereas *Echinochloa crus-galli*, *Cyperus difformis, Scirpus maritimus* and *Monochoria vaginalis* were effectively controlled by Pretilachlor + Trisulfuron, Metsulfuron methyl + Chlorimuron ethyl and Bensulfuran methyl + Bispyribac sodium in transplanted field. In direct seeding field, weed control efficiency of pre-planting herbicide, Sulfentrazone for *Echinochloa crus-galli*, *Cyperus difformis* and *Scirpus maritimus* were more than 80%. Consequently, Pretilachlor + Trisulfuron, Bensulfuran methyl + Bispyribac sodium and 2,4-D Amine also effectively controlled most of sedges and grasses in direct seeded rice.

Screening of crop residues for weed control efficiency in rice

The study was conducted at BRRI farm, Gazipur in T. Aman 2017 to evaluate the performances of different rates of sorghum crop residues, rice straw and along with sorghum aqueous extracts on weed control efficiency. The experiment was laid out in RCB design with three replications. The plot size was one square meter. The treatments were: crop residue of sorghum @ 3.0, 4.0, 5.0 t ha^{-1}. Crop residue of sorghum @ 5.0 t ha^{-1}; T_4= crop residue of sorghum liquid @ 15.0 L ha^{-1}; = crop residue of rice straw @ 5.0 t ha^{-1}; weed free and control (no weeding). To prepare the aqueous extract of sorghum, plant material was chopped with an electric fodder cutter into 2-3 cm pieces. The chopped plant material was soaked in water for 24 h at room temperature in a ratio of 1:5 (w/v) and was filtered through a 10 and 60 mesh sieve. Along with crop residues the stock solution of aqueous extract was applied in rice field @ 15 L ha^{-1} at three days after transplanting. BRRI dhan72 was used as a test variety. Thirty-days old seedling was transplanted with 20 × 20 spacing on15th August 2017. Weed data were taken at 30 DAT from 50 × 50 cm area. Minimum number of weed (10) and maximum weed reduction (90%) was observed in sorghum liquid treated plot followed by rice straw treated plot. The highest yield (5.50 tha^{-1}) was obtained from weed free plot followed by rice straw (4.77 tha^{-1}).

YIELD MAXIMIZATION

Yield maximization of aromatic rice through integrated nutrient management

Integrated nutrient management involves maintenance of soil fertility, sustainable productivity, quality and improvement of farmer's profitability through the combined use of chemical fertilizer, organic manures and bio-fertilizers. The present study was conducted to evaluate appropriate integrated nutrient management practice in aromatic rice. The experiment was conducted at BRRI farm, Gazipur during T. Aman 2017. The treatment included inorganic and organic combinations of nutrient management and varieties. The experiment was conducted by following RCB design with three replication. Twenty-five-days old seedlings were transplanted on 28 July 2017 having 20 × 20 cm spacing with two seedlings per hill. Organic manure was applied three days before final land preparation. BRRI dhan70 and BRRI dhan75 were used as variety. Nutrient management treatments included recommended rate of fertilizer (RRF) @ 24-10-13-9-1.3 kg/bigha of urea-TSP-MoP-gypsum-zn sulphate for BRRI dhan70 and 20-7-11-8-1.5 kg/bigha of urea-TSP-MoP-gypsum-zn sulphate for BRRI dhan75 (F1), RRF with DAP (Reduced 4 kg urea for BRRI dhan70 and 2.8 kg for BRRI dhan75 per bigha) (F2), RRF with trio compost (2 t/ha) (mixture of water hyacinth, rice husk and cow dung) (F3), 75% RRF +25% from N from PM (F4), 75% RRF+ 25% N from vermicompost (F5), Control (without Fertilizer) (F6). Results indicated that dry matter and tiller production increased with advancement of plant age from active tillering until physiological maturity. The contribution of the dry matter accumulation to the grain yield found a significant relationship among them and dry matter production was very closely associated with grain yield (Fig. 3a). Regression analysis showed that LAI at booting stage was significantly correlated with grain yield (Fig. 3b). The type of regression between LAI and grain yield was linear in nature. Interaction effect of variety and INM management was significant in grain yield and yield characters

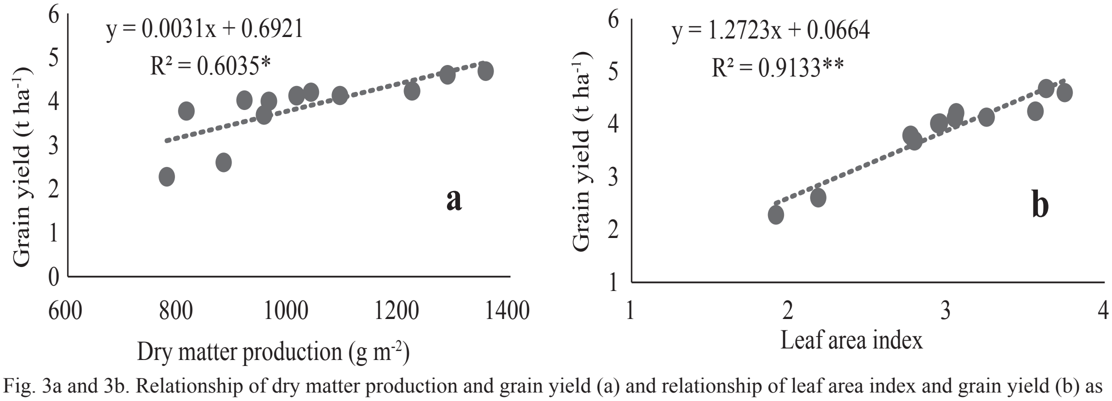


Fig. 3a and 3b. Relationship of dry matter production and grain yield (a) and relationship of leaf area index and grain yield (b) as affected by variety and integrated nutrient management.

(P>0.05) but individual effect of variety is not significant , INM significantly varied. Higher grain yield of 4.68 and 4.24 t ha^{-1} was observed in BRRI dhan75 and BRRI dhan70 respectively with 75% BRRI recommended fertilizer dose + 25% N from PM followed by BRRI recommended fertilizer dose with DAP (urea-DAP-MoP-gypsum-zinc sulphate @ 15-7-11-8-1.5 kg/bigha for BRRI dhan75 and 19-10-13-9-1.3 kg/bigha for BRRI dhan70).

Yield maximization of Boro rice through integrated crop management approach

The experiment was conducted in Boro 2017-18 at BRRI farm Gazipur to determine optimum planting time and proper agronomic management for achieving higher yield of Boro rice in climate change situation. The experiment was laid out in split plot design with three replications. Thirty-eight-day-old seedling (soaking–TP) for TP_1 and TP_2 and thirty-two-days old seedling for TP_3 was transplanted with two seedlings for Mg_1 and 3-4 for Mg_2 per hill at a spacing of 20 × 20 cm.

Leaf area index increased with advancement of planting time and all tested entries had higher LAI at later planting (20 February) in both management options due to favourable temperature for plant growth. Both entries had higher LAI with Mg_2 than Mg_1 at all times of planting BRRI dhan28 had higher LAI than BRRI dhan81 due to higher number of tillers. All the tested entries produced higher number of panicle at 24 January planting than 27 December planting due to favourable temperature for growth and 20 February planting was the lowest due to higher temperature. More number of panicle was found in Mg_2 than Mg_1 in both entries at all the times of planting. BRRI dhan28 had higher number of panicle than BRRI dhan81 both in 27 December and 24 January planting. All tested entries produced higher yield at 24 January planting with both the treatments. Similar yield was observed both in 27 December and 20 February planting. BRRI dhan28 and BRRI dhan81 gave about 0.5 t ha^{-1} higher yield in Mg_2 than Mg_1. BRRI dhan28 gave about 0.31 t ha^{-1} higher yield BRRI dhan81.

Nutrient management for yield maximization of hybrid and fine rice

An experiment was conducted at BRRI farm, Gazipur during Boro 2017-18 to obtain maximum grain yield of hybrid and fine rice. The nutrient management for hybrid rice was: N_1= BRRI recommended fertilizer dose (120-20-60-12-2.6 kg ha^{-1} N, P, K, S and Zn), N_2= 20% over N_1, N_3= N_1 but USG instead of prilled urea, N_4= 70% of N_1+ 1.5 t ha^{-1} organic manure (combination of CD, PL, VC) and N_5= STB fertilizer dose (Control). The hybrid varieties were: V_1= BRRI hybrid dhan3 and V_2= BRRI hybrid dhan5. The nutrient management for fine rice was: N_1= BRRI recommended fertilizer dose (92-14-50-8-1.5 kg ha^{-1} N, P, K, S and Zn), N_2= 20% over T_1, N_3= T_1 but USG instead of prilled urea, N_4= 70% of T_1 + 1.5 t ha^{-1} organic manure (combination of CD, PL, VC) and N_5= STB fertilizer dose. The fine rice varieties were: V_1= BRRI dhan50 and V_2= BRRI dhan63. Treatments were distributed in split plot design; while different nutrient management was followed in main plot and variety in sub plot. The interaction effects of nutrient management and variety were significant in case of yield components, grain yield and sterility. Significantly higher grain yield was observed in BRRI hybrid dhan3 compared to BRRI hybrid dhan5 due to higher number of panicles, more grains $panicle^{-1}$ and TGW. Significantly higher sterility was observed in BRRI hybrid dhan5 which might influence in grain yield. There was no clear indication of increasing yield using USG, integrated nutrient management or soil test based nutrient management over BRRI recommended dose or 20% higher than recommended dose. Cold spell during 1-15 January 2018 was the main cause of poor growth and yield performance of hybrid rice. The interaction effects of nutrient management and variety were significant in TGW and grain yield. Higher grain yield was observed in BRRI dhan50 compared to BRRI dhan63. Significantly lower grain yield was observed in 20% higher nutrient (N_2), it was mainly due to higher sterility%.

Nutrient management for yield maximization of hybrid rice in T. Aman

An experiment was conducted at BRRI farm, Gazipur in T. Aman 2017 to obtain maximum grain yield of hybrid rice. The nutrient management for hybrid rice was: N_1= BRRI recommended fertilizer dose (100-15-50-10-2 kg ha^{-1} N, P, K, S and Zn), N_2= 20% over N_1, N_3= N_1 but USG instead of prilled urea, N_4= 70% of N_1+ 1.5 t ha^{-1} organic manure (combination of CD, PL, VC) and N_5= STB fertilizer dose (Control).

The hybrid varieties were: V_1= BRRI hybrid dhan4 and V_2= BRRI hybrid dhan6. Treatments were distributed in split plot design, while different nutrient management was followed in main plot and variety in sub plot. Irrespective of nutrient management, panicle m^{-2}, grain panicle^{-1} and grain yield was significantly influenced by hybrid varieties. Significantly higher yield and yield components were observed in V_2 (BRRI hybrid dhan6). Irrespective of variety, all the nutrient management practices gave statistically similar results on tested parameters. Poor yield performance of hybrid varieties was due to high sterility that resulted from lodging (due to depression and heavy rain).

Yield maximization of Boro rice through organic and inorganic fertilizer management

Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Chaturvedi, 2005). Organic manures and chemical fertilizers are both important for rice cultivation. Organic manures improve the physical condition of the soil and supply limited quantities of plant nutrients through enhanced microbial activity. Sustainability in crop yield and soil health could be achieved by the application of mineral fertilizers along with organic manures.

The objectives of the study was to observe dry matter production, tillering pattern and maximize grain yield of rice under varying fertilizer management from organic and inorganic sources. The experiments were conducted at the Bangladesh Rice Research Institute, Gazipur during Boro 2017-2018 seasons to maximize the yield of BRRI dhan58 with additional organic manure combination with different splitting of N. The experiment was carried out with six different splitting of N and others fertilizer with two organic manure. The N and K fertilizers splitting were-

- N_0 (No nitrogen) + others fertilizers
- N_1 (30% basal+35% AT+35% pI)+PKZnS (Basal)
- N_2 (30% 15 DAT+35% AT+35% PI)+ PZnS (Basal) + K 50% at basal + K 50% at PI
- N_3 (15% basal+45% AT+30% PI+ 10% heading) +PKZnS (Basal)
- N_4 (standard fertilizer) @ 40-13-22-15-1.5 urea-TSP-MoP-Gyp-$ZnSO_4$-Zn /bigha
- N_5 without any fertilizer

Fertilizer from organic sources were cowdung at 5 t ha^{-1} and decomposed poultry manure 2.5 tha^{-1}. All treatments were laid out in a split plot design with three replications. Inorganic fertilizers were in main plot and organic manure were in subplot. Forty-day-old-seedlings of BRRI dhan58 were transplanted on 09 January 2018 at 20 × 20 cm spacing with two seedlings hill^{-1}.

Interaction effect of N and OM management was not significant in grain yield and yield characters ($P>0.05$) but individual effect of N management significantly varied. Among N management treatment N_2 (30% N at 15 DAT+35% N at AT+ 35% N at PI+ PZnS (Basal)+K 50% basal+50% at PI) produced the highest grain yield (7.68 t ha^{-1}) followed by N_3 (15% basal N +45% N at AT+30% N at PI+ 10% N at heading)+PKZnS (Basal). The lowest grain yield was observed from N_0 treatment (3.32 t ha^{-1}). In N_0 treatment N was not applied but CD and PM was applied in addition with PKZnS fertilizer. Higher grain yield of N_2 treatment was associated with higher panicle m^{-2}, grains panicle^{-1} and 1000 grain weight. Considering OM management, cowdung and poultry manure applied treatments produced statistically similar grain yield. Straw yield and biological yield was also the highest in N_2 treatment but HI did not differed significantly among N treatment. Average yield advantages of N_2 treatment compared to the other N treatment is 0.48 t ha^{-1}. Grain yield and yield character of absolute CD and PM did not differ significantly. The current N management scheduling of three equal splits needs a thorough attention for its modification. It may be concluded that fertilizer management with 30% N at 15 DAT+35% N at AT+ 35% N at PI+ PZnS (Basal)+K 50% basal+50% at PI could be used for yield maximization in Boro rice.

Soil Science Division

SUMMARY

In T. Aman, MER genotype HHZ23-DT16-DT1-DT1 produced the highest grain yield (6.44 t/ha) than the other genotypes under 35 kg N ha^{-1} fertilizer application. Among the Biotech genotypes, BR (Bio) 8333-BC5-1-20 produced the highest grain yield (6.11 t/ha) at 90 kg N/ha, which is statistically similar to 120 kg N ha^{-1}. Among the ALART materials supplied from Plant Breeding Division, HHZ 5-DT20-DT2-DT1 line produced the highest grain yield (5.56 t ha^{-1}) at 90 kg N ha^{-1}. The calculated optimum N dose for BRRI dhan58 from quadratic equation was 144 kg N ha^{-1} and economically optimum N dose was 142 kg N ha^{-1}. A combination of 100kg K and 120 kg N ha^{-1} for BRRI dhan74 was suitable for grey terrace soil. Application of P fertilizer (12 kg ha^{-1}) significantly increased grain yield of BRRI dhan49 at 1.70-4.60 mg kg^{-1} soil P level. At the lowest soil P level (1.70-2.90 mg kg^{-1}), P fertilizer @ 20 kg P ha^{-1} produced higher grain yield of BRRI dhan58 compared to BRRI dhan69.

Long-term application IPNS based fertilizers showed increasing trend of rice yield, while inorganic fertilizer alone showed yield plateau. At balanced fertilizer treatment, K @ 80 kg K ha^{-1} produced significant higher grain yield than 60 kg K ha^{-1}. In T. Aus and T. Aman 2017, statistically similar grain yield was produced in 100% STB and 50% STB + MM fertilizer dose. But in T. Aman, under triple cropping pattern, 50% STB + MM produced statistically higher grain yield than 100% STB and FP dose. In Boro 2017-18 under double cropping pattern, 50% STB + MM fertilizer treatment produced significantly higher yield than 100% STB fertilizer dose but under triple cropping pattern, 100% STB and 50% STB + MM fertilizer treatments produced statistically similar grain yield. Vermicompost (VC) @ 0.5 t ha^{-1} with full doses of chemical fertilizer could be suitable for sustaining rice productivity and soil health.

Deep placement of UB and IPNS based organic amendments showed similar CH_4 emission in both AWD and CSW conditions. IPNS based organic amendments showed higher seasonal CH_4 emission compared to broadcast PU under both water regimes. However, AWD condition significantly reduced cumulative CH_4 emission compared to CSW irrigation regimes. Although organic manure practices increased CH_4 emission during wet rice cultivation but it could be an effective soil management tool to increase net ecosystem balance (NECB) in soil and CO_2 capturing from the atmosphere. High soil (45°C) temperature affected soil C and N mineralization. The mode of action differed with soil type and fertilizer management practices. High temperature increased NH_4-N mineralization three fold in saline soil compared to terrace soil. P mineralization was high at high temperature and IPNS treatment. K mineralization was high in chemical fertilizer treatment. Soil bacteria were affected more compared to fungi and actinomycetes due to high temperature and nutrient management practices.

Seven beneficial soil bacteria were isolated and identified from Gazipur (*Paenibacillus polymyxa, Bacillus* sp), Komolganj (*B subtilis*), Lalmonirhat (*Bacillus mycoides, Proteus* sp, *B cereus*) and Patuakhali (*B pumilus*). Bio-organic fertilizer at 2 $tha^{-1}$with 30% less chemical N and 100% omission of TSP fertilizer produced statistically similar grain yield with complete fertilization.

SOIL FERTILITY AND PLANT NUTRITION

Determining N requirement of ALART materials. Before releasing a variety, ALART materials need to adjust fertilizer requirement. Among the nutrient elements N is the most limiting nutrients for rice production. Field trials were conducted at BRRI HQ farm, Gazipur (AEZ 28) during T. Aman and Boro seasons of 2017-18. In T. Aman MER genotypes (BR8204-5-3-2-5-2, BR7528-2R-HR16-12-23-P1, BR7954-14-2-1, BR8210-10-3-1-2, HHZ23-DT16-DT1-DT1) were evaluated. In Boro season, BR (Bio) 8333-BC5-1-20, BR (Bio) 8333-BC5-2-16, BR (Bio) 8333-BC5-2-22, BR (Bio) 9785-BC2-6-2-2, BR (Bio) 9785-BC2-20-1-3 from Biotechnology Division and BRC 266-5-1-1-1, BR 8631-12-3-6-P3, BR 8631-12-3-5-P2, BR8938-19-4-3-1-1, HHZ12-SAL2-Y3-Y2, HHZ5-DT20-DT2-DT1 from Plant Breeding Division were evaluated. Five fertilizer treatments were used during T. Aman and Boro season. In T. Aman season, fertilizer doses: N0, N35, N70, N105, N140 kg ha^{-1} and Boro season N0, N45, N90, N135, N180 kg ha^{-1} were applied with three replications. Standard doses of P, K and S were applied to each experiment.

T. Aman 2017 and Boro 2017-18. Genotype HHZ23-DT16-DT1-DT1 produced the highest grain yield (6.44 t ha^{-1}) than the other genotypes under 35 kg N ha^{-1} fertilizer application. All the tested genotypes produced the highest grain at 35 kg N ha^{-1}. In Boro, among the tested genotypes, BR (Bio) 8333-BC5-1-20 produced the highest grain yield (6.17 t ha^{-1}) at 120 kg N ha^{-1}, which is statistically similar to 90 kg N ha^{-1}. BR (Bio) 8333-BC5-1-20, BR (Bio) 8333-BC5-2-22 and BR (Bio) 9785-BC2-6-2-2 produced the highest grain yield at 135 kg N ha^{-1}, which was statistically similar with 90 kg N ha^{-1}. Yield of BR (Bio) 8333-BC5-2-16 at 90 kg N ha^{-1} was statistically similar with 45 and 135 kg N ha^{-1}. Among the ALART materials supplied from breeding division, grain yield of HHZ 5-DT20-DT2-DT1 line was significantly the highest in respect of all nitrogen doses. HHZ 5-DT20-DT2-DT1 and BR 8631-12-3-5-P2 Produced the highest grain yield at 90 kg N ha^{-1} which were statistically similar with 135 kg N ha^{-1} dose. The grain yield of BR 8938-19-4-3-1-1, BRC 266-5-1-1-1, HHZ 12-SAL2-Y3-Y2 and BR 8631-12-3-6-P3 rice genotypes were the highest at 135 kg N ha^{-1}. The highest grain yield of HHZ 12-SAL2-Y3-Y2 at 135 kg N ha^{-1} was significantly different from 90 and 180 kg N ha^{-1} doses. In case of BR 8631-12-3-6-P3 grain yield at 90, 135 and 180 were statistically identical.

Determinating nitrogen doses for MV rice. The optimum N requirement of BRRI dhan58 was determined. The experiment was laid out in a RCB design with three replications.

Grain yield and optimum N requirement. In Boro season, the grain yield of BRRI dhan58 increased with the increased N rates up to 125 kg ha^{-1}, then it declined. However, the straw yield increased with the increased N rates. The estimated nitrogen and grain yield response function derived from regression analysis was quadratic in nature with R^2 values significant ($P<0.01$). The calculated optimum nitrogen dose, from the quadratic equation that maximized the grain yield, was 144 kg N ha^{-1}. However, the economically optimum nitrogen dose appeared as 142 kg N ha^{-1} (Fig. 1).

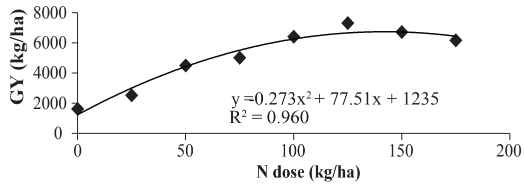


Fig. 1. Grain yield response of BRRI dhan58 to added N, Boro 2018, at BRRI HQ, Gazipur.

Influence of N and K rates. The objectives of the present study were to find the suitable N and K ratio for MV rice cultivation and to study their dynamics in soil-and plant systems. Four years study from T. Aman 2014 to Boro 2018 was conducted at BRRI HQ farm, Gazipur (AEZ 28). Potassium @ 0, 50, 100, 150 and 200 kg ha^{-1} in the main plots and 0, 100, 120 and 140 kg ha^{-1} in the sub-plots were tested with BRRI dhan74. Phosphorus and S was applied as blanket dose. Split-plot design was used with three replications.

Grain yield and uptake of P and K. Interaction effect of K and N on grain yield of BRRI dhan74 was significant (Table 1). In K deficient condition, application of increasing nitrogen significantly decreased grain yield of Boro rice and in N deficient condition, K rates were not responsible for increased grain yield at T. Aman. Application of N @ 120 kg ha^{-1} with 100 kg K ha-1 produced 6.39 t ha^{-1} rice grains, which was statistically identical with the highest grain yield of 6.46 t ha^{-1} achieved with a combination of 140 kg N and 100 kg K ha^{-1}. So, 100 kg K and 120 kg N^{-1} combination is suitable for BRRI dhan74 rice cultivation to get optimum yield. In Boro 2018, interaction effect of K and N rates on total K and P uptake was significant. Total K uptake significantly increased with the increased K rates at different levels of N rates. At K deficient condition increasing dose of N increases the total K uptake and also at N deficient condition K uptake increased with increasing level K. The highest K uptake (75.5 kg ha^{-1}) was obtained in combination of 120 kg N and 150 kg K ha^{-1}. After that total K uptake was decreased with more application of N and K dose. At K deficient condition total P uptake was increased with increasing dose of N but at N deficient condition increasing level of K reduced P uptake at different ranges. The highest P uptake (22.1 kg ha^{-1}) was obtained in combination of 120 kg N and 100 kg K ha^{-1}. After this combination increasing level of K and P declines the total P uptake as well as reduces the grain yield.

Table 1. Effect of N and K rates on grain yield of BRRI dhan74, Boro 2018, BRRI HQ, Gazipur.

K dose (kg ha^{-1})	N dose (kg ha^{-1})			
	0	100	120	140
0	3.16 aA	2.80 d B	2.52 d C	2.43 e C
50	2.41 c C	4.81 c B	5.79 c A	5.87 c A
100	2.68 b C	5.70 b B	6.39 aA	6.46 aA
150	2.56 bc C	6.20 aA	6.17 b A	5.64 d B
200	2.51 bc C	5.88 b B	6.31 ab A	6.21 b A
CV (%)	2.98			

Performance of rice varieties under phosphorus deficit conditions. Acute P deficiency reduces rice yield depending on internal and / or external mechanisms that allow greater soil P extraction, which needs to be investigated. An experiment was conducted at BRRI HQ farm, Gazipur during 2017-18 in wet and dry seasons having different levels of soil available P. Soil available P were grouped into four where each level had three plots considered as three replications. The soil available P levels were considered as main plots in both the seasons. Soil available P groups were 1.80-2.50, 2.51-3.20, 3.21-3.90 and 3.91-4.60 mg kg^{-1} in wet season while 1.70-2.30, 2.31-2.90, 2.91-3.50 and 3.51-4.10 mg kg^{-1} in dry season. In sub-plots, 0 and 12 kg ha^{-1} P fertilizer doses were arranged in wet season and 0 and 20 kg ha^{-1} in dry season. In wet season, BRRI dhan49 was used as tested genotype, whereas BRRI dhan58 and BRRI dhan69 were set in sub-sub plot in dry season. Each plot received 92 kg N, 42 kg K and 10 kg S ha^{-1} in wet and 150 kg N, 60 kg K and 10 kg S ha^{-1} in dry seasons as flat dose.

Grain and straw yields. In the T. Aman season, interaction effect of soil available P (SP) and fertilizer P (FP) on grain yield was significant but there was no significant effect on straw yield. In fertilizer P control plots, the highest grain yield of BRRI dhan49 (4.16 t ha^{-1}) was recorded in soil available P of 3.91-4.60 mg kg^{-1}, which was statistically similar to yield of soil available P of 3.21-3.90 mg kg^{-1}. Soil P level 1.80 mg kg^{-1} gave the lowest grain yield (3.27 t ha^{-1}), which was similar to soil P level of 2.50 mg kg^{-1}. It indicates that soil P level from 1.80 to 3.20 mg kg^{-1} did not have effects on rice grain yield. Similarly, there was no grain yield effect of soil P level from 3.21 to 4.60 mg kg^{-1}. On the other hand, in fertilizer P applied plots, the greatest soil P level 3.91-4.60 mg kg^{-1} gave the highest grain yield (4.81 t ha^{-1}), which was statistically similar to soil P level of 3.21-3.90 and 2.51-3.20 mg kg^{-1}. Soil levels of P with 1.80-2.50 mg kg^{-1} showed the lowest grain yield (4.46 t ha^{-1}), which was statistically identical to soil P levels of 2.51-3.20 and 3.21-3.90 mg kg^{-1}. Furthermore, in all the soil P levels, P fertilizer applied plots showed significantly better performance.

Grain and straw yields. At Boro season, grain yield of BRRI dhan58 in the fertilizer P control plot progressively increased with the increasing level of soil P and the highest grain yield (3.70 t ha^{-1}) was recorded in the highest soil P level, which was significantly different from any other soil P levels. On the other hand, soil P levels had no effect on grain yield of same variety under fertilizer P applied plots. However, P fertilizer application significantly increased grain yield compared to fertilizer P control plots at all levels of soil P. The highest grain yield (3.96 t ha^{-1}) of BRRI dhan69 in P fertilizer control plot was found at the highest soil P level (3.51-4.10 mg kg^{-1}), while the lowest yield was observed at the lowest soil P level (1.70-2.30 mg kg^{-1}), which was statistically similar to soil P levels of 2.31-2.90 and 2.91-3.50 mg kg^{-1}. In P fertilizer control plots, BRRI dhan69 gave higher grain yield than BRRI dhan58 at the lowest soil P level but above 1.70-2.30 mg kg^{-1} soil P level there was no significant yield difference between two genotypes. On the other hand, in P applied plots, BRRI dhan58 produced higher grain yield than BRRI dhan69 at the lowest soil P level, whereas significant grain yield difference between two genotypes was not found above 1.70-2.30 mg kg^{-1} soil P level. Soil available P levels significantly affected straw yield of Boro rice and interaction effect of fertilizer P and variety on straw yield was also significant. The highest straw yield was recorded with the highest soil P (3.51-4.10 mg kg^{-1}), which was significantly different from any other soil P levels. Both genotypes, BRRI dhan58 and BRRI dhan69, gave statistically equal straw yield in P unfertilized condition and they gave statistically higher straw yield in P fertilized condition than P unfertilized condition.

IDENTIFICATION AND MANAGEMENT OF NUTRITIONAL DISORDER

Long-term use of organic and inorganic nutrients in lowland 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 treatments were revised twice (see BRRI 2016) and after 47^{th} crop, treatments were modified with omission of Zn because of its sufficiency in the soil. The STB doses of NPKS were 138-10-80-5 kg ha^{-1} and 100-10-80-5 kg ha^{-1} for Boro and T. Aman respectively after 47^{th} crop (BARC, 2005). Urea N was applied in three equal splits at final land preparation, at active tillering and at 5-7 days before PI. The rest of the fertilizers were applied at final land preparation. In Boro 2009-10, organic materials were used as third modification in T_5, T_8, T_9, T_{10} and T_{11} treatments. Oil cake (OC, 2 t ha^{-1}), saw dust (SD, 3 t ha^{-1}), cow dung (CD, 3 t ha^{-1}), mixed manure, MM (CD: PM: SD: OC = 1:1:1:0.5) and PM @ 2 t ha^{-1}) in T_{10}, T_9, T_5, T_{11} and T_8 treatments. Only N @ 138 kg ha^{-1} was applied as top dress with organic amended treatments. Both missing elements and reverse management plots were merged for making 12 treatments. In T. Aman 2011-12, T_9 and T_{11} treatments were changed to accommodate 60 and 40 kg K ha^{-1} respectively. NPKSZn @ 100-7-80-3-5 kg ha^{-1} was used in T. Aman 2013 and it was 138-7-80-3-5 kg ha^{-1} in Boro 2013-2014. CD (3 t ha^{-1}), PM (2 t ha^{-1}) and mustard OC (2 t ha^{-1}) were used in T_5, T_8 and T_{10} treatments. From T. Aman 2015, vermicompost (VC) was used in place of mustard OC with same rate. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis.

Grain yield. In T. Aman 2017 omission of N, P and K decreased rice yield than that of complete fertilizer treatment (Table 2). Among organic materials treated plots, VC and CD treated plot had the highest grain yield (4.26 and 4.03 t ha^{-1}) followed by PM (4.02 tha^{-1}). Different rates of K in the complete fertilizer treatment significantly influenced rice yield of BRRI dhan49. The highest rice yield (3.54 t ha^{-1}) was obtained with 80 kg K ha^{-1} and the lowest (3.17 tha^{-1}) with 40 kg K ha^{-1} but there was no significant difference between 40 kg and 60 kg Kha^{-1}. In Boro 2017-18, complete fertilizer treatment gave 6.68 t ha^{-1} grain yields, which significantly decreased to 3.91, 4.22, and 4.01 t ha^{-1} due to omission of all nutrients, N, P and K, respectively. However, the decrease in grain yield due to S and Zn omission was insignificant. Application of VC and 2 t ha^{-1}, CD @ 3 tha^{-1} and PM @ 2 tha^{-1} with IPNS based fertilization produced the highest grain yield (7.25, 7.19 and 7.03 t ha^{-1}), which was statistically significant with complete fertilizer treatment. Reduced dose of K @ 40 kg K ha^{-1} produced significantly less grain yield with complete fertilizer treatment, but K @ 40 kg ha^{-1} and K @ 60 kg Kha^{-1} produced similar grain yield of BRRI dhan29.

Annual rice yield during 2010-2018. Long-term application of organic with IPNS based fertilizers showed increasing trend of rice yield, while inorganic fertilizer alone showed no increasing trend of rice yield during 2010-2017 (Fig. 2).

Intensive wetland rice cropping and grain yield. The experiment was designed to harvest three rice crops in a year and to evaluate the consequences of intensive cropping on soil fertility over time. The experiment was initiated in 1971 in a permanent layout with NPK fertilizer application. After several modifications of treatments in 1982, 1984 and 1991, six treatments viz. control, reverse control (NPKSZnCu), NPK, NPKS, NPKSZn and NPKSZnCu were imposed in 2000. Recently tested varieties in T. Aus, T. Aman and Boro seasons were BRRI dhan48, BRRI dhan46 and BRRI dhan50 respectively. The NPK doses used were 140-25-80, 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.

Table 2. Effect of organic and inorganic nutrients on rice grain and straw yields of BRRI dhan49, T. Aman 2016 and BRRI dhan29, Boro 2017, BRRI HQ, Gazipur.

Treatment	T. Aman		Boro	
	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
NPKSZn@100-7-80-3-5 kg/ha	3.54	4.73	6.68	6.84
NPSZn (-K)	2.79	4.23	4.01	4.72
NKSZn (-P)	3.18	4.42	4.22	4.81
PKSZn (-N)	3.51	4.93	3.91	4.32
CD (3 t/ha) + IPNS	4.03	5.5	7.19	7.46
NPKS (-Zn)	3.53	4.79	6.83	7.23
NPKZn (-S)	3.56	4.88	6.98	7.29
PM (2t/ha) + IPNS	4.02	5.6	7.03	7.45
NPKSZn.@100-7-60-3-5 kg/ha	3.24	4.71	6.48	6.79
VC (2t/ha) + IPNS	4.26	5.19	7.25	7.54
NPKSZn@100-7-40-3-5 kg/ha	3.17	4.66	6.19	6.51
Control	2.63	3.44	2.51	3.09
$LSD_{0.05}$	0.20	0.45	0.49	0.68
CV (%)	4.17	6.61	5.94	7.65

Rice production trend and annual nutrient removal. Annual rice production is in decreasing trend because of continuous rice cultivation without fertilizer application (Fig. 3). In 2017, grain yield in control plot was 1.02-2.11 t ha^{-1} irrespective of season. When NPKSZnCu fertilizers were used as reverse treatment, total rice production jumped to 11.48 t $ha^{-1}yr^{-1}$ which is close to complete fertilization (12.48 t ha^{-1} yr^{-1}). The highest N (261.87 kg ha^{-1} yr^{-1}), P (57.69 kg ha^{-1} yr^{-1}) and K (258.77 kg ha^{-1} yr^{-1}) removal was found with reverse management treatment.

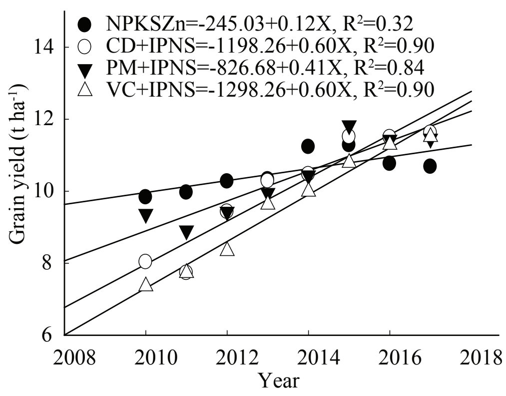


Fig. 2. Annual rice grain yield trend under inorganic and organic amended soil.

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. In Boro-Fallow-T. Aman pattern, BRRI dhan58 and BRRI dhan49 were used. In Boro-T. Aus-T. Aman pattern, BRRI dhan74, BRRI dhan48 and BRRI dhan46 were included as test variety. Fertilizers used were: T_1=control, T_2=STB dose (NPKS @ 160-25-60-20 kg ha^{-1} for Boro, 70-12-48-10 kg ha^{-1} for T. Aus and 84-15-54-14 kg ha^{-1} for T. Aman), T_3= STB (50%) + MM (CD @ 2 t ha^{-1} + ash @ 1 t ha^{-1} oven dried), T_4= 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. In Boro under double and triple cropping pattern, 100% STB and 50% STB + MM fertilizer dose produced statistically similar grain yield (Table 3). In T. Aus 2017, the highest grain yield of BRRI dhan48 was found in 100% STB treatment, which was statistically similar with 50% STB + MM and FP fertilizer dose. In T. Aman 2017, under double cropping pattern, 100% STB and 50% STB + MM fertilizer dose produced statistically similar grain yield. However 50% STB + MM fertilizer dose produced statistically higher

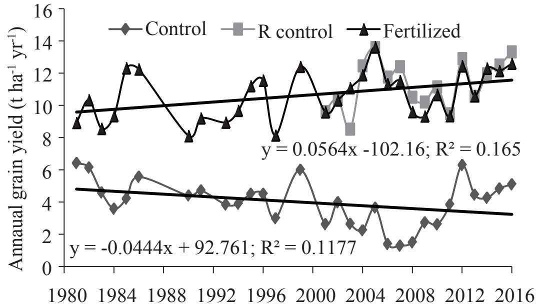


Fig. 3. Changes in annual rice production under wetland conditions over 37 years.

yield than FP (Table 4). In Boro 2017-18 under double cropping pattern 50% STB + MM fertilizer treatment produced significantly higher yield than 100% STB fertilizer dose but under triple cropping pattern, 100% STB and 50% STB + MM fertilizer treatments produced statistically similar grain yield. Moreover both the treatments produced significantly higher yield than FP in triple cropping pattern. It may be concluded that STB (100%) dose of fertilizer and integrated nutrient management (INM) are good options for obtaining higher rice yields in double or triple rice cropping pattern.

Performance of vermicompost and poultry manure on rice yield and soil health. The present study was undertaken to find out the effect of PM and VC with chemical fertilizers on yield and yield attributes of T. Aman and Boro rice and its impacts upon soil nutrient status and nutrient uptakes. The experiment was conducted at BRRI HQ farm, Gazipur since Boro 2015. Initial soil (0-15 cm depth) properties were: clay loam texture; pH 6.78; 12.3 g kg^{-1}organic C; 1.3 g kg^{-1} total N, 1.8 mg kg^{-1} available P and 50 mg kg^{-1} soil exchangeable K. The VC contained 50% MC, 2.0% total N, 0.52% P, 0.42% K and 0.3% S. PM contained 50% MC, 1.9% total N, 0.56% P, 0.75% K and 1.1% S. PM and VC were used with full doses of chemical fertilizer @ 0.5, 1.0, 1.5, 2.0 and 2 t ha^{-1}+ IPNS fertilizer and compared with control. Each treatment was assigned in 4- × 5-m sized plot and repeated three times in a RCB design. Seedlings of BRRI dhan29 and of BRRI dhan49 were transplanted at 20- × 20-cm spacing in Boro and T. Aman seasons. Chemical fertilizers (N-P-K-S-Zn = 138-10-80-5-5kg ha^{-1}) were applied one day before rice transplanting. At harvesting, rice plants were collected for analysis of N, P and K content and nutrient uptakes based on BRRI standard methods.

Rice productivity. Integrated use of OM and chemical fertilizer significantly stimulated rice yield in both the seasons in 2017-18. Grain yield was 2.69-2.78 t ha^{-1} in control plot, which increased with increasing VC rates. Among the PM and VC manure treated plots rice grain yields were not significant but total biomass were different. Only chemical fertilizer (NPKSZn) showed significant difference in rice yield than PM and VC treated plot. The nutrient added through VC was N, P, K and other mineral nutrients might affect rice yield increase. Since the selected VC contained N-P-K= 2-5.0-4.2 g kg^{-1}, 2 Mg ha^{-1} of VC application can supply approximately N-P-K= 40-10-8.2 kg ha^{-1}. Among the treatments, use of 0.5 mg ha^{-1} VC with full doses of chemical fertilizer showed higher yield than other treatments during T. Aman and Boro season.

SOIL AND ENVIRONMENTAL PROBLEMS

Greenhouse gas emissions from rice field. The experiments were conducted to study the effects of N placement and its sources on rice yield, NUE and emissions of CH_4 gas under continuous standing water (CSW) and alternate wetting and drying (AWD) irrigation regimes. Field experiments were conducted at BRRI HQ farm, Gazipur (T. Aman 2017 and Boro 2017-18) and farmers field at Bhaluka, Mymensingh (Boro 2017-18) under both AWD and CSW conditions. For Gazipur site, eight treatments with different N sources including integrated plant nutrient system (IPNS) based organic amendments were tested. PU was applied as broadcast in three equal splits in Boro season and two splits in T. Aman season at 7-10 DAT, while urea briquettes (UB) were applied as a single application during first top dressing (TD) of PU. In the IPNS treatments, poultry litter (PL) and vermicompost (VC) was applied before transplanting. For Bhaluka site, conventional farmers practice and AWD conditions were tested. Recommended NPKSZn fertilizers were applied in both the conditions. Under CSW condition, plots were remained flooded until two weeks before

Table 3. Annual grain production (t ha^{-1}) of double and triple cropping pattern under continuous wetland condition, BRRI HQ farm, Gazipur 2017.

Treatment	Double cropping			
	Boro 2016-17 (BRRI dhan58)	Fallow	T. Aman 2017 (BRRI dhan49)	Annual yield (t ha^{-1})
T_1 = Control	1.87	-	3.07	4.94
T_2 = STB	5.20	-	3.97	9.17
T_3 = 50% STB+MM	5.18	-	4.21	9.39
T_4 = FP	4.45	-	3.58	8.03
$LSD_{0.05}$	0.65	-	0.44	
Triple cropping				
	Boro 2016-17 (BRRI dhan74)	T. Aus 2017 (BRRI dhan48)	T. Aman 2017 (BRRI dhan46)	Annual yield (t ha^{-1})
T_1 = Control	1.57	1.95	3.16	6.68
T_2 = STB	5.00	3.34	4.28	12.62
T_3 = 50% STB+MM	4.75	3.24	5.02	13.01
T_4 = FP	3.84	3.11	4.44	11.39
$LSD_{0.05}$	0.70	0.60	0.36	

Table 4. Yield scenario of Boro rice under different treatments of double and triple cropping pattern at BRRI HQ farm, Gazipur 2017-18.

Treatment	Yield (t ha^{-1})			
	Double cropping 2016-17 (17th crop, BRRI dhan58)	Double cropping 2017-18 (19th crop, BRRI dhan58)	Triple cropping 2016-17 (25th crop, BRRI dhan74)	Triple cropping 2017-18 (28th crop, BRRI dhan74)
control	1.87	1.91	1.57	1.68
STB	5.20	4.84	5.00	6.24
STB (50%)+MM	5.18	5.55	4.75	5.92
Farmer practice	4.45	4.35	3.84	4.63
$LSD_{0.05}$	0.65	0.53	0.70	0.80

harvesting. Under AWD condition, irrigation water was applied when water falls below 15 cm of soil surface. At Gazipur site, floodwater samples were collected every day at 8:00 AM before one day of fertilizer application and continued for seven days after each TD of PU to measure floodwater NH_4^+-N using spectrophotometer at 420 µm. Ammonia (NH_3) volatilization were measured using 'closed chamber technique' and boric acid trap method. The concentration of CH_4 flux in the collected samples were measured using a gas chromatograph (Shimadzu GC-2014, Japan) equipped with a flame ionization detector (FID) and electron capture detector (ECD).

Rice yield, total N uptake and NUE. In T. Aman, grain yields recorded in control treatment were 2.7 t ha^{-1} in AWD and 2.8 t ha^{-1} in CSW condition, while in Boro season; it was 2.7 t ha^{-1} in AWD and 3.1 t ha^{-1} in CSW. Deep placement of UB remarkably increased total N uptake (TNU) and recovery efficiency of N (RE_N) than that of PU in both the seasons.

Floodwater NH_4^+-N and NH_3 volatilization. Irrespective of N rate, source and season, the amount of floodwater NH_4^+-N was higher in broadcast PU treatment after 1-2 days of fertilizer application, while floodwater NH_4^+-N was negligible in deep placement of UB treatment throughout the seven days measurement period, ie, close to control treatment. Similarly, IPNS based organic fertilizers, except the UB+IPNS with PL showed a slight peak of floodwater NH_4^+-N after two days of fertilizer application. However, broadcast application of PU significantly increased NH_3 volatilization compared to UB and PU+IPNS with PL treatment (Fig. 4). Notably, the variation in NH_3 volatilization between UB and PU+IPNS with PL treatment was similar. As in Boro, similar pattern of floodwater NH_4^+-N and NH_3 volatilization was observed in T. Aman season.

Methane emissions. Control treatments produced significantly lower seasonal CH_4 emission compared to other treatments. Deep placement of UB and IPNS based organic amendments showed similar CH_4 emission in both AWD and CSW conditions (Fig. 5). IPNS based organic amendments showed higher seasonal CH_4 emission compared to broadcast PU under both the water regimes. Seasonal cumulative CH_4 emissions were lower at Bhaluka site (Fig. 6) due to less organic substrate compared to Gazipur site. However, AWD condition significantly reduced cumulative CH_4 emission compared to CSW irrigation regimes in both the locations.

Climate smart agricultural practices for crop production and greenhouse gas emission in Bangladesh. Agriculture in Bangladesh varies in 30 agro-ecological zones and 88 sub-zones. These zones have been developed based on physiography, soil types, nature of seasonal flooding and agro-climatology. Although different crops are grown across the country, climate change impacts are visible on their performances. Sustaining food security under changing climatic conditions requires adoption of climate resilient production technologies. So, activities on climate smart agricultural practices were initiated at three villages of Gazipur and Kishoreganj districts during 2015. Two villages were selected from two districts are (i) Pakundia and (ii) Kotiadi, Kishoreganj at 24°14,45.27,,-24°19,46.77,, N latitude and 90°40›46.84» - 90°47,37.33,, E longitude. In T. Aman season, BRRI dhan62, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan72 and BRRI dhan73 was introduced with RCM and farmer's practices based management. After T. Aman harvest mustard crop was grown in Kotiadi. For mustard crop, the recommended fertilizer doses were urea-TSP-MOP-Gypusm-Boric acid @ 197-145-66-132-7 kg ha^{-1}. In Boro season, fertilizer was used at RCM and farmer's dose. Mustard plots were divided into two parts to accommodate full doses of RCM fertilizer (T_1) and 50% reduction of RCM dose except urea (T_2).

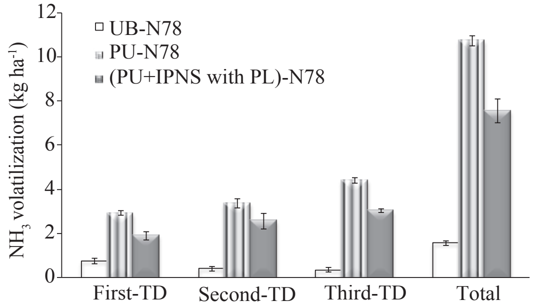


Fig. 4. Ammonia volatilization from UB, broadcast PU and PU+IPNS with PL during Boro 2018 under AWD condition at BRRI HQ farm, Gazipur. UB, PU and PL describes urea briquette, prilled urea and poultry litter respectively. Vertical bars indicate standard error of mean (n=3).

Grain yield and GWP. Farmers used BRRI dhan49 and we introduced BRRI dhan71 and BRRI dhan75 having 35 days shorter growth duration than farmers, preferred variety in T. Aman season. In general, CH_4 emission rate from paddy soil is 1-2 kg day^{-1} ha^{-1} (Haque *et al*., 2014, 2016). So, because of shorter life cycle reduced about 15-20 GWP (CO_2eq kg ha^{-1}) and increased about 15-30% rice yield with BRRI dhan71 and BRRI dhan75 compared to BRRI dhan49 (Fig. 7a and 7b). Therefore, introduction of short duration rice variety and cultivation of mustard crop can reduce greenhouse gas emission from paddy soil.

Greenhouse gas emission from Boro-T. Aman-Fallow cropping pattern in Bangladesh. Organic and inorganic fertilization had impact on greenhouse gas emission (GHG) from Boro-T. Aman-Fallow cropping pattern. In this study wet season GHGs emission was measured. The wet season (WS) rice variety (BRRI dhan49) was transplanted in the third week of July and harvested in the third week of November. Treatments imposed were: chemical fertilizers (NPKSZn), CD, PM and VC with IPNS based inorganic fertilizations and control. Static closed-chamber method was used to estimate CH_4, respiration (CO_2), and N_2O emission rates during wet rice season.

Methane, CO_2 and N_2O emissions. Methane emission patterns varied with different organic manure and inorganic fertilizer application. Among the treatment PM and CD showed the highest CH_4 emission peak during rice season than VC, NPKSZn and control treatments. Similar with the CH_4

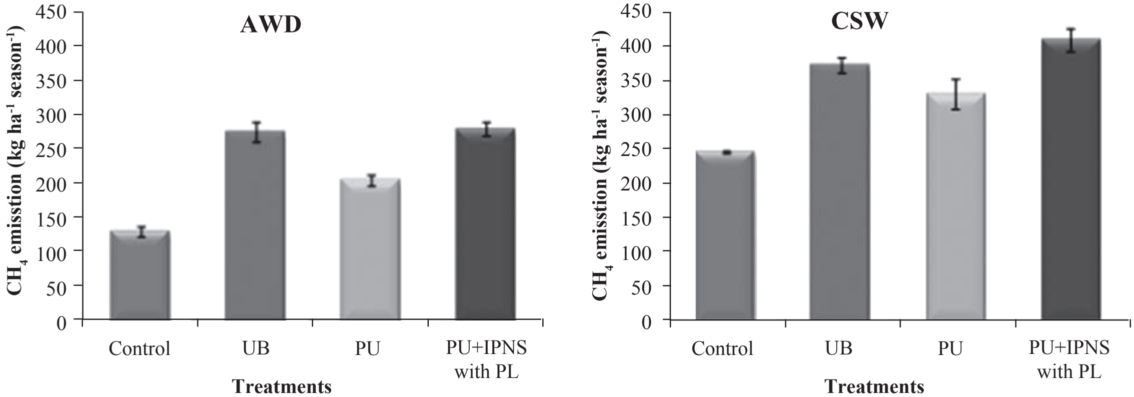


Fig. 5. Effect of N sources and methods of application on cumulative CH_4 emissions from rice field (Boro season 2018) under AWD and CSW conditions at BRRI HQ farm, Gazipur. Vertical bars indicate SE of mean (n=3).

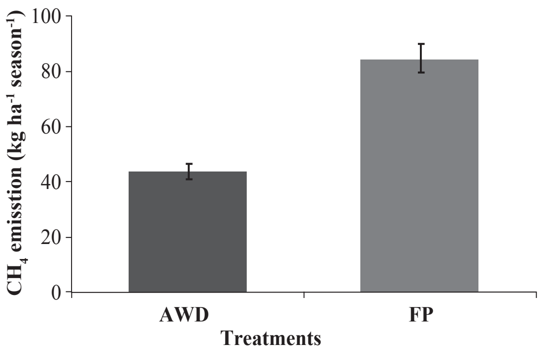


Fig. 6. Effect of AWD and farmers practice (FP) on cumulative CH_4 emissions from rice field (Boro season 2018) at Bhaluka, Mymensingh. Vertical bars indicate SE of mean (n=3).

emission patterns, soil respiration (CO_2 emission) rates increased with rice plant growth, peaked before flowering stage, and thereafter declined until maturity. Compared to the CH_4 and CO_2 emission rates, N_2O emission rates were very low during rice cultivation, irrespective of treatment background (Fig. 8).

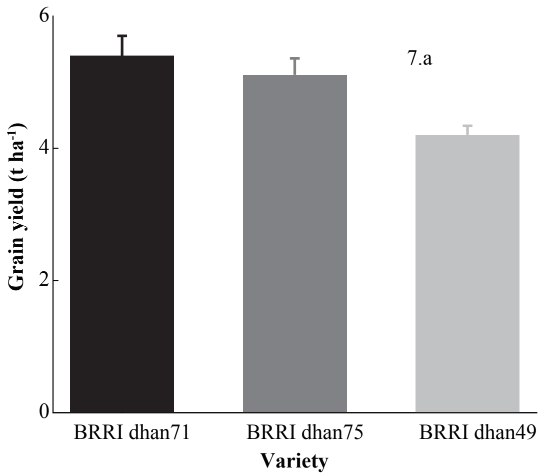
SOIL MICROBIOLOGICAL STUDIES

Identification of potential strain. A number of 30 plant growth promoting bacteria were isolated from AEZ11 and AEZ28. Among the isolated strain seven potential strain were selected for molecular identification (16S rRNA gene amplification and sequencing using appropriate primers) based on their N_2 fixation, phosphate solubilization and indoleacetic acid production capabilities (Table 5). Pure isolates were sent to Institute of Bioscience for identification.

Soil processes as influenced by temperature. Global temperature is rising due to the greenhouse gases released. Soil temperature directly influences microbial activity and nutrient mineralization. Hence present study was taken to determine nutrient mineralization rate and changes of microbial population in IPNS and chemical fertilizer practice at two different temperature regimes. Soil samples were collected from AEZ 18 (Saline soil) and AEZ 28 (Terrace soil), and incubated at two different temperatures; normal temperature (28 ±2°C), and 45°C. Each type of soil (3 kg) was taken into a plastic pot and kept in incubator with respective temperatures. Soil moisture was maintained as saturated. Chemical fertilizer NPKS (@ 135-18-82-20) and IPNS (cow dung @ 3 ton ha^{-1}+NPKS @ 120-13.5-75.1-20) was added according to the treatments. The incubation study was carried out for one month. Initial soil microbial and chemical properties such as; OC, N, P, K, was determined. Soil nutrient mineralization and changes in soil microbial population was determined after 3, 6, 9, 14, 20 and 30 days of incubation. Design of the experiment was complete randomadized design with two factors. Carbon mineralization rate (*k)* was calculated as

$$k = 2.303\frac{(\log C_o - \log C)}{t}$$

When, C_o is the initial carbon content and C at the time (t). Total bacteria, fungus and actnomycetes



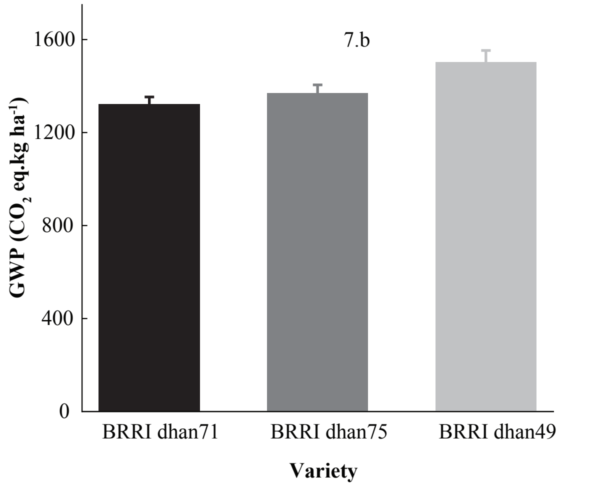


Fig. 7a. Grain yield and GWP as influenced by newly introduced improved T. Aman varieties in Kotiadi and Pakundia, Kishoreganj 2017; Error bars indicate standard error. Fig. 7b. Global warming potential (GWP) as influenced by newly introduced improved T. Aman varieties in Kotiadi and Pakundia, Kishoreganj 2017; Error bars indicate standard error (n = 6).

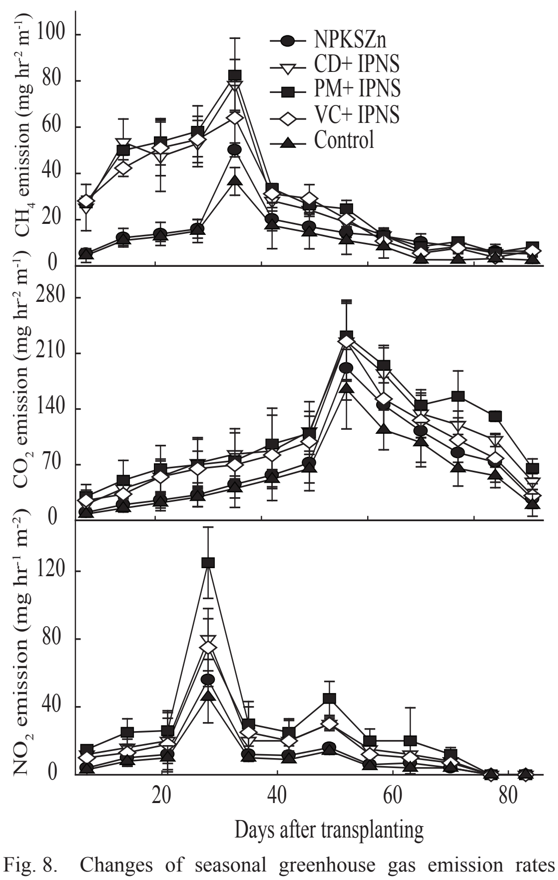


Fig. 8. Changes of seasonal greenhouse gas emission rates under organic amendment conditions during rice cultivation.

population was counted using nutrient agar plate. Free-living N_2 fixing bacteria population were determined in N-free media (Prasad *et al*., 2001) and Phosphate solubilizing bacteria (PSB) population in National Botanical Research Institute Phosphate (NBRIP) media plates.

Effect of temperature on soil organic C mineralization. Organic carbon gradually decreased over time irrespective of temperature and nutrient management practice. Carbon mineralization rate was significantly high in Saline soil compared to Terrace soil (Fig. 9). High temperature enhanced C mineralization in both the types of soil. Between two nutrient management practices, OC content was high in IPNS treatments. In the Terrace soil at 28°C temperature, C mineralization rate (r) was slightly high (0.011) in chemical fertilizer compared to IPNS treatment (0.010). On the other hand, at 45°C temperature, C mineralization rate was high in IPNS (0.015) compared to chemical fertilizer (0.013) treatment (Fig. 1a and b). In the IPNS treatment, C mineralization increased by 33% due to high temperature. In saline soil, OC content sharply declined after 3 to 6 days of incubation. In this soil, C mineralization was high in chemical fertilizer compared to IPNS treatment. At 28°C temperature C mineralization rate was 0.020 in chemical fertilizer and 0.017 in IPNS treatment, respectively. On the other hand, at 45°C temperature, C mineralization rate was 0.034 in chemical fertilizer and 0.031 in IPNS treatment respectively (Fig. 1c and d) in Saline soil. High

Table 5. Identification of indigenous potential bacteria using 16S rRNA gene amplification and sequencing.

Strain	Location	% IAA	% N	% P
Bacillus mycoides	Lalmonirhat	0.01	0.07	0.04
Proteus sp.	Lalmonirhat	0.01	0.13	0.01
B cereus	Lalmonirhat	0.36	0.08	0.11
B subtilis	Komolganj, Moulovibazar	0.01	0.08	0.04
B pumilus	Patuakhali	0.03	0.04	0.08
Paenibacilluspolymyxa	Gazipur	0.03	0.07	0.11
Bacillus sp.	Gazipur	0.40	0.14	0.05

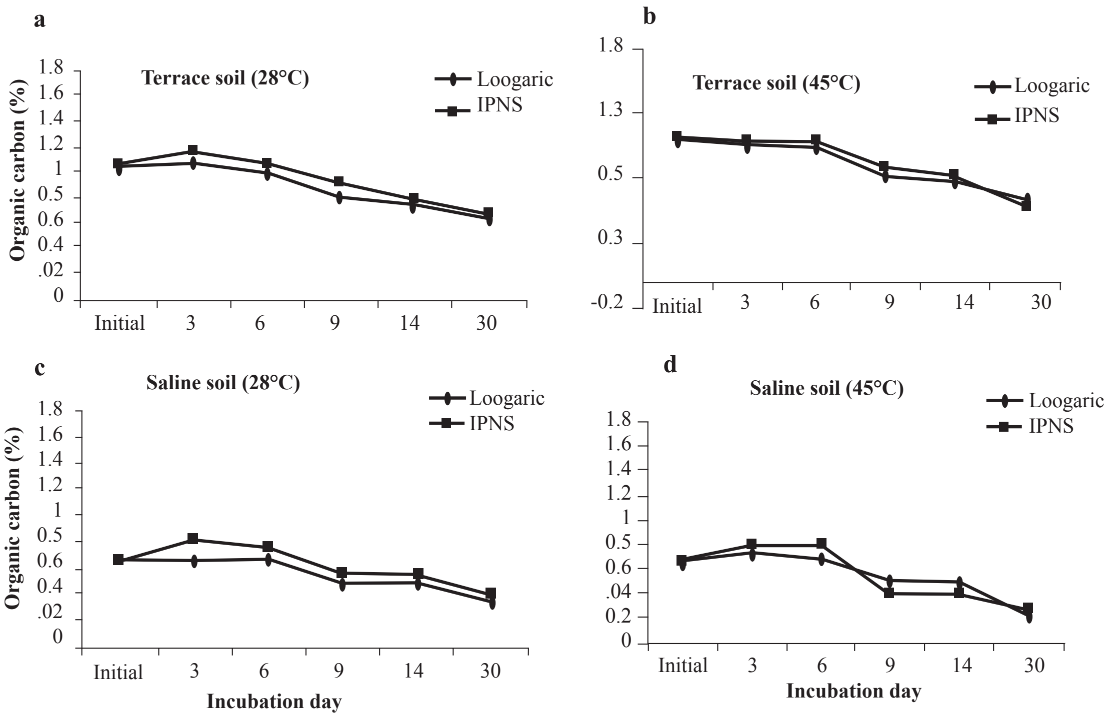


Fig. 9. Effect of temperature and nutrient management practices on C mineralization in terrace and saline soil.

temperature increases C mineralization by 41% in chemical fertilizer treatment compared to IPNS.

Effect of temperature on soil N mineralization. There were significant treatment and interaction effect (temperature × fertilizer management practices) found for NH_4-N mineralization in both the soil types. At normal temperature (28°C) in Terrace soil, significantly high NH_4-N mineralized from chemical fertilizer amended soil. The highest NH_4-N mineralization (31.5 ppm) was found at day 3 and after then it declined sharply. In this soil, at high temperature (45°C) NH_4-N mineralization was high in IPNS treatment and it decreased gradually over time. In Saline soil irrespective of fertilizer management, high temperature significantly induced (about 3 fold) NH_4-N mineralization. In between two fertilizer practices, NH_4-N mineralization was high in chemical fertilizer treatment. The highest 80.97 ppm NH_4-N mineralization was found at day 9 in this treatment and after that it declined sharply.

Effect of temperature on soil biological process. The pattern of microbial population changes in response to temperature was not similar for bacteria, actinomycetes, and fungi. The highest population change was found in bacteria. There was no significant interaction effect of temperature and nutrient management practices was found for actinomycetes population in both the soil types. Irrespective of soil and nutrient management practices, N_2 fixing bacteria population was high in IPNS treatments. At 28°C temperature, there was no significant effect of nutrient management practices found on free-living N_2 fixing bacteria population in Terrace soil. In this soil at 45°C temperature, N_2 fixing bacteria survived only up to 14 days of incubation. In the Saline soil N_2 fixing bacteria population found only up to nine days of incubation in both the temperatures. Significant effect of temperature and nutrient management practices was found on phosphate solubilizing bacteria population in Saline soil. In the Terrace soil, high population was found at three days of incubation and after that population declined. Whereas, in Saline soil there was a linear declined of PSB population recorded.

Evaluation of bio-organic fertilizer in soil plant system. Using bio-organic fertilizer, about 25-30% urea and 100% use of TSP fertilizer can be saved in rice cultivation. Moreover it can improve soil biology and soil C stock for ensuring future food security of Bangladesh. The organic materials added in bio-organic fertilizer were collected from local *kacha* bazaar and residential area. Biochar prepared from unfilled rice grain and added as 15% weight basis. A number of 10 indigenous bacteria (phosphate solubilizing, N_2 fixing and indoleacitic acid producing) were multiplied using molasses (2.5%) in Shaker for three days. Inoculumn was added as 100 ml kg^{-1} solid material. Finally, carrier material, biochar, RP (5%) and inoculum were mixed all together and kept for three months in normal temperature. The final product is odorless and looks like compost material. Three different field experiments were conducted on clay loam soil at BRRI HQ farm, Gazipur, BRRI RS, Barisal and BRRI RS, Rajshahi in T. Aman and in Boro 2017-18 at Gazipur, Cumilla, Rajshahi and Barishal. Bio-organic fertilizers were used at 2 t ha^{-1} (dry weight basis). Treatments were as T_1= Bio- organic fertilizer @ 2 t ha^{-1}, T_2= NPKS, T_3= Bio-organic fertilizer @ 2 t ha^{-1}+70% NKS, T_4= Control. Bio-organic fertilizers were applied at the same time of chemical fertilizer application.

Effect of bio-organic fertilizer on grain yield. In T. Aman season, bio-organic fertilizer (BoF_1@ 2 t ha^{-1}) has potential to supplement 25-30% N and 100% P requirement for BRRI dhan71 at Gazipur, Barishal and Rajshahi soil without sacrificing yield (Table 6). In Boro season, application of bio-organic fertilizer at BRRI Gazipur and regional stations of Cumilla, and Barishal also substitute 100% TSP fertilizer and supplement 30% crop urea requirement (Table 7). Result showed that it can produce similar grain yield of 100% chemical fertilizer when it applied with 30% reduced chemical N fertilizer or full dose of chemical fertilizer. Similar results were also obtained for yield contributing characters such as panicle length, panicle/m^2 and filled grain.

Table 6. Effect of bio-fertilizer on paddy yield at BRRI HQ, Gazipur, BRRI RS, Rajshahi and BRRI RS, Barishal (variety BRRI dhan71).

Treatment	Grain yield (t/ha)		
	Gazipur	Rajshahi	Barisal
T_1	3.75 b	3.87 b	3.40 b
T_2	3.90 a	4.09 b	3.61 ab
T_3	3.87 a	4.44 a	3.94 a
T_4	3.18 c	3.55 c	1.90 c
CV (%)	2.97	3.51	7.15

T_1=BoF (2 t/ha), T_2= NPKS (100%), T_3= BoF+ NKS (75%), T_4= Control, NPKS kg/ha @ 67-10-41-10.

Table 7. Effect of bio-fertilizer on paddy yield at BRRI HQ Gazipur, BRRI RS, Cumilla and BRRI RS, Barishal (variety BRRI dhan58).

Treatment	Grain yield (t/ha)		
	Gazipur	Cumilla	Barishal
T_1	4.69 b	6.58b	5.84a
T_2	6.04 a	8.31ab	6.33a
T_3	5.88 a	8.67a	6.0a
T_4	2.81 c	3.29c	3.23b
CV (%)	6.40	6.74	7.21

T_1=BoF (2 t/ha), T_2= NPKS (100%), T_3= BoF+ NKS (30%), T_4= Control, NPKS kg/ha @ 118-10-41-10.

Irrigation and Water Management Division

SUMMARY

Ganges-Kobadak project survey indicated that repairing existing canals and proper management could increase crop production by minimizing water loss. Direct seeding method required less water with low yield compared to the transplant method. With little prediction error, both web-based and drought model gave satisfactory drought prediction. In Barishal region, dry season saline free irrigation water was available at upstream of Tentulia, Buriswar, Biskhali and Boleswar rivers. In Borguna polder areas, about 40-50 thousand cubic meter canal water (Salinity ranged 0.48-1.15 ds/m) could be irrigated in dry season. A portable solar system had 18-15 l/s pumping capacity (0.3-14.7 m head) and 200-300 kg/h paddy threshing capacity. A model study in NW and SW regions of Bangladesh revealed that farmers used more water than requirement, needed to be optimized. In eastern gangetic plain area, polythene pipe distribution system saved water, time and cost, increased command area and water productivity. Analysis of extreme temperatures predicated that decrease in cold days could reduce Boro rice production. A developed soil fertility assessment scale based on geometric and weighted means satisfactorily agreed with dry season irrigated rice yields of Bangladesh. Dacope, Khulna farmers liked BRRI dhan76 when Amtali, Borguna farmers preferred BRRI dhan77 in T. Aman season. Growing vegetables in bags with wet season rice gave farmers extra income with 10-12% rice yield loss. In coastal areas, July to November river water was suitable for irrigation. Stored fresh water in mini-pond helped farmer to grow high value crops in costal region, increased land productivity and family income.

WATER USE EFFICIENCY IMPROVEMENT IN IRRIGATED AGRICULTURE

Study on the present operational status of Ganges-Kobadak (G-K) irrigation project after six decades of its initiation

The study was executed in Ganges-Kobadak (G-K) surface irrigation project area to investigate the present actual irrigation coverage, to identify the present project constrains, and to prepare recommendation for better project performance after completion its installment in 1954. Irrigation project area comprises thirteen upazilas of four districts as Kushtia, Chuadanga, Jhenaidah and Magura. Initially the project has been implemented mainly in order to provide supplementary irrigation in the monsoon and pre-monsoon. But considering the demand of the area, now-a-days GKIP is providing irrigation facilities from mid-January to mid-November every year in Kharif-I, Kharif-II and Rabi seasons. Under the condition of an assured water supply for irrigation, now almost 100% HYV paddy, whose water requirement is substantially higher, is being cultivated in G-K Irrigation Project. That is why, on average production rate of paddy has increased from 1.23 t/ha to 4.70 t/ha in the project area. Figure 1 shows the annual rice production achievement by G-K project irrigation system. Some constraints on increasing crop productivity are: (i) Poor irrigation intensity, (ii) Lack of specific, organized technology transfer, (iii) Weak or no participation of poor farmers in water management, (iv) In-effectiveness of water management groups or associations in certain areas and waterlogging in low and inadequate canal capacity as the hindering factors for cropping intensity. A major problem in the area is water logging of the low lands due to inadequate drainage systems and a consequent difficulty in getting 'Jho' condition of the soil in some lands. So, by repairing the canal systems, proper gate control, proper inspection, employing adequate manpower, increasing project authority's cooperation and increasing farmers' consciousness in irrigation management, it is possible to reduce water loss and provide adequate water supply in the project area and avoiding waterlogging condition.

Optimization of irrigation water use for Boro cultivation under different establishment methods

The experiment was conducted in BRRI HQ farm, Gazipur during Boro season 2017-18 to find out suitable method of Boro cultivation under water limiting condition. Performances of two crop establishment methods (Direct seeding and transplanting) were tested along with three water management practices (Continuous standing water, alternate wetting and drying practice and maintaining aerobic condition). BRRI dhan28 was the tested variety. Treatments were: T1- Transplanting with

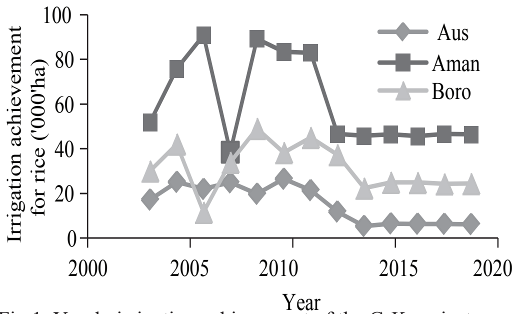


Fig.1. Yearly irrigation achievement of the G-K project.

maintaining continuous standing water (TP-CSW); T2- Transplanting with alternate wetting and drying (TP-AWD) irrigation practice; T3- Transplanting with maintaining aerobic condition (TP-ARC); T4- Dry direct seeding with maintaining continuous standing water (DS-CSW); T5- Wet direct seeding with alternate wetting and drying (WS-AWD) irrigation practices; and T6- Dry direct seeding with maintaining aerobic condition (DS-ARC). Each treatment was replicated thrice. For treatment T4 and T6, land was prepared in dry condition for line sowing of seeds on 4 January 2018. In treatment T5, sprouted seeds were sown in puddled land with drum seeder on 31st December 2017. Transplanting was done in treatment T1, T2 and T3 on 28 January 2018 after puddling of land.

Table 1 shows that irrigation frequency was higher for direct seeding methods compared to transplanting methods. But irrigation depths were higher in treatments under transplanting methods compared to direct seeding methods. Highest yield was obtained under treatment T1 (6.64 t/ha) followed by T2 (6.54 t/ha) and T3 (6.39 t/ha). It indicates that similar yield could be achieved with less irrigation by adoption of AWD and aerobic rice condition. The highest yield in direct seeded rice was obtained in T4 (6.02 t/ha) followed by T5 (5.49 t/ha) and T6 (5.25 t/ha). The lower yields in direct seeded plots were mainly due to poor establishment rate and more weed infestation. The experiment results show that irrigation requirement is less in direct seeding plots compared to the transplanted plots though yield is lower.

Effect of perched water table depletion on growth and yield of BRRI dhan49

The experiment was conducted in BRRI HQ farm, Gazipur during T. Aman 2017 to determine plant response under different water regimes. BRRI dhan49 was tested against four irrigation treatments. The treatments were, I1: Continuous standing water, I2: Supplemental irrigation when water level goes 15 cm below ground surface, I3: Supplemental irrigation when water level goes 30 cm below ground surface and I4: Rainfed condition. During the growing period of BRRI dhan49 total 683 mm rainfall occurred. Rainfall received in vegetative, reproductive and ripening phases was 402, 274 and 7.4 mm respectively for all the treatments. About 180 mm irrigation was applied in I1, whereas 95 mm water was applied in I2 and only 48 mm in I3. All the treatment gave statistically similar yield since rainfall was sufficient in vegetative and reproductive phases. The highest 4.31 t ha^{-1} yield was found in I2 followed by 4.13 and 4.10 t ha^{-1} in I3 and I2 respectively. The lowest yield (3.97 t ha^{-1}) was found in I4.

Table 1. Irrigation applied, growth duration and yield obtained under different crop establishment treatments along with water management during Boro 2017-18 at BRRI HQ farm, Gazipur.

Treatment	Method	Growth duration	Number of irrigation	Irrigation applied (mm)	Rainfall (mm)	Total water use (mm)	Yield (t ha^{-1})
T1	TP-CSW	138	13	710	490	1200	6.64
T2	TP-AWD	138	11	640	490	1130	6.54
T3	TP-ARC	138	16	590	490	1080	6.39
T4	DS-CSW	129	15	580	567	1147	6.02
T5	WS-AWD	133	13	620	567	1187	5.49
T6	DS-ARC	129	20	452	567	1019	5.25

UTILIZATION OF WATER RESOURCES IN RAINFED ENVIRONMENT

Agricultural drought forecasting for mitigating drought in T. Aman rice

The experiment was conducted at BRRI HQ farm, Gazipur in T. Aman 2017. The objective of this research is to develop the method for forecasting of agricultural drought based on weather data as early warning systems in Bangladesh. BR11 was used as test variety. Forecasted rainfall and evapotranspiration were used as input of drought model to quantify agricultural drought. Forecasted ET_0 was measured by -8.4% underestimation over observed ET_0 (Fig. 2). In case of rainfall, forecasted and observed values were made some deviation due to uneven distribution of rainfall with -4.5% underestimation (Fig. 3). But this variation was found 7.9% based on seasonal rainfall when forecasted and observed rainfall were 762 and 827 mm which respectively. Table 2 shows that forecasted and observed drought calculated from drought model seemed to zero from 8th week to 18th week of growth stage of BR11. Drought model measured the forecasted drought which was 12.4 mm during that period (Table 2). Table 2 also showed that this amount of forecasted drought is less than the observed drought (15.5 mm) due to higher amount of observed rainfall than the forecasted rainfall. Two supplemental irrigations based on AWD technique in the T2 plots each of 50 mm have been applied. Table 2 also depicted that another supplemental irrigation has been forecasted by drought model at the early of 21st week. There is no significant difference in yield and yield contributing parameters as sufficient rainfall occurred during the growing period (Table 3).

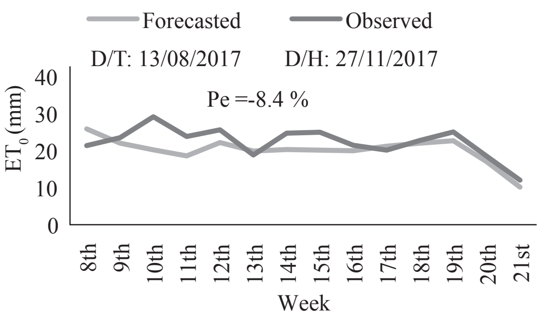


Fig. 2. Forecasted vs Observed ET_0.

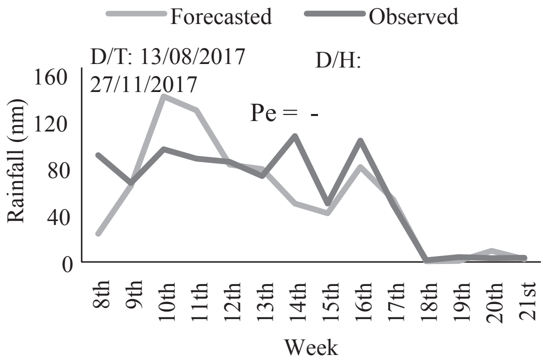


Fig. 3. Forecasted vs observed rainfall.

Forecasted rainfall and evapotranspiration give satisfactory results with low prediction error. So, web-based model gives good forecasting. Drought prediction by drought model was found quite satisfactory with little bit higher underestimation. There is no effect on drought in yield and yield contributing parameters due to higher rainfall during the growing season.

LAND PRODUTIVITY IMPROVEMENT IN THE COSTAL ENVIRONMENT

Assessment of suitable water resources availability for irrigation to increase crop production in tidal areas of Barishal region

The study was taken to identify suitable water resources for dry season crop production in the Barishal division. Four major river systems of the area: Tentulia, Buriswar, Biskhali and Boleswar were taken under the study. Water samples were collected from the rivers to measure the electrical conductivity during March to June 2018. Table 4 presents the measured data at different points of the rivers during the observation period. In Tentulia river at Panpatti ghat, Golachipa, the highest salinity was found 0.760 dS/m (below 1 dS/m). This indicates that water of the upstream side from this point was suitable for irrigation during dry season. In Buriswar river, at Barobogi, the highest salinity was found 0.710 dS/m (below 1 dS/m). This indicates that water of the upstream side from this point is suitable for irrigation during dry season. In Biskhali river at Kalmegha, the highest salinity was found 0.480 dS/m (below 1 dS/m). Therefore, water

Table 2. Amount of agricultural drought quantified during growth stage of BR 11 in T. Aman 2017.

Week	Growth stage	Drought (mm)		Prediction error (%)	Irrigation #		
		Forecasted	Observed		I_0	I_1	I_2
8th week		0.0	0.0	-	0	0	0
9th week		0.0	0.0	-	0	0	0
10th week	Vegetative	0.0	0.0	-	0	0	0
11th week		0.0	0.0	-	0	0	0
12th week		0.0	0.0	-	0	0	0
13th week		0.0	0.0	-	0	0	0
14th week	Reproductive	0.0	0.0	-	0	0	0
15th week		0.0	0.0	-	0	0	0
16th week		0.0	0.0	-	0	0	0
17th week		0.0	0.0	-	0	0	0
18th week		0.0	0.0	-	0	0	0
19th week	Ripening	0.0	0.0	-	0	0	1
20th week		12.4	15.5	-20.0	0	1	1
21st week		5.8	8.4	-30.3	0	0	0
Average				-25.1			

Table 3. Average grain yield and yield contributing parameters under different treatments of BR 11 in T. Aman 2017.

Treatment	Tiller/m^2	Panicle/m^2	Filled grain/panicle	Unfilled grain/ panicle	1000 grain wt (gm)	Yield (t ha^{-1})
Rainfed	271	264	142	29	24	4.75
Forecasted (T1)	274	265	143	26	25	4.95
Supplemental (T2)	276	268	145	26	24	5.14

Table 4. Salinity in water of different river of Barishal region during dry season 2018.

Location	River	Salinity (dS m^{-1})			
		16-17 March	22-23 April	5-6 May	25-26 June
Panpatti ghat	Tentulia		0.510	0.760	
Taltoli launch ghat				0.670	0.210
Borobogi		0.520	0.710		
Chotobogi hat	Burishwar	0.350	0.480		0.190
Amtoli ferryghat		0.320	0.410	0.500	0.168
Lebukhali ferry ghat		0.300		0.350	0.147
Kakchira ferryghat		0.240	0.400	0.550	0.182
Kalmegha		0.340	0.480	0.420	0.195
Patharghata 2 no ward	Bishkhali	1.650	1.33	0.480	0.343
Nissanbaria			2.10		
M Baliatoli			4.11		
Charduani		5.40	5.50	1.000	0.733
Khatachira		5.30		1.600	
Boromasua	Boleshwar	3.20		1.100	0.589
Chotomasua		3.08	3.00	0.800	0.354
Charkhali ferryghat		1.08	0.550	0.180	0.234

in upstream side of Bishkhali river from Kalmegha point is suitable for irrigation in dry season. In Boleswar river at Charkhali ferryghat, the highest salinity was found 1.080 dS/m (close to 1 dS/m). Therefore, water in upstream side of Boleswar river from Charkhali ferryghat point is suitable for irrigation in dry season. A considerable part of the upstream Tentulia, Buriswar, Biskhali and Boleswar river was suitable for irrigation throughout the dry season. The adjacent area of the rivers could be used for irrigated crop production.

Water resources assessment for dry season crop cultivation in selected polders of coastal region

The study was conducted in polder number 43/1 situated at Amtoli, Borguna during February to April 2018. Volume of water stored in a particular canal section was calculated by multiplying length, width and depth of the canal section. Total 84.4 km long primary and secondary canals were surveyed in polder 43/1. About 50,22,009 and 42,68,707 cubic meter water was stored in the canals during January and February respectively. Water salinity of the study polder varies from 0.48 dS/m to 1.15 dS/m.

RENEWABLE ENERGY

Evaluation of smallholder surface water solar irrigation system for crop production

The experiment was conducted to evaluate the feasibility of solar powered pumps for rice irrigation. The technical and economical performances of centrifugal and submersible pumps, powered by a small capacity solar panel system, were analyzed. Eight solar panels each 320 watt (size: 1 × 1.95 sq.m) have connected together in arrays, which produced 2,560-watt DC energy. A 1.5 KW AC single phase centrifugal pump was purchased and connected with pump controller using cables. A pump inverter (2.2 KW) converts DC current from the solar array into AC current to drive the pump. After folding the area is 7.88 m^2. A 1.5 KW single phase centrifugal pump was test at a 1.2-1.5 m suction head and the discharge was observed 10-12 lit/s approximately. The design discharge of the pump is 18-25 lit/s at the head 0.3-14.7 m. Another 1.5 KW BRRI open drum paddy thresher has been operated successfully with this portable panel system. The threshing capacity of the paddy thresher is 200-300 kg/h which can operate 2 men easily. Some constraints observed during the field test. Other home appliances will be tested soon. The portable solar system can operate an irrigation pump and a paddy thresher successfully.

TECHNOLOGY VALIDATION IN THE FARMERS' FIELD

Irrigation water requirement of major cropping systems in Bangladesh: A model study

The study was carried out to estimate water requirement and net irrigation requirement of widely cultivated crops in north-west and south-west region of Bangladesh. CROPWAT 8 model was used in this study. Historical weather data (1981-2015) from Bangladesh meteorological department (BMD), soil data from soil resource development institute (SRDI) and crop data from relevant sources was used as input in the model.

Normal annual rainfall of north-west and south-west regions varies from 1,467 to 2,290 mm and more than 75% rainfall occurs in monsoon. The highest (2,290 mm) rainfall was observed in Rangpur followed by 1,990 mm in Dinajpur and 1,750 mm in Bogura. Jute (519 mm) and T. Aus rice (499 mm) showed the highest crop water requirement although they have less growth duration than the many other crops (Table 5). Boro, T. Aman, Maize, Wheat and potato crops required 477, 446, 415, 255 and 202 mm respectively. Timely transplanting of T. Aman rice accounted no irrigation, where estimated net irrigation requirement of Boro and T. Aus rice was 897 and 439 mm, respectively (Table 6). Table 6 shows the net irrigation requirement of major cropping patterns was calculated. Result shows that the highest 1251 mm net irrigation water estimated for Boro-T. Aus-T. Aman cropping pattern whereas the lowest 369 mm water was required for Wheat-Jute-T. Aman. Average estimated net irrigation was 897 mm for the most popular Boro-Fallow-T. Aman pattern in the study region of which the highest 1,056 mm was found in Bogura and the lowest 765 mm in Rangpur. Since T. Aus rice received much rainfall in its later stage, so T. Aus based pattern

Table 5. Crop water requirement (as computed through CROPWAT for normal weather) for major crops in test locations of north-west and south-west region of Bangladesh.

Crop	Crop water requirement ($ET_{c,}$ mm)							
	Bogura	Rangpur	Rajshahi	Ishurdi	Chuadanga	Jashore	Dinajpur	Avargae
Boro	463	438	504	498	459	553	423	477
T. Aman	426	443	461	454	439	460	437	446
T. Aus	473	452	525	521	503	568	452	499
Mustard	173	159	177	176	162	184	155	169
Wheat	257	238	268	263	242	286	232	255
Jute	497	479	543	538	519	579	478	519
Maize	407	374	418	418	419	490	376	415
Lentil	204	207	184	197	238	199	186	202
Potato	206	189	212	208	193	222	182	202

Table 6. Average net irrigation requirement of major crops in various locations of Bangladesh (as computed through CROPWAT with normal weather data).

Crop	Net irrigation water requirement (mm)							
	Bogura	Rangpur	Rajshahi	Ishurdi	Chuadanga	Jashore	Dinajpur	Average
Boro*	1056	765	923	871	868	874	923	897
T. Aman	0	0	0	0	0	0	0	0
T. Aus*	397	271	483	508	496	514	407	439
Wheat	275	168	186	194	186	182	169	194
Jute	29	29	126	64	98	64	61	67
Mustard	115	116	113	129	127	123	112	119
Maize	320	314	323	370	365	378	328	343
Lentil	106	119	93	118	124	91	86	105
Potato	148	189	181	154	139	159	170	163

*Including land preparation.

required comparatively less water than Boro based pattern. CROPWAT model estimated the highest (734 mm) and the lowest (380 mm) irrigation, which was in Rajshahi and Rangpur respectively for Potato-T. Aus-T. Aman cropping pattern. Mustard-Boro-T. Aman cropping pattern estimated 915 mm average net irrigation in the study area. CROPWAT model estimated 1,251 mm net irrigation water for Boro-T. Aus-T. Aman cropping pattern whereas the lowest 369 mm water was required for Wheat-Jute-T. Aman.

Improving dry season irrigation for marginal and tenant farmers in the Eastern Gangetic Plains

The objective of this study is to understand the bio-physical, socio-economic and institutional aspects of groundwater irrigation in the northwest region of Bangladesh along with identifying potentials for improvement. The study was conducted in Pabna, Bogura, Rangpur and Thakurgaon districts. Data were collected on irrigation water applied, conveyance losses, crop yield, cost of production and revenue earned etc. Alternate wetting and drying (AWD) and polythene pipe distribution systems were introduced for field level performance demonstrations.

Yield obtained and water saving by alternate wetting and drying (AWD) practice. A total of 16 demonstrations were conducted in the study sites. Table 7 shows the mean number of irrigation, amount of irrigation water applied and grain yield for both AWD and FP. The average number of irrigation for AWD and farmers' practice of all the sites were 10.4 and 13.1, respectively. It indicates that AWD practice can reduce 2-4 irrigations compared to FP. Table 7 also shows that the average depth of irrigation of all the sites for AWD and FP were 543 mm and 661 mm, respectively. The average irrigation water saving for all the sites is 17.6 percent. Table 8 also shows that the average yield is similar for both AWD and FP. The average yield for AWD and FP were 4.68 and 4.54 t/ha in Bogura, 6.93 and 6.95 t/ha in Pabna, 6.25 and 6.16 t/ha in Rangpur, 8.10 and 7.66 t/ha in Thakurgaon respectively. The average yield of all the sites for AWD and FP were 6.40 and 6.23 t/ha respectively. It indicates that AWD may offer some yield advantage compared to maintaining continuous standing water.

Irrigation water and irrigation time saving by polythene pipe distribution system. Polythene pipe was supplied in six STW schemes to minimize water losses with earthen canal distribution system. Table 9 shows the average irrigation depth applied by polythene pipe and earthen canal distribution systems in different sites. The amount of irrigation by polythene pipe and earthen canal distribution system were 591 and 690 mm in Pabna: 289.0 and 362 mm in Bogura; and 372 and 468 mm in Rangpur, respectively. The irrigation water saving in Pabna, Bogura and Rangpur were 14.3, 20.0 and 20.3 percent respectively. The average water saving of sites were 18.2 percent. Table 9 also shows the time required for applying irrigation water per unit area (1 decimal = 40.5 m^2) by polythene pipe and earthen canal distribution systems. The time requirement for irrigation by polythene pipe and earthen canal distribution system was 13.8 and 16.1 min/decimal in Pabna; 19.6 and 24.4 min/decimal in Bogura; and 23.2 and 29.0 min/decimal in Rangpur respectively. The irrigation time saving in Pabna, Bogura, and Rangpur was 14.3, 19.5 and 18.7 percent respectively. The above result shows that polythene pipe irrigation water distribution system not only saves irrigation water but also irrigation time compared to the earthen canal. The reduction in irrigation time as well as saving of irrigation water may help to increase the command area of the irrigation scheme and water productivity.

Impact of extreme temperatures on rice production in Bangladesh

Based on the data continuity 26 weather stations were selected out of 36 stations for 1971-2015. Eleven climate extreme indices were calculated from this data set by using RClimDex 1.0 software. The crop yields were taken from the different Statistical Yearbooks on a district based information source for rice (Aus, Aman and Boro). The MAKESENS model was used for detecting and estimating trend. Figure 4 shows the annual

Table 7. Net irrigation requirement of major cropping patterns in north-west and south-west region of Bangladesh (as computed through CROPWAT with normal weather data).

Cropping pattern	Bogura	Rangpur	Rajshahi	Ishurdi	Chuadanga	Jashore	Dinajpur	Avargae
Boro-Fallow-T. Aman	1056	765	923	871	868	874	923	897
Potato-T. Aus-T. Aman	545	460	792	662	635	673	577	621
Wheat-Jute-T. Aman	426	321	503	391	340	312	290	369
Mustard-Boro-T. Aman	887	790	970	905	931	1036	889	915
Boro-T. Aus-T. Aman	1363	998	1374	1332	1210	1244	1235	1251

Table 8. Mean number of irrigation, irrigation water applied, rainfall received, grain yield under AWD and FP with relative irrigation water saving by AWD.

Trial #	Location	Mean number of irrigation		Mean depth of irrigation (mm)		Mean rainfall received (mm)	Mean grain yield (t/ha)		Mean water saving by AWD (%)
		FP	AWD	FP	AWD		FP	AWD	
5	Rangpur	13.8	11.6	756.4	634.8	376.8	6.16	6.25	16.82
4	Pabna	16.0	12.0	811.5	635.0	327.9	6.95	6.93	21.63
3	Thakurgaon	11.7	9.3	651.0	540.7	202.0	7.66	8.10	16.84
4	Bogura	10.3	8.3	397.8	337.8	196.0	4.54	4.68	15.00
Mean	Overall	13.0	10.3	654.2	537.1	276.7	6.33	6.49	17.57

Table 9. Mean irrigation water and irrigation time saving by polythene pipe compared to earthen canal irrigation water distribution system at different STWs.

STW #	Location	Mean water pumped (mm)		Water saved (%)	Mean sp. irrigation time (min/decimal)		Irrigation time saved (%)
		Earthen canal (mm)	Polythene pipe (mm)		Earthen canal	Polythene pipe (mm)	
1	Pabna	690.0	591.0	14.3	16.1	13.8	14.3
2	Bogura	361.5	289.0	20.0	24.4	19.6	19.5
3	Rangpur	468.3	371.7	20.3	29.0	23.2	18.7
	Mean	506.3	417.2	18.2	23.2	18.9	18.2

series for temperature extremes in Bangladesh during 1971-2015. The cold days (TX10) and cold nights (TN10) were significantly decreased by -0.143 (P= 0.006) and -0.254 (P= 0.001) days/year respectively. The cold spell duration indicator (CSDI) decreased by-0.04 days/year (P= 0.227) in Bangladesh during the 1971-2015; however, it was not significant at the 0.05 level. But in recent decade the rate was sharply increased. The growing season length (GSL) in Bangladesh was shortened at a rate of 0.0013 days/year (P= 0.71). The average annual diurnal temperature range (DTR) increased at a rate of 0.0088 °C/year (P= 0.0004) significantly at the 0.05 level.

The results showed that the effect of cold extremes was more prominent over warm extremes on rice production. Figure 5 shows the relationship between cold extremes (VCD, TX10, TN10 and CSDI) and county average of different seasons rice yields. The plotted results showed that in all seasons rice yield was in decreasing trend with all cold extremes indices in Bangladesh. The increasing trend of cold extremes indices increased the respiratory demand of rice and for that most of the produced energy lost for that. It also influences in water requirement of the rice. Therefore, the rice yield may be decreased. The interaction of average temperature indices on rice yield was computed through multiple regression analyses. The predicted yield was in close agreement with the observed yield (Fig. 6). Our analyses indicate that decrease in tropical nights and cold days will play a significant role ($p<0.05$) in reduction of Boro rice yield in future. The model has an F-value of 3.77 with a p-value of 0.002. This implies that the overall model result was statistically significant at the 1% level of probability. The R^2 value indicates that 53% of the significant variations in Boro rice yields are explained by the climatic variables. The t-value of tropical nights was -3.41 and for cold days was -2.00, which were statistically significant at the 5% level of probability.

Delineation of soil fertility status in Bangladesh

In this study, a simple method of soil fertility scoring for Bangladesh using soil organic carbon (SOC), available phosphorus (P), sulphur (S), zinc (Zn), boron (B) and exchangeable potassium (K) was developed. The data were collected from existing literatures and scoring was done on a "0-100" scale. Figure 7 shows the soil fertility score as geometric, arithmetic and weighted mean ratings. Considering geometric mean rating, fertility of about 4.7% soils belong to medium category (score >70); almost 24.51% of them are very poor to poor (score <20-

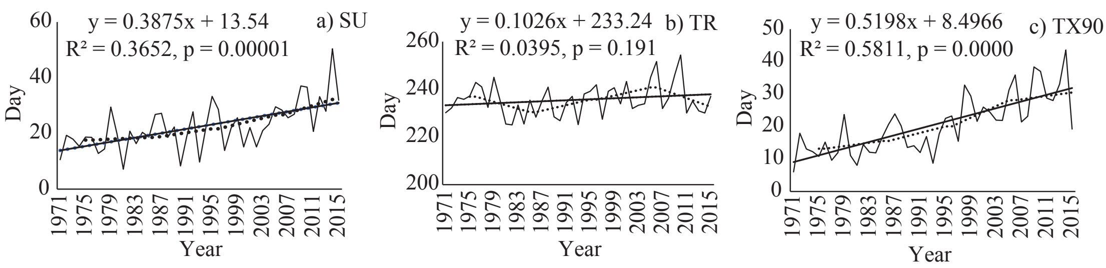


Fig. 4. Averaged series for indices of the annual and decadal extreme temperature events in Bangladesh. The straight line represents the linear regression and the dotted line represents the decadal average for the data sets during 1971-2015.

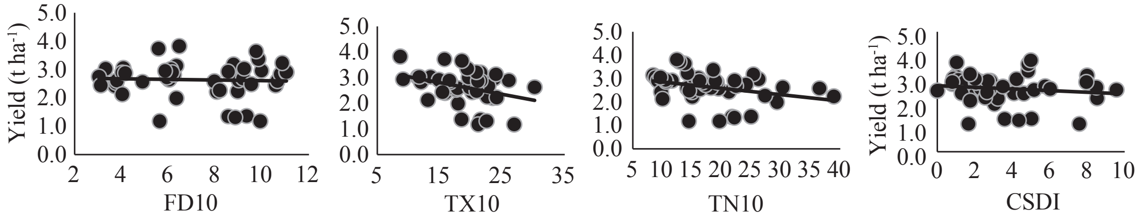


Fig. 5. Effect of cold extreme indices on different seasons rice yield in Bangladesh during 1971-2015 for dry season irrigated rice (Boro rice).

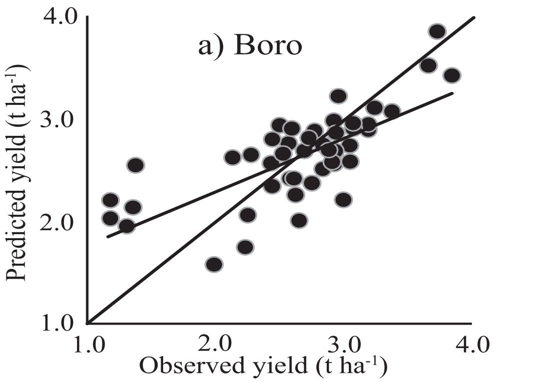


Fig. 6. Multiple regression of all temperature extreme indices on different rice yield in Bangladesh during 1971-2015.

30) and the rest (70.82%) in between low to medium category (Fig. 7a). Arithmetic means showed that 13.17% soils were very low to low fertile (score <30-40), 15.12% in medium fertility levels and 70.59% in between low and medium category (Fig. 7b). At per weighted mean rating, about 2.86% soils had high fertility (score >80), 7.85% medium (score 70-80), 12.21% had very low to low and major areas (77.06%) represented in between low and medium fertility status (Fig. 7c). Geometric mean and weighted mean scoring methods showed better relationships with dry season irrigated rice yields in Bangladesh indicating that this technique can be employed for soil fertility assessment.

Selection of suitable T. Aman rice varieties for facilitating Rabi crops intensification

The experiment was setup in a RCBD at Dacope, Khulna and Amtali, Barguna with BRRI developed such as rice varieties BR11, BR23, BRRI dhan53, BRRI dhan54, BRRI dhan66, BRRI dhan73, BRRI dhan76 and BRRI dhan77 along with the popular local varieties. BRRI dhan76 was the most preferred variety to farmers in Dacope followed by the check variety BR23. BRRI dhan73 was least preferred among the potential ones in the current year. On the other hand, BRRI dhan77 was the most preferred variety at Amtali followed by BRRI dhan53.

Growing vegetable crops with rice under waterlogged lowland condition

This study was undertaken to improve land productivity and profitability and to increase the home consumption of vegetables in the coastal zones of Bangladesh. The seedlings of the popular and high value creeping type vegetables were grown in poly bag. After observing the performance and production of vegetables with lowland rice last year. Seven farmers in Dacope covering 1.0 ha of land and in Amtali three farmers covering 0.5 ha of land were cultivating vegetables with rice (Table 10). In Dacope site, farmers got 230 to 956 kg of rice with 383 to 1062 kg of different vegetables based on the cultivated land area. Farmers reported that they had 10% yield loss due to land occupied by bag placement in the rice land. The total returns from rice with vegetables varied from 1,16,720 to 3,00,923 Tk/ha (Table 10). On the other hand, in Amtali site, farmers got 248 to 576 kg of rice with 92 to 336 kg of different vegetables based on the cultivated land area. Farmers also reported that they had 10-12% yield loss due to land occupied by bag placement in the rice land. The total returns from rice with vegetables varied from 1,21,037 to 1,46,942 Tk/ha (Table 10). Farmers got the additional vegetables crops with rice in wet season, which gave the opportunity for extra income.

Study on water salinity dynamics in coastal areas

Dynamics of surface water salinity. In Dacope, Khulna, average salinity of the river water remained below 1.0 dS/m up to December 2016 (Fig. 8) and is considered highly suitable for irrigating crops.

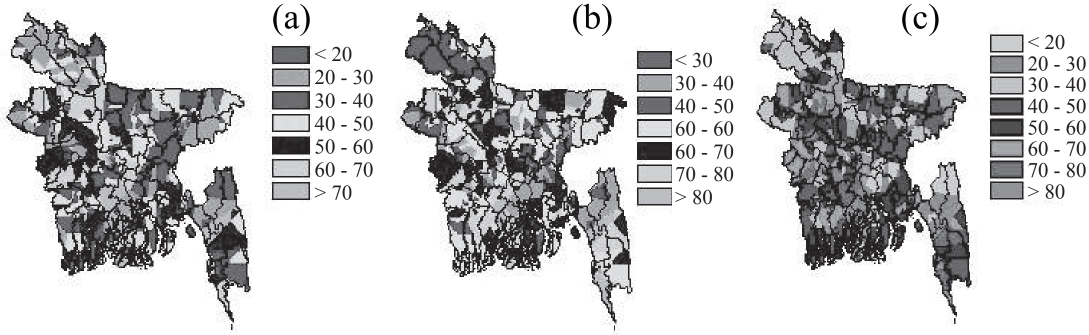


Fig. 7. Soil fertility score according to (a) geometric, (b) arithmetic and weighted means for Bangladesh.

Even river water remained suitable (<4.0 dS/m) for irrigation up to end of December 2016. After that the river water salinity gradually increased and at the end of Rabi/Boro cropping season it reached about 25 dS/m in April 2017. The canal water was trapped on 13th December 2016 at the period of high tide making canal water salinity of 1.23 dS/m. Its salinity increased in a slower rate and reached up to 3 dS/m in March 2017 due to evaporation and influence of groundwater flow (Fig. 8). After the onset of rainy season ie in June 2017 the river water salinity sharply goes down and from July-December 2017, there was no salinity and after that it start to increase as previous year (Fig. 8). In Amtali, Barguna, the river water salinity starts to increase after November 2016 and reached its peak at May 2017. After the onset of rainfall in June 2017 the salinity level of river water sharply decreased and from July to November 2017 the river water became fresh and after that its salinity starts to increase. The canal water was trapped on 20th December 2016 and canal water salinity was 1.1 dS/m. Its salinity increased in a slower rate and reached up to 2.3 dS/m in April 2017 due to evaporation (Fig. 9).

Dynamics of groundwater salinity. Generally, groundwater level and salinity in the experimental field at Pankhali, Dacope varied between 0.00-

Table 10. Returns from vegetables with T. Aman rice at Dacope and Amtali 2017.

Farmer	Area (dec.)	Rice yield (kg)	Vegetables yield (kg)	Return from rice (Tk)	Return from veg. (Tk)	Total return (Tk ha^{-1})
			Dacope, Khulna			
Akhil Haldar	28	442	507	12090	12090	184651
Poritosh Ray	26	407	604	14100	14100	211350
Jebon Mondol	15	230	383	10750	10750	252817
Moksed Sheikh	30	472	1062	27100	27100	300923
Md Imran Sheikh	36	577	753	26200	26200	258961
Md Sain Gazi	50	781	482	8000	8000	116720
Abdur Rajjak Sheikh	62	956	593	19850	19850	155280
Total	247	3867	4384	116090	116090	193430
			Amtali, Barguna			
Md Alamin	36	523	336	10200	10200	141783
Md Gofur	39	576	255	10085	10085	136872
Md Fardaus	17	248	92	3375	3375	121037
Md Munchur Halal	30	459	215	8665	8665	146942
Total	122	1806	898	32325	32325	138591

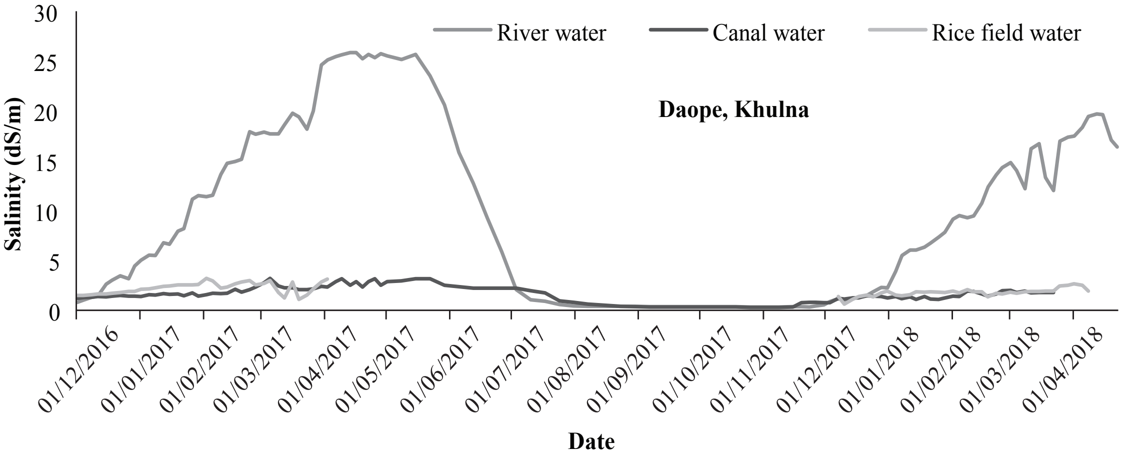


Fig. 8. River, canal and rice field water salinity, Dacope, Khulna during 2016-18.

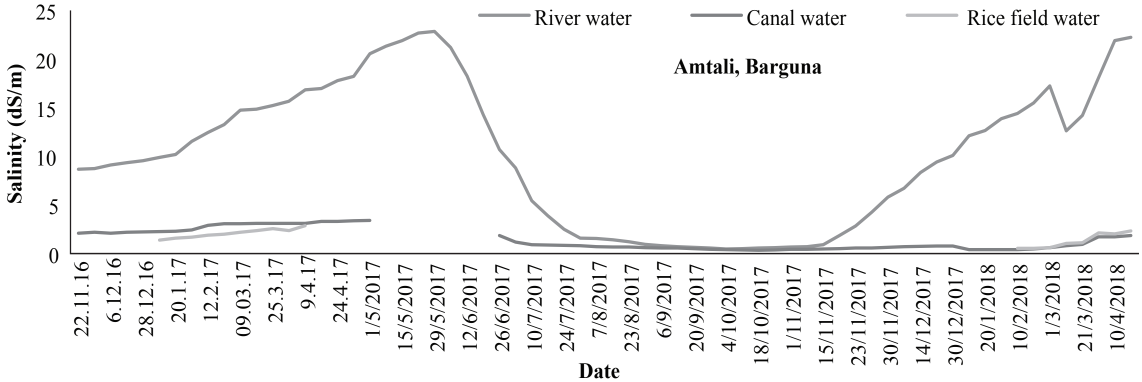


Fig. 9. River, canal and rice field water salinity, Amtali, Barguna, during 2016-18.

1.37 m from field surface and 2.30-3.52 dS/m. The lowest value of 2.30 dS/m was observed in January and the highest (3.52 dS/m) in May. In Dacope, groundwater salinity remained less than 4.0 dS/m during the study period and is considered suitable for irrigation development. Whereas, groundwater level at Sekandarkhali, Amtali varied between 0.91 to 2.42 m from ground surface and groundwater salinity was from 3.12 to 11.7 dS/m. The lowest value of 3.12 dS/m was observed in November 2017 and the highest value of 11.7 dS/m in May 2017 and it indicated that the upper aquifer groundwater in most cases was not suitable for irrigation.

In both the study locations, river water became saline (> 4.0 dS/m) after December and as high as 20-25 dS/m in April. Therefore, surface fresh water was trapped in local canals within December. Groundwater salinity was monitored from observation well. In Dacope, groundwater level varied from 0.75 to 0.95 m and salinity from 2.3 to 3.52 dS/m. In Amtali, groundwater level varied from 1.02 to 1.40 m and its salinity from 3.25 to 11.7 dS/m, which is beyond the permissible limit of irrigation.

Planting time for Boro rice cultivation in saline areas (APSIM model)

The study was conducted at Amtali, Barguna during the dry season of 2017-18. There were three varieties like BRRI dhan28 (popular but non-saline tolerant Boro variety), BRRI dhan67 and BINA dhan10 (saline tolerant Boro varieties) were tested in this study. The growing season maximum temperature varied from 25.3 to 34.6°C and the maximum temperature was within the critical limit (35°C) in May. During rice growing season, about 475 mm rainfall was occurred, which was congenial for rice growth and also created some flooding situation, which reducely the irrigation cost and salinity effect. Among the six sowing dates 30 November and 15 December sowing dates performed better irrespective of variety in plant height and yield (Table 11). The data revealed that irrespective of variety 30 November sowing produced the highest yield followed by 15 December (Table 11). The highest amount of irrigation water was used in 15 October sowing and the lowest amount of irrigation water was used in 30 December sowing (Fig. 10). The irrigation water productivity varied from 0.54 to 1.07 kg/m^3 and the total water productivity varied from 0.50 to 0.72 kg/m^3 (Fig. 11).

Production of Boro rice in the coastal area is an option for cropping intensification in the comparatively low land areas where water receding delayed after T. Aman harvest. Boro rice may be grown where the fresh water resources are available during crop growing season.

Integrated approach of crop intensification through excavation of mini-pond for storing fresh water in coastal region

A mini-ponds was excavated with a participatory way for conserving rainwater and multi-purpose use of ponds for fish culture and supplemental use of high value crops. Based on the service area of crop field only 3-6% area was used for mini-pond. Integrated approach for increasing dry season high value crop production can improve the cropping intensity of the coastal zones. It also increases the total land productivity and income of any family.

Block demonstration of Boro rice by using canal water

The experiment was setup in RCBD at Dacope, Khulna and Amtali, Barguna with the tested rice varieties such as BRRI dhan28, BRRI dhan58, BRRI dhan67 and BINA dhan10. Table 12 shows the yield and yield components of Boro rice in trial farmers of both the areas. All the tested rice varieties performed well in the coastal region. In Dacope

Table 11. Time of sowing effects on plant height, 1000 grain weight, effective tillers, yield and growth duration of BRRI dhan28, BRRI dhan67 and BINA dhan10 at Amtali, Boro 2017-18.

Sowing date	Variety	Plant height (cm)	Filled grain/ panicle	1000 grain wt (gm)	Panicle/m^2	Yield (t ha^{-1})	Growth duration (day)
	BRRI dhan28	80.5	120	22.1fg	213	3.5h	159c
15 Oct	BRRI dhan67	86.2	112	23.9de	199	4.4def	161b
	BINA dhan10	90.4	100	29.0a	224	5.9a	164a
	BRRI dhan28	80.5	106	25.7b	218	3.7gh	154e
30 Oct	BRRI dhan67	86.2	107	24.2cde	253	4.7cde	158d
	BINA dhan10	88.3	96	28.7a	253	5.5ab	160c
	BRRI dhan28	97.3	122	25.5bc	230	4.1efg	150g
15 Nov	BRRI dhan67	100.5	107	25.1bcd	198	4.6cdef	152f
	BINA dhan10	98.9	106	28.2a	257	4.6cdef	154e
	BRRI dhan28	88.6	131	23.3ef	222	4.6cdef	146i
30 Nov	BRRI dhan67	88.6	122	23.2ef	230	5.0bc	147i
	BINA dhan10	103.5	143	28.7a	239	5.0bc	148h
	BRRI dhan28	97.3	122	22.1fg	492	4.4def	138l
15 Dec	BRRI dhan67	100.5	125	20.6gf	530	4.1fg	143k
	BINA dhan10	98.9	136	24.4bcde	525	5.0bc	144j
	BRRI dhan28	86.2	131	21.3gh	361	4.8cd	130n
30 Dec	BRRI dhan67	88.3	145	19.8h	355	4.9bcd	137m
	BINA dhan10	98.9	110	24.0cde	240	5.0bcd	138lm
LSD(0.05)		8.8	20.5	1.56	104	0.579	1.1
CV (%)		5.8	10.4	3.8	21.6	7.38	0.5

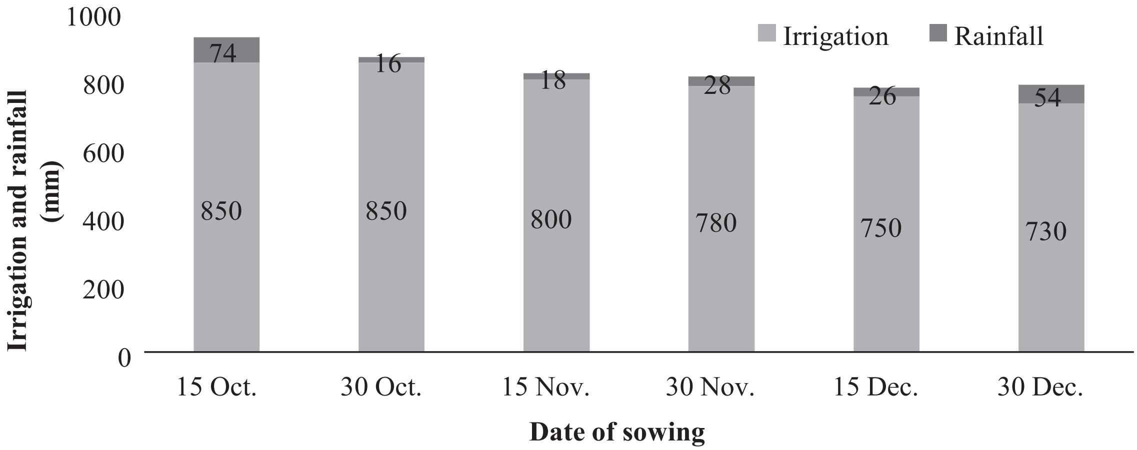


Fig. 10. Applied irrigation and rainfall in rice growing season, Amtali, Barguna, Boro 2017-18.

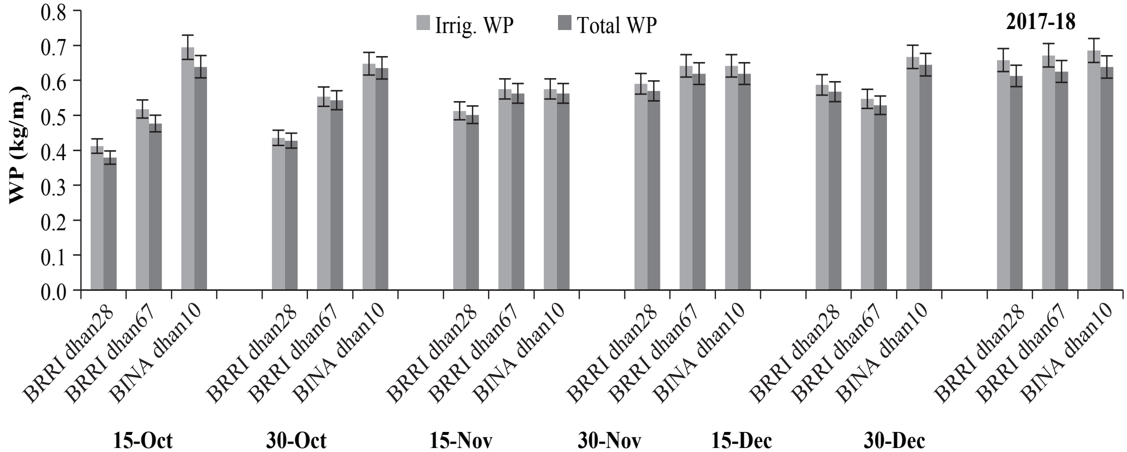


Fig.11. Irrigation and total water (irrigation + rainfall) water productivity of different varieties under different sowing dates, Amtali, Barguna, Boro 2017-18.

area, BRRI dhan67 and BINA dhan10 produced the highest grain yield (6.49 and 6.22 t/ha respectively) followed by BRRI dhan28, whereas, in Amtali area BRRI dhan67 gave the highest yield (5.3 t/ha) followed by BRRI dhan58 (Table 12). Salt tolerant BRRI dhan67 performed well in both the sites. But, fresh water availability was the main constraints for cultivation of Boro rice. A canal was excavated in Sekandarkhali, Amtali area and the farmers were interested to grow more rice in the next season.

Performance of Aus rice for crop intensification in coastal zones

The experiment was setup in RCBD at Dacope, Khulna and Amtali, Barguna with the tested rice varieties BRRI dhan48 and local mala. Table 13 shows the yield and yield components of Aus rice in trials farmers of both the areas. In Dacope area, BRRI dhan48 gave the yield of 4.6 t/ha and in Amtali area it gave the yield of 4.1 t ha^{-1}, whereas local Malachaina yielded only 2.9 t ha^{-1} (Table 13).

Measurement of GHG emission from rice field under different fertilizer and water management

The experiment was conducted in BRRI HQ farm, Gazipur during Boro 2017-18 to identify greenhouse gas emission and net ecosystem carbon budget under alternate wetting and drying (AWD) condition. Five different fertilizer management options were used as

Table 12. Yield and agronomic parameters of Boro varieties at Dacope, Khulna and Amtali, Barguna during Boro, 2017-18.

Variety	Farmers #	Area (ha)	Date of transplanting	Date of harvesting	Panicle/m^2	Filled grain/ panicle	Yield (t/ha)
			Dacope, Khulna				
BRRI dhan67	4	1.13	27-31/01/2018	28-30/04/2018	292a	109a	6.49a
BINA dhan10	3	1.05	25/01/2018	29/04/2018	281a	86b	6.22a
BRRI dhan28	2	0.81	01/02/2018	28/04/2018	262a	99a	4.92b
LSD(0.05)					31	14	1.2
CV(%)					4.9	6.3	9.7
			Amtali, Barguna				
BRRI dhan67	19	3.14	13/01/2018	10/05/2018	298a	108a	5.3a
BRRI dhan58	2	0.31	17/01/2017	15/05/2018	292ab	101a	5.0ab
BRRI dhan28	5	0.67	15/01/2017	05/05/2018	267b	99a	4.7b
LSD (0.05)					25	20	0.6
CV(%)					3.9	8.7	4.6

Table 13. Performance of tested T. Aus varieties at Amtali, Borguna and Dacope, Khulna during T. Aus 2017.

Variety	Date of transplanting	Date of harvesting	Plant height (cm)	Panicle/m^2	Filled grain/ panicle	Yield (t/ha)
			Amtali, Borguna			
BRRI dhan48	21/05/2017	28/07/2017	91.7	263a	73a	4.1a
Malachaina	21-27/05/2017	27-29/7/2017	77.0	200b	62a	2.9b
LSD(0.05)				42	28.6	0.65
CV(%)				5.1	12.1	5.3
			Dacope, Khulna			
BRRI dhan48	10/05/2017	10/08/2017	111.3	312	98	4.6

treatment and each of them was replicated thrice. The treatments were, T_1 = NPKSZn (Complete dose of chemical fertilizer), T_2 = Cow dung (2 t ha^{-1} in dry weight basis) + IPNS, T_3 = Poultry manure (2 t ha^{-1}) + IPNS, T_4 = Vermicompost (2 t ha^{-1}) + IPNS, T_5 = Absolute control (No fertilizer application). Forty-day-old seedling of BRRI dhan29 was transplanted following randomized complete block design. During Boro 2017-18 a total 190 mm rainfall occurred from March to April. As a result, rainfall was sufficient to meet the consumptive use for rice crop. About 420 mm irrigation (7 split application) was applied following AWD irrigation method. BRRI dhan29 gave the highest yield (6.91 t ha^{-1}) in treatment T_3, followed by 6.79, 6.61 and 6.56 t ha^{-1} in treatment T_2, T_3 and T_4 respectively (Table 14). Only 3.03 t ha^{-1} grain yield was found without applying fertilizer. Sample collection of greenhouse gases has been done and laboratory analysis is going on.

Table 14. Yield and water productivity analysis under different fertilizer management options during Boro 2017-18 at BRRI HQ farm, Gazipur.

Treatment	Panicle/m^2	Filled grain	1000 GW (gm)	Grain yield (t ha^{-1})	Irrigation applied (mm)
T_1	230	138	24.97	6.56	420
T_2	256	143	24.4	6.79	420
T_3	267	129	25.1	6.91	420
T_4	242	118	23.9	6.61	420
T_5	185	111	24.19	3.03	420
LSD(0.05)	64.5	18.5	2.57	0.44	
CV(%)	14.2	7.7	5.6	3.9	

Plant Physiology Division

SUMMARY

Twenty-four experiments under seven different projects have been carried out during 2017-18 in Plant Physiology Division of BRRI. Among the different research projects, most of the experiments were pertaining to five major stress environment ie salinity, submergence, drought, heat and cold. Only few experiments were associated with growth studies. In salinity stress, around 700 germplasm and breeding lines were characterized and 78 of them were found tolerant at seedling stage. Salt tolerant cultivars exhibited much higher Malondialdehyde (MDA) concentration and low in proline concentration after 72 hours under varying salinity stress. Under two weeks of complete submergence environment, among 270 genotypes, only 21 were found tolerant to flash flood submergence. BRRI dhan79 was found tolerant to submergence stress up to tillering stage. In stagnant flooding conditions, out of 41 advanced lines seven genotypes were found moderately tolerant. In drought tolerant experiment, more than 300 germplasm and advanced breeding lines were tested. Out of the tested genotypes, 19 germplasm and seven advanced lines (IR118194-B-21-3, IR118194-B-6-2, IR118194-B-6-4, IR94391-131-358-19-B-6-1-4, IR95817-14-1-1-2, IR96321-558-563-B-2-1-1 and BR6848-3B-12) were identified as drought tolerant. At high temperature environment, one advanced breeding line was identified as moderately heat tolerant. Under marker assisted breeding programme for heat tolarance, 28 F_1s were confirmed and in the confirmed progenies 1,534 BC_1F_1 seeds were produced. In backcross population, 88 fixed lines were selected from 20 lines of BC_2F_5 stage and confirmed to have fixed QTL through genotyping. A total of 264 segregating lines were selected through genotypic and phenotypic similarity. Some 200 rice genotypes of different sources were screened for seedling stage cold tolerance of which one exotic rice genotype Mineasahi showed cold tolerance at seedling stage, while 33 germplasm and a local variety Kanihati-1 showed moderately tolerant. Twelve advanced breeding lines, eight BRRI varieties, a local improved variety Kanihati-1 and an exotic variety Mineasahi were evaluated for reproductive stage cold tolerance. Mineasahi was found as the best cold tolerant genotype at reproductive stage. Advanced rice genotype BR(Bio) 9777-124-1-1-2, BRRI dhan67 and BRRI dhan69 were found moderately tolerant at reproductive stage. Sixteen rice genotypes of IRTON-IRRI along with BRRI dhan28 and BRRI dhan36 as checks were tested in Rangpur of which five genotypes- TP7594, TP20692, TP25175, 26717 and 24361 were selected on the basis of phenotypic acceptance, sterility, grain size, yield and cold tolerance. Among the tested 13 Nepalese rice varieties, Lekali dhan-1, Lekali dhan-3, Chandan Nath-3 and Khumal-13 showed tolerant at seedling stage having SES ranged from 3.55 to 4.69 with survivability 92-100%. Photosensitive rice varieties might flower in less than 10 hours photoperiod.

SALINITY TOLERANCE

Exploring new sources of salinity tolerance from BRRI Genebank germplasm at seedling stage

Four-hundred-five germplasm along with standard tolerant Nona Bokra, Pokkali, IR58443 and sensitive check IRRI154 were screened at 12 ds/m salinity. Out of the tested germplasm, 25 were found tolerant to moderately tolerant (SES score and survivability ranged from 3.33-5.50 and 83.33-100.0% respectively).

Screening of rice genotypes for salinity tolerance at seedling stage

Rice genotypes from different sources ie STR, IRSSTN, 47 Somaclonal lines and Indian rice varieties along with tolerant check IR58443-6B-10-3 and sansitive check IRRI154 were screened for 14 ds/m salinity stress to identify salinity tolerance genotypes.

IRSSTN materials. Among eighty genotypes thirty genotypes were found tolerant to moderately tolerant (SES 3-5, Survivability percentage 77.8-100%).

STR materials. Among the tested genotypes 87870-6-1-1-1-1-B-3 was found tolerant (SES 3, Survivability 100%) and 8384-3-B-7-1-1-1 was found moderately tolerant (SES 5, Survivability 100%).

Somaclonal line. Among sixteen lines none of the genotypes was found tolerant to salinity (SES 6-9, survivability 22.2-72.2%).

Indian genotypes. Among seven genotypes tested none was found tolerant (SES 6-7, survivability 50-77.8%).

Identification of novel sources of salt tolerance through physiological and biochemical characterization of diverse rice germplasms

To identify novel salt tolerant donors through physiological characterization, 117 rice genotypes from different sources were screened for salinity tolerance according to the method of Gregorio *et al.* (1997) at the Plant Physiology net house in BRRI. The experiment was conducted in RCB design with two replications. In each tray IRRI154 and Pokkali, Nonabokra, FL478 and IR58443-6B-10-3 were used as sensitive and tolerant check, respectively.

Among 117 genotypes, only 21 showed visual score 3 to 5 that was tolerant to moderately tolerant. The survivality percentage of these genotypes varied from 57 to 100%. Moreover, these tolerant and moderately tolerant genotypes showed minimum reduction on shoot length, root length, shoot dry weight and root dry weight over control condition. All the genotypes were divided into four sub clusters both at control and stress conditions. However, most of the tolerant genotypes belonged to the same sub group as cluster IV. Considering SES score, survivability percentage and reduction percentage of shoot length, root length and seedling dry weight over control, 21 genotypes were selected for further physiological and biochemical studies.

Investigations of antioxidant systems of high-yielding salt tolerant rice varieties. Rice plants develop various physiological and biochemical mechanisms in order to survive in soils with high salt concentration. The present study aimed to evaluate the antioxidant capacities of the high yielding salt tolerant varieties. Eleven rice genotypes (BRRI dhan40, BRRI dhan41, BRRI dhan47, BRRI dhan53, BRRI dhan54, BRRI dhan61, BRRI dhan67, BRRI dhan73, BINA dhan10, IR58443 and IRRI154) differing in salinity tolerance were evaluated under salt stress at seedling stage. Results revealed salt tolerant cultivars exhibited much higher Malondialdehyde (MDA) concentration (Fig. 1) and low in proline concentration (Fig. 2) after 72 hours under varying salinity stress. Chlorophyll and carotenoids did not show significant variation within a brief period of stress. Up-regulation of the antioxidant system specifically MDA and proline content after 72 hours of stress varied differently possibly due to possessing different mechanism having different responding time.

SUBMERGENCE TOLERANCE

Screening of rice genotypes for flash flood submergence tolerance

Some 150 germplasm from BRRI Genebank and 120 advanced breeing lines along with tolerant check

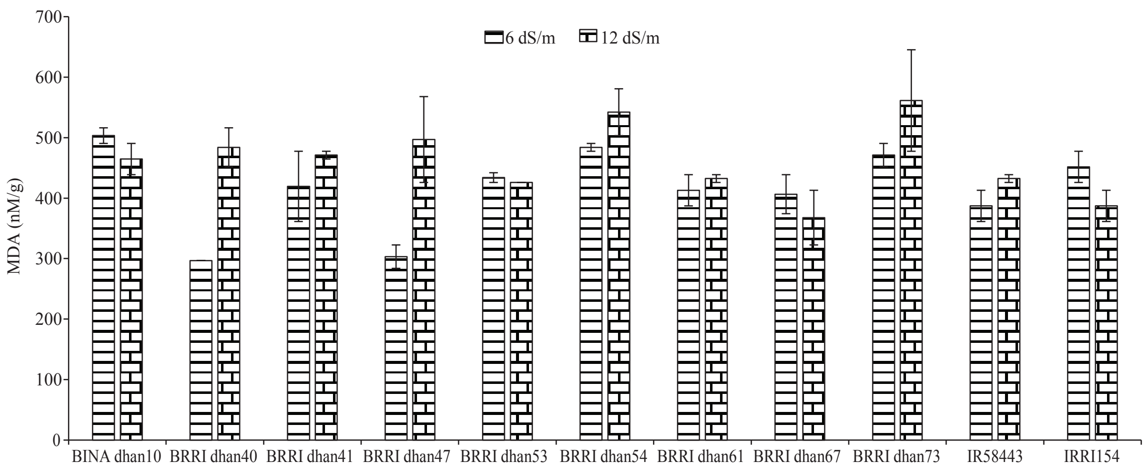


Fig. 1. Malondialdehyde (MDA) concentration after 72 hours of stress.

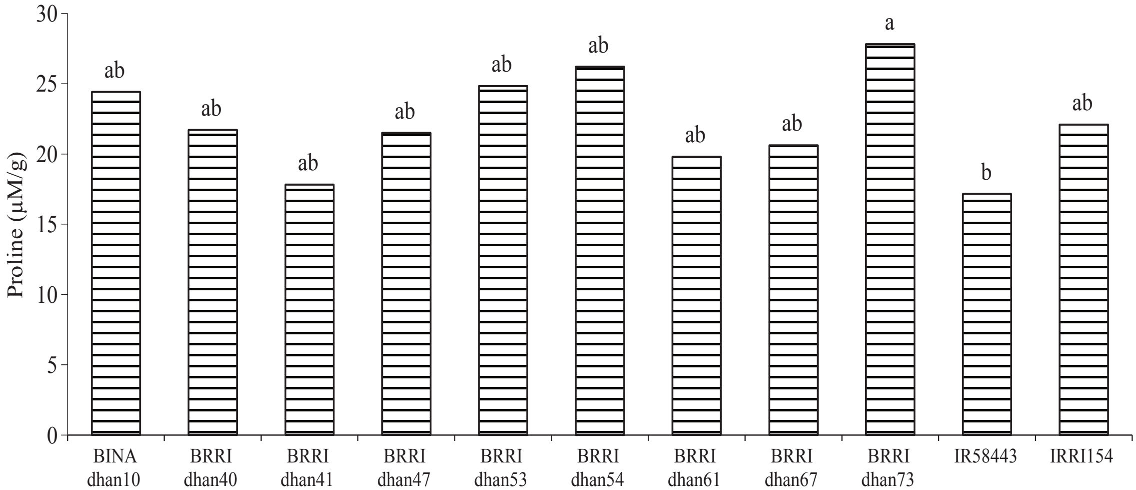


Fig. 2. Proline concentration ($\mu M\ g^{-1}$) after 72 hours at 12 ds/m salinity stress.

FR13A, BRRI dhan52 and sensitive check BR5 were tested to identify tolerant genotypes at seedling stage under complete submergence. Germplasm were grown in plane sheet tray containing 20 kg of well fertilized soil. Each tray accommodated with 20 lines and each line containing 30 plants. After 5th leaf initiation the tray were submerged in a concrete pool up to 14 days at 1 meter water depth. After 14 days, the tray were pulled out from water and allowed to recover. In case of advanced breeding line 25-day-old seedlings were transplanted in submergence tank. Two weeks after transplanting the plants were completely submerged by tap water and retain 80 cm water depth from the base of the plant for 16 days. The light intensity was recorded 50-110, 10-30, 0.5-7 μ mole/m^2/s at upper, middle and lower level respectively of submerged water. The water pH was 7.8-8.5 and water temperature ranged from 29-31°C during submergence. The water turbidity of the tank was 30-70 FNU (Formazin Nephelometric Unit). None of the germplasm survived under complete submerged condition. Among the advanced breeding lines, 21 lines (BR9175-2-1-1-11-2, BR9167-1-1-2-11-1, IR 108541:6-36-3-8-B-B, IR 108541:6-36-1-30-B-B, IR 108541:6-29-3-3-B-B, IR 108541:1-23-1-14-B-B, IR16D1059, IR16D1056, IR16D1048, IR16D1047, IR16D1040, IR15D1038, IR15D1024, IR15D1031, IR15D1048, IR15D1080, IR16D1026, IR16F1035, IR16F1033, IR16F1039, IR16F1036) were found tolerant compared with the tolerant check.

Effect of complete submergence at different growth stages of submergence tolerant BRRI varieties

Two submergence tolerant BRRI varieties BRRI dhan52 and BRRI dhan79 with BRRI dhan75 (susceptible check) were tested to determine the effect of complete submergence at different growth stages on survivability of the plant. The plants were grown in 10 inches earthen pot. For each variety six pots were prepared (each pot contained three plants). Four pots were submerged in a concrete pool at seedling, tillering, PI and booting stage for 14 days. Both the tolerant varieties showed 100% tolerantce at seedling stage but in case of BRRI dhan52, none of the plant survived at tillering stage where as BRRI dhan79 showed moderately tolerant, which had slight elongating capacity under submergence condition. At PI and booting stage BRRI dhan52 recovered poorly without new tiller appearance compared with BRRI dhan79. The grain formation after PI and booting stage submergence was not satisfactory. Majority spikelets of the panicle were sterile. BRRI dhan79 showed better tolerance level compared to BRRI dhan52.

Screening for stagnant flooding tolerance of advanced breeding lines at whole growth period

Forty-one advanced breeding materials along with four check varieties (BRRI dhan51, BRRI dhan52, BINA dhan11, BINA dhan12) were tested in 60 cm (gradually increase) water pressure till maturity to identify stagnant flooding tolerance genotypes. Among the genotypes seven were found moderately tolerant (Survivability percentage 65-100%, yield reduction 49-18%).

DROUGHT TOLERANCE

Screening of rice germplasm for drought tolerance at reproductive phase, T. Aman 2017

Two hundred seventy-six rice germplasm collected from BRRI Genebank along with check variety BRRI dhan56, BRRI dhan66, BRRI dhan71 and IR64 were tested during T. Aman season 2017 at BRRI farm, Gazipur following field-managed screening protocol (IRRI, 2008). Thirty-day-old seedlings were transplanted at a spacing of 20 cm × 20 cm. The experiment was laid out in Alpha lattice design with two replications. Standard agronomic management practices were followed. Irrigation was withheld for four weeks after transplanting and field were drained out properly for not allowing any standing water until maturity. Out of 276 germplasm including three tolerant checks, 19 genotypes showed the best performance in relation to yield under drought stress at reproductive phase.

Evaluation of advanced breeding lines under drought stress at reproductive stage in the rain-out shelter

This experiment was conducted in the rain-out shelter of Plant Physiology Division at BRRI HQ, Gazipur during T. Aman 2017 to evaluate 18 OYT and eight PYT materials with check variety BRRI dhan56, BRRI dhan66, BRRI dhan71 and IR64. Thirty-day-old seedlings were transplanted in puddled soil at a spacing of 20 cm × 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 and soil moisture was recorded. Out of 18 OYT three genotypes namely IR118194-B-21-3, IR118194-B-6-2 and IR118194-B-6-4 performed better having score 3 under drought condition. On the other hand, out of eight PYT IR94391-131-358-19-B-6-1-4 performed better followed by IR11N313.

Performance of advanced breeding lines under control drought condition at reproductive stage

Nine RYT, eight OYT and eight genotypes collected from IRRI along with check variety BRRI dhan56, BRRI dhan71 and IR64 were evaluated in Plant Physiology net house shaded by polythene sheet at BRRI HQ, Gazipur during T. Aman 2017. Twenty-five-day-old seedlings were transplanted in drum (56 cm × 43 cm) containing 110 kg puddled soil in two sets where 1st set was grown in well-watered conditions and 2nd set under stress condition. At panicle initiation stage water was drain out from the 2nd set so that the plants experience 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: = Πr^2h

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 Nov-Dec.

Out of nine RYT genotypes IR95817-14-1-1-2 performed better followed by IR95815-4-1-1-3 and out of eight OYT genotypes IR96321-558-563-B-2-1-1 performed better. Among the eight IRRI genotypes CAMPONI SML showed better performance.

Evaluation of advanced breeding line for screening against drought stress at vegetative stage

One advanced breeding line namely BR6848-3B-12 along with BRRI dhan43 were evaluated under control drought condition. The methodology was more or less same as previous experiment except the stress was initiated at vegetative stage. The advanced breeding lines BR6848-3B-12 showed better performance under drought condition.

Screening germplasm under drought stress at vegetative stage in the rain-out shelter

One hundred and sixty germplasm including BRRI dhan43 and BRRI dhan65 were tested in Aus 2017 under control drought condition in the rain-out shelter. Pre-germinated seeds were sown in Aus season in the rain-out shelter. Out of 160 germplasms 27 genotypes could flower and produce seed of which seven genotypes did not lodge.

HEAT TOLERANCE

Evaluation of advanced breeding lines and germplasm for heat tolerant rice

Two experiments were conducted to evaluate the breeding lines and germplasm to develop a high temperature tolerant rice variety. Seeds of 14 breeding lines supplied from Plant Breeding Division were sown in the seed bed in February. Twenty-five-day-old seedlings were transplanted in earthen pot, which was filled with soil. All pots were placed in natural condition until heading with BRRI recommended management practices. During heading all the pots were placed in controlled glass house at high temperature (35±3°C) and high humidity (75±5%) for seven days. Among the 14 breeding lines, one entry showed 40.5% fertility under heat stress treatment and got SES score 5. Following the same procedure 41 BRRI germplasm were rescreened against high temperature. Among the 41 germplasm 23 scored 5 (Acc. no. 152, Acc. no.183, Acc.no. 267, Acc.no. 272, Acc.no. 568, Acc.no. 571, Acc.no. 808, Acc.no. 811, Acc.no. 812, Acc.no. 813, Acc.no. 814, Acc.no. 817, Acc. no. 1317, Acc.no. 1318, Acc.no. 1546, Acc.no. 1549, Acc.no. 1626, Acc.no. 1643, Acc.no. 1680, Acc.no. 1681, Acc.no. 1684, Acc.no. 1688 and Acc. no. 1692) and 10 scored 3 (Acc.no.184, Acc.no.185, Acc.no.187, Acc.no.563, Acc.no.1203, Acc. no.1208, Acc.no.1321, Acc.no.1629, Acc.no.1630 and Acc.no.1689).

Introgression of heat tolerant QTL (*qHTSF4.1*) into Bangladeshi mega rice varieties through marker-assisted breeding

For promotion of high temperature spikelet fertility QTL (*qHTSF4.1)* in to a long duration Boro variety (BRRI dhan58) and an Aus variety (BRRI dhan48) was started to cope with the prevailing high temperature sterility problems in Bangladesh. Hybridization of BRRI dhan58 and BRRI dhan48 with Nagina22 (a heat tolerant Indian variety, N22) were carried out and F_1's developed from BRRI dhan48/N22 and BRRI dhan58/N22 were confirmed through R4M30 marker. Out of 75 F_1's, 28 (18 and 10 on the background of BRRI dhan58 and BRRI dhan48 respectively) from both cross combinations were confirmed and 1st backcrossing was carried out in the confirmed progenies. A total of 1534 BC_1F_1 seeds were produced for both cross combinations by backcrossing with respective recipient parents.

Marker assisted introgression of spikelet fertility QTL from N22 into two Bangladeshi mega rice varieties BRRI dhan28 and BRRI dhan29

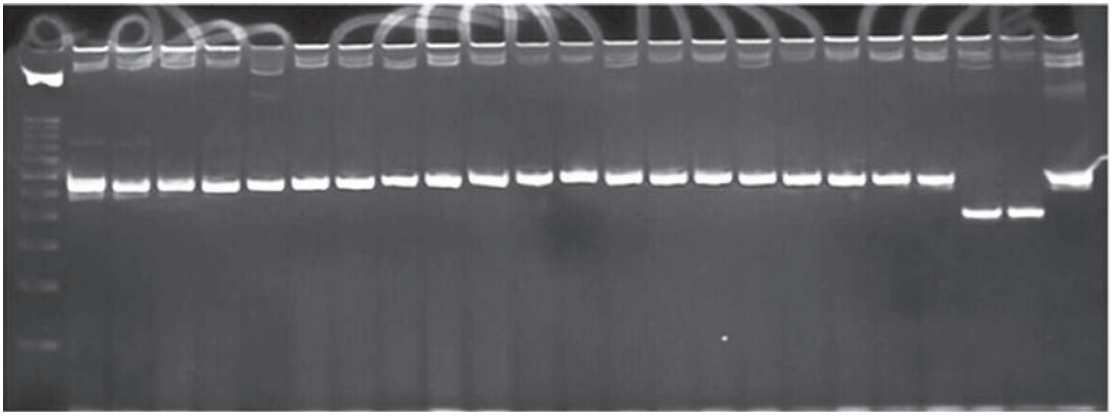
For developing heat tolerant BRRI dhan28 and BRRI dhan29 by introgressing spikelet fertility QTL (*qHTSF4.1*) through MABC is on-going. From second backcross population, 88 fixed lines were selected from 20 lines at BC_2F_5 stage and confirmed to have fixed QTL through genotyping of R4M30 marker (Fig. 3). From third backcross population, 264 segregating lines at BC_3F_2 were selected through genotypically by using an InDel marker (R4M30) and during harvesting of the selected lines, phenotypic similarity with reference to the respective recurrent parents (BRRI dhan28 and BRRI dhan29) were also compared.

COLD TOLERANCE

Screening of rice genotypes for seedling stage cold tolerance

Some 200 rice genotypes of different sources (168 BRRI Genebank germplasm, 13 BRRI varieties, 11 local varieties and eight exotic materials) along with four check varieties namely BRRI dhan28, BRRI dhan36, BRRI dhan69, Bhutan 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 × 30 cm breadth × 2.5 cm height) filled with gravels and crop residue free granular soil and allowed to grow until three leaf stage. The plastic trays were then placed into cold water tanks adjusted to constant temperature at 13°C. Among the tested rice genotypes, one exotic rice genotype Mineasahi showed cold tolerance at seedling stage, while 33 germplasm (BRRI Acc no. 1617, 1619, 1620, 1622, 1623, 1633, 1671, 1687, 1696, 1697, 1698, 1705, 1722, 1723, 1725, 1726, 1737, 1338, 1740, 1743, 1744, 1746, 1747, 1750, 1751, 1752, 1765, 1767, 1777, 1778, 1781, 1782 and

L 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 BR28 BR29 N22



L B B B B B B B B B B B B B B B B B B B B A A B

Fig. 3. PAGE (8%) of BC_2F_5 fixed QTL lines at the marker R4M30 (Lane 1-10 = Progenies of BRRI dhan28, 11-20 = progenies of BRRI dhan29, Parent-BRRI dhan28, Parent-BRRI dhan29 and Donor-N22 allele.

1784), three BRRI varieties (BR6, BRRI dhan43 and BRRI dhan67) and a local variety Kainihati-1, showed moderately tolerant at seedling stage. Other genotypes were susceptible to highly susceptible.

Screening of advanced breeding lines for reproductive stage cold tolerance

Some 12 advanced breeding lines along with three check varieties namely BRRI dhan28, BRRI dhan36 and HbjB-VI were tested in natural field condition. There were two seeding times. One set of seeds were sown on 15 October with a view to having rice reproductive phase at cold. Other set was sown on 15 November as control. Thirty-day-old seedlings were transplanted in the main field. Among the tested genotypes, none was found tolerant, while only one genotype BR(Bio)9777-124-1-1-2 was found as moderately tolerant at reproductive stage (Table 1). Its growth duration, plant height, last internode length, sterility and grain yield, were less affected than the other tested genotypes in stress condition except HbjB-VI.

Evaluation of some rice varieties for reproductive stage cold tolerance

Low temperatures at reproductive stages of rice plants cause spikelet sterility and ultimately cause yield loss. Eight BRRI varieties (BR6, BRRI dhan42, BRRI dhan43, BRRI dhan60, BRRI dhan62, BRRI dhan67, BRRI dhan69 and BRRI dhan74), a local improve variety Kanihati-1 and an exotic variety Mineasahi were tested along with BRRI dhan28, BRRI dhan36 and HbjB-VI as checks for reproductive stage cold tolerance. All

Table 1. Effect of cold treatment on selected advanced breeding line, Boro 2017-18.

Genotype	Growth duration (d)		Plant height (cm)		Last internode length (cm)		Sterility (%)		Yield (t/ha)		1000 grain wt (g)	
	14Oct	15Nov	14Oct	15 Nov	14 Oct	15 Nov	14 Oct	15 Nov	14 Oct	15Nov	14 Oct	15Nov
BR(Bio)9777-124-1-1-2	165.5	147.5	85.0	103.5	22.54	29.5	42.29	14.83	2.95	6.07	23.67	23.82
BRRI dhan28	165.5	146.5	79.25	105.0	22.91	31.24	76.98	10.77	1.94	6.25	22.13	22.44
BRRI dhan36	170.5	150.0	76.87	89.62	20.62	29.70	79.45	23.65	1.87	5.75	23.23	23.58
HbjB-VI	168.5	154.0	110.62	125.6	26.12	32.08	32.59	22.24	2.11	2.64	24.63	24.83
$LSD_{5\%}$ Genotype (G)	2.17		6.28		1.27		12.09		1.09		0.48	
$LSD_{5\%}$ Sowing time (S)	0.79		2.29		0.46		4.41		0.40		0.27	
$LSD_{5\%}$ for G*S	3.57		8.89		1.80		17.10		1.55		0.68	

genotypes were tested in growth chamber (GC), cold water tank (CWT) and natural condition in BRRI HQ, Gazipur during Boro 2017-18 season. For evaluation under artificial condition (GC and CWT), 20-day-old seedlings were transplanted in pots at Plant Physiology nethouse. Three pots of each genotype at reduction division stage were introduced into a GC at 17°C for 10 days and another three pots in CWT filled with 20-25 cm depth of water maintained at 18-19°C. Plants were kept in the CWT during the entire booting stage. On the other hand, three pots of same genotype were kept at natural condition as control.

For evaluation under natural condition, one set of seeds were sown on 15 October and other set was sown on 15 November as control. Thirty-day-old seedlings were transplanted in main field. Changes in panicle exertion, spikelet fertility, grain yield, growth duration, plant height and last internode length of different rice genotypes were determined for evaluating their cold tolerance level.

Cold treatment caused longer growth duration, higher percentage of sterility, shorter plant height, last internode and panicle length, poor panicle exertion and less filled grain/ panicle over control treatment in all rice genotypes (Table 2). Mineasahi and HbjB-VI were less affected due to cold stress. Rice genotypes- Mineasahi showed significantly less reduction of plant height, last internode and panicle lengths than other genotypes after cold treatment. Mineasahi and HbjB-VI had significantly better panicle exertion and lower panicle degeneration (Table 2) at cold conditions. Furthermore, higher number of filled grains per panicle and lower percentage of sterility were recorded from Mineasahi and HbjB-VI after cold treatment (Table 2). Rice genotypes Mineasahi was found the best cold tolerant genotype at reproductive stage in all the trials (GC, CWT and natural cold condition). After cold stress, rice varieties BRRI dhan67 and BRRI dhan69 had higher spikelet fertility than BRRI dhan28 and BRRI dhan36, but lower than HbjB-VI (Table 2).

Growth duration and yield of some local rice varieties under direct seeding condition

Short growth duration and reproductive stage cold tolerant Boro variety is our crying need to escape from flash flood at *Haor* areas of Bangladesh. Eleven local rice varieties (Kanihati-1, Kanihati-2, Kanihati-3, Kanihati-4, Kanihati-6, Kanihati-7, Kanihati-8, Kanihati-9, Kanihati-10, Kanihati-11 and Kanihati-12) were evaluated along with BRRI dhan28, BRRI dhan36 and Bhutan as check varieties

Table 2. Physiological parameters of some rice genotypes after cold treatment in growth chamber (GC), cold water tank (CWT) and natural cold (NC) conditions.

Genotype	Growth duration increased (day)			Pl height reduced (cm)			Last internode length reduced (cm)			Panicle exertion (%)			Sterility (%)		
	GC	CWT	NC	GC	CWT	NC	GC	CWT	NC	GC	CWT	NC	GC	CWT	NC
BR6	9	10	17	10.17	10.78	15.12	5.24	5.58	7.71	72.45	70.24	75.12	84.55	86.75	78.19
BRRI dhan42	10	11	16	10.64	11.0	16.65	5.53	5.76	10.08	71.24	70.14	74.25	86.89	86.97	95.29
BRRI dhan43	10	11	19	10.24	10.79	16.88	5.74	5.87	10.04	71.47	70.27	74.89	87.75	88.14	82.87
BRRI dhan60	10	12	19	12.56	13.10	16.88	5.57	5.92	10.58	70.68	70.02	75.97	89.52	91.46	70.16
BRRI dhan62	11	12	16	10.45	11.05	15.62	7.62	7.67	11.86	69.56	68.86	73.25	92.67	94.12	72.21
BRRI dhan67	8	9	14	7.17	7.68	12.25	4.85	4.93	7.17	75.68	75.22	78.89	54.79	54.23	61.76
BRRI dhan69	8	9	15	6.73	7.12	14.63	4.73	4.98	7.09	76.53	75.41	79.58	55.26	55.86	57.63
BRRI dhan74	12	12	18	14.12	15.24	20.63	8.66	8.97	11.3	68.47	65.47	72.54	92.58	92.97	83.20
Kanihati	8	10	19	8.97	10.15	19.37	5.93	6.27	9.33	84.31	76.31	78.24	84.56	86.78	69.45
Mineasahi	3	4	9	0.58	1.19	9.0	0.17	0.61	1.41	99.8	99.2	99.2	34.15	34.47	24.15
BRRI dhan28	10	12	19	9.05	10.16	25.75	6.72	6.98	8.33	72.85	70.82	75.72	77.18	84.12	**70.26**
BRRI dhan36	9	10	20	8.42	8.67	20.21	5.67	6.13	7.08	75.43	72.41	71.85	77.09	81.28	73.78
HbjB-VI	7	8	14	7.63	7.57	15.02	4.82	5.56	5.96	90.28	87.55	98.25	51.14	53.33	46.48
$LSD_{5\%}$ Genotype (G)		1.89			1.93			1.66			12.43			13.46	
$LSD_{5\%}$ Treatment method (M)		0.69			1.29			0.86			3.62			4.91	
$LSD_{5\%}$ for G*M		2.87			3.68			3.77			15.46			19.04	

in BRRI HQ farm, Gazipur. Spouted seeds of all varieties were directly sown on puddle soil on 15 December 2017. Data on growth duration, yield and yield components were recorded. Growth duration of all the tested local varieties of Kanihati had longer growth duration than check varieties Bhutan and BRRI dhan28. Check variety Bhutan had the lowest growth duration and it was only 130 days. Growth duration of Kanihati-6 and Kanihati-12 were similar to BRRI dhan36, but not other genotypes. None of the varieties of Kanihati could out yielded BRRI dhan28 and BRRI dhan36 (Table 3).

International temperate rice observational nursery (IRTON, 2017)

Sixteen rice genotypes of IRTON-IRRI along with BRRI dhan28 and BRRI dhan36 as checks were tested in BRRI RS, Rangpur. Vegetative vigor and tillering ability were measured at seedling stage and other parameters except heading were measured at maturity. The experiment was laid out in RCBD with two replications. Considering phenotypic acceptance, sterility, grain size, yield and cold tolerance ability five genotypes (TP7594, TP20692, TP25175, 26717 and 24361) were selected.

Evaluation of Nepalese rice varieties for cold tolerance at seedling stage

A total of 15 Nepalese high-yielding rice varieties were collected from Khumaltar research station of Nepal through IRRI-BRRI collaboration with support of funding from TRB-BRRI Project. The aim of this collection is to evaluate cold tolerance and yield for suitability of release as Boro season variety for *Haor* regions of Bangladesh. Nepalese high yielding rice varieties generally grown in the valleys, terai and mid to high altitude condition usually experiencing cold at different growth stages due to differing in elevation. A total of 22 rice varieties including 13 Nepalese varieties were tested for seedling stage cold tolerance at 13°C air temperature in the growth chamber of Plant Breeding Division. In this experiment seven BRRI varieties (BR1, BR18, BRRI dhan28, BRRI dhan29, BRRI dhan36, BRRI dhan58 and BRRI dhan69) were used as check. Among the tested 13 Nepalese rice varieties, Lekali dhan-1, Lekali dhan-3, Chandan Nath-3 and Khumal-13 showed tolerant at seedling stage having SES ranged from 3.55 to 4.69 with survivability 92-100% (Table 4). The following four varieties could be regarded as good source of cold tolerance at seedling stage.

GROWTH STUDIES

Determination of photo-period induction cycle of photosensitive rice varieties

An experiment was conducted to determine the required photoinduction cycle to flower of photosensitive varieties at 9, 9.5 and 10.0 hour photoperiod. A photoperiodic cycle that induces

Table 3. Growth duration yield and yield components of some local varieties.

Variety	Growth duration (day)	Yield (t ha^{-1})	Panicle/m^2 (number)	Grain/ Panicle (number)	1000 grain weight (g)
Kanihati-1	152	5.25	412.59	78.25	23.63
Kanihati-2	154	4.53	431.77	75.54	24.33
Kanihati-3	154	4.02	426.62	72.37	24.21
Kanihati-4	149	4.6	424.42	81.19	23.09
Kanihati-6	144	4.76	432.78	79.56	26.13
Kanihati-7	153	4.78	436.87	83.52	24.73
Kanihati-8	151	4.95	428.43	82.51	25.54
Kanihati-9	154	5.3	420.55	76.67	22.47
Kanihati-10	154	5.2	436.45	85.46	21.99
Kanihati-11	150	4.14	433.83	70.37	20.72
Kanihati-12	144	6.05	416.56	69.82	22.97
BRRI dhan28	140	6.20	462.75	85.46	22.35
BRRI dhan36	143	6.72	468.91	81.72	23.61
Bhutan	130	2.55	254.36	64.23	21.82
$LSD_{5\%}$	3.49	0.78	17.25	12.18	0.43

Table 4. Seedling stage cold tolerance of Nepalese rice varieties in growth chamber condition at 13°C air temperature.

Variety	SES score (Mean ±SD)	Survivability (%) (Mean ±SD)
Khumal-2	8.10±0.66	32.80±16.00
Khumal-4	7.84±1.23	34.00±33.80
Khumal-5	7.92±0.45	48.40±24.80
Khumal-6	7.33±1.23	60.30±36.40
Khumal-7	6.83±1.02	70.40±19.60
Kuamal-9	7.22±1.44	46.70±26.40
Khumal-13	4.69±2.64	92.30±10.90
Lakali dhan-1	3.55±2.53	100.00±0.00
Lakali dhan-3	4.13±2.25	100.00±0.00
Manjushree-2	6.99±2.06	46.10±38.70
Chandan nath-3	4.54±2.19	100.00±0.00
DRR-44	8.0±0.82	40.90±30.40
Shukha dhan-6	7.59±0.59	49.40±17.70
BR1	8.77±0.21	11.40±10.30
BR18	7.06±0.34	66.70±11.80
BRRI dhan28	7.91±0.00	45.50±7.40
BRRI dhan29	7.84±0.61	43.70±18.10
BRRI dhan36	7.23±0.45	69.40±13.10
BRRI dhan58	7.73±0.27	49.80±21.00
BRRI dhan69	7.78±0.98	30.60±18.30
Pokkali	7.03±0.94	59.40±18.60
Nona Bokra	6.79±1.01	70.60±29.70

the initiation of flowers on plants is called a photoinductive cycle. A 10-h photoperiod alternating with a 14-h dark period is one possible photoinductive cycle of a short-day rice cultivar. This experiment was conducted to observe the required photoinduction cycle for some photosensitive rice cultivar when the photoperiod is shorten from 10 hour. Observations were made on dates of seeding and heading.

Photoinduction cycle was calculated for mother tiller as follows: Number of days from seeding to heading - 30 days. Number of photoinduction cycle varied for all the entries for different photoperiod (Table 5).

Trait discovery for improving yield potential of current high-yielding ideotype. *Semi-dwarf1* (*sd1*) gene for HYV development and heterosis in hybrid made great breakthrough in rice production in the past centuries. However, the concept on New Plant Type (NPT) and MAS for pyramiding of major effect QTLs/Genes did not able to produce desirable ideotype expected by researchers for boosting yields at least 20%. Therefore, the current project is aimed to explore the desirable physiology through trait discovery required for maintaining good balance between source-sink relationships for boosting future rice yield potential through ideotypic approach. A total of 38 traits were comprehended for yield and component traits; panicle traits, leaf traits, physiological and light interception related traits specifically radiation use efficiency, lodging resistance and some other traits. An in-depth physiological characterization, a total of 18 varieties/advanced breeding lines/ germplasm were studied in T. Aman 2017 season. However, none of the tested entries qualify or close to the optimized traits for targeted yield potential 10-12 t/ha. The highest amount of total dry matter and HI was found as 18.69 t/ha and 0.49 respectively (Table 6).

Table 5. Photoinduction cycle of photosensitive varieties at 9, 9.5 and 10 hours photoperiod.

Genotype	Photoinduction cycle		
	9 h photoperiod	9.5 h photoperiod	10.0 h photoperiod
BR22	13	14	13
BR23	32	31	33
BRRI dhan54	15	16	13
BRRI dhan76	35	31	33
BRRI dhan77	40	38	39
Dudkolom	26	25	27
Sadamota	31	32	36
Nizersail	19	15	17

Table 6. Morpho-physiological traits measured from 18 genotypes tested in T. Aman 2017 season field experiment. Each value is the mean of 12 randomly selected hills except grain yield measured from 5 sq.m. harvest.

Variety/Line/Accession	GD	PH	Pan/m^2±SD	PL±SD	Spikelet/m^2±SD	PFG±SD	SGW (mg)	PDW±SD	HI	TDM (t/ha)	GY (t/ha)
BRRI dhan47	121	105.75	207.8±55.49	24.81±2.94	25182.04±7687.63	56.99±7.63	23.47	2.03±0.45	0.40	8.29	3.39
BRRI dhan28	101	105.46	315.6±76.96	24.17±2.84	38630.38±16291.07	57.22±7.65	17.09	1.45±0.22	0.33	7.97	3.84
BRRI dhan29	125	106.42	236.7±80.09	24.58±2.48	33968.69±15033.48	65.38±7.67	19.47	2.26±0.45	0.45	9.65	4.46
BRRI dhan71	113	125.77	184.02±51.17	25.09±2.72	28898.06±10003.93	69.01±7.66	20.90	2.49±0.41	0.41	9.67	4.15
BR11	125	116.42	216.69±52.13	24.41±2.32	32687.42±8178.45	58.94±9.37	21.11	2.22±0.36	0.46	9.90	4.07
BR10	132	127.46	164.47±78.91	25.4±2.43	25921.02±12555.03	84.61±4.92	20.74	2.94±0.52	0.43	11.47	4.53
BRRI dhan30	132	125.58	195.58±53.98	25.29±2.57	28085.73±10447.42	79.93±6.84	20.41	2.51±0.47	0.40	11.34	4.62
BR(BE)6158RW-BC2-1-2-1-1	127	123.67	233.36±73.97	25.74±2.6	25517.63±9795.93	72.72±8.98	22.15	2.07±0.73	0.40	10.24	4.18
BR(BIO)9786-BC2-65-1-1	125	116.42	252.25±110.82	26.37±2.35	40459.5±19061.76	71.98±7.79	25.83	2.89±0.48	0.44	13.43	6.93
Habataki-PB	101	94.08	266.7±95.72	22.21±2.86	35276.54±14508.96	50.89±11.59	18.03	1.66±0.52	0.23	6.33	3.26
BR9680-2-3-2-2	113	117.40	149.21±58.89	27.86±3.96	29117.82±12718.65	51.73±9.21	20.01	2.52±0.82	0.31	8.15	2.97
BR(BIO)9786-BC2-161-1-2	113	113.28	219.81±79.71	24.64±2.32	35392.87±14575.04	64.84±15.03	22.08	2.45±0.77	0.35	10.37	4.94
Lao bhog (217)*	133	161.71	266.7±69.01	28.58±2.24	20201.41±6159.37	88.46±6.5	26.90	1.95±0.48	0.34	17.24	4.82
Dudkat (237)*	132	148.33	313.37±113.89	24.92±3.34	37770.28±15302.92	79.25±9.07	21.80	2.11±0.5	0.32	14.98	6.49
BUTA (406)*	148	151.29	324.49±86.19	23.51±3.58	43845.48±16201.29	70.49±7.07	19.32	1.89±0.54	0.31	14.96	5.95
Acc 2927*	124	156.08	317.82±166.16	23.19±3.13	37939.19±23538.85	69.02±19.2	20.82	2.24±0.55	0.32	18.69	5.56
Habataki-4190	101	97.50	268.92±77.51	23.23±2.93	44481.12±15374.3	59.91±7.19	18.30	1.99±0.25	0.49	9.11	4.88
Gutiswarna (7328)	125	111.29	260.03±105.43	22.22±2.37	42469.75±21408.57	63.71±11.75	18.25	2.2±0.55	0.38	10.17	4.71

Note: GD = growth duration, PH = plant height, Pan/m^2±SD = Panicle per sq.m. ±SD, PL±SD = panicle length±SD, Spikelet/m^2±SD = spikelets/sq.m±SD, PFG±SD = percent filled grains±SD, SGW = single grain weight, PDW±SD = panicle dry weight±SD, HI = harvest index, TDM = total dry matter and GY = grain yield. *Grain yield of these four accessions were estimated from 12 hills.

Entomology Division

SUMMARY

The highest incidences of rice insect pests were observed in T. Aman season than Aus and Boro season respectively during weekly sampling at BRRI HQ, Gazipur. On the other hand, more insect pests and natural enemies were observed in rice bund than other habitats during Aus season. In T. Aman season the highest insect population and natural enemies were found in seedbed and irrigated rice habitat respectively. Irrigated rice habitat also harbored more insect pest and natural enemies during Boro season.

During survey at different AEZ it was found that T. Aman seedbed in all the locations of Sylhet region were highly infested by thrips. Rice hispa outbreaks occurred in south Surma and Golapganj upazila of Sylhet district during T. Aman 2017 season. Dark headed borer rather than yellow stemborer was predominant in Rajshahi region.

The highest catch of insect pests and natural enemies in light trap was recorded at BRRI RS, Habiganj than the other locations. The peak population of brown planthopper was observed in November at Habiganj and Gazipur. The highest peak of yellow stemborer and green leafhopper was observed at Habiganj in September and June respectively. In Barishal, peak of green leafhopper also observed in June.

Historical data of 22 years, model predicts that species diversity will be reduced by 2050.

More parasitism found in rice hispa and brown planthopper eggs in eco-engineering plots than insecticide treated and control plots. Moreover, eco-engineering plot reduced 50% key pest population and 75% chemical insecticides from rice field without any yield reduction.

Yield loss of BRRI dhan46 due to leaf roller was observed 34.15% when 35.67% leaf/hill were rolled by the larvae.

One hundred and seven out of 115 insecticides were found effective against brown planthopper and six were found effective against rice hispa.

A total of 68 INGER IRBPHN 2017 materials were screened against brown planthopper at greenhouse condition to identify resistance sources against major insect pests of rice in which nineteen breeding lines were found having moderately resistant score (3-5).

SURVEY AND MONITORING OF RICE ARTHROPODS

Pest and natural enemy incidence at BRRI farm, Gazipur

Rice insect pests, their natural enemies and crop damage intensities in six habitats were monitored weekly by 100 complete sweeps from each habitat at BRRI research farm, Gazipur. The overall insect pest incidence was low in all season. Higher incidences of insect pests were found in T. Aman than the Aus season (Fig. 1). The highest insect pest and natural enemies were found in rice bund during Aus season. Short-horned grasshopper (SHG), rice bug (RB), spider (SPD) and damselfly were dominant in all habitats of Aus season. In T. Aman season the highest insect population and natural enemies were found in seedbed and irrigated rice habitat respectively. Short-horned grasshopper was dominant insect in all habitats of T. Aman season. Spider, damselfly and ladybird beetle were the dominant predators in all the habitats of these season. Visual counting from 20 hills showed that the population and the damage of insect pests were below the economic threshold level (ETL).
PI: Mir Md. Moniruzzaman Kabir, **CI:** Sadia Afrin, **PL:** Sheikh Shamiul Haque

Insect pests survey in different AEZs of Bangladesh

Insect pests were below the ETL level both Aus and T. Aman 2017 in Sylhet region except rice hispa in T. Aman season. The population of SHG was found highest in sweep net collection (23.67/20 sweep) during Aus season followed by green leafhopper (GLH), rice leaf roller (RLR) and rice hispa (9.87, 5.0 and 3.67/20 sweep) respectively in Sylhet region. But in T. Aman season rice hispa (RH) population was found highest (144/20 sweep) followed by GLH and SHG (11.87 and 9.73/20 sweep) respectively (Fig. 2). Rice hispa outbreaks occurred in South Surma and Gopalganj upazila of Sylhet during T. Aman 2017 (Fig. 2). During visual counting it was observed that T. Aman seed bed in all the locations were highly infested by thrips. Entire lengths of leaves of seedlings were rolling. Plants were completely wilted followed by severe yellowing and scorching.

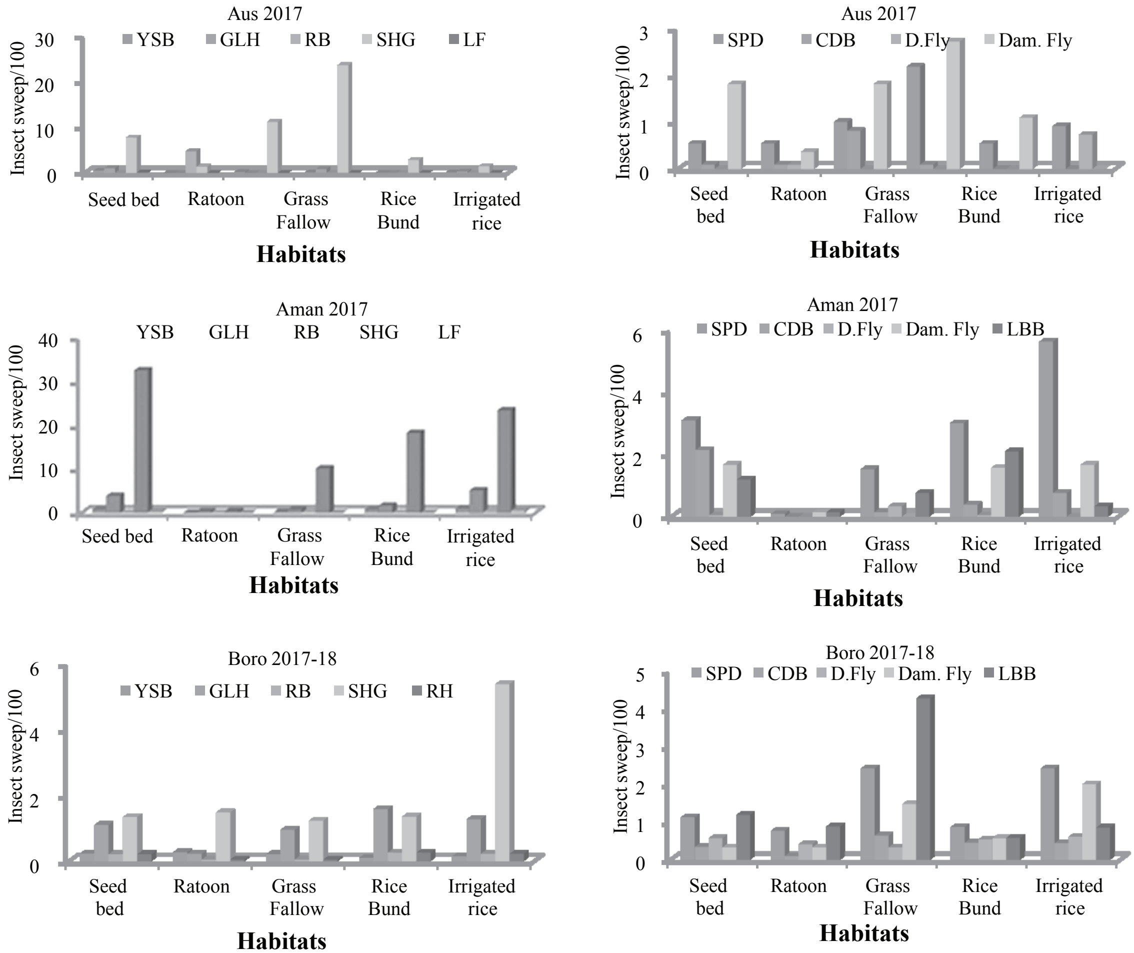


Fig. 1. Incidence of insect pests and natural enemies in rice and non-rice habitats during Aus, and T. Aman 2017 and Boro 2017-18 in BRRI HQ farm, Gazipur.

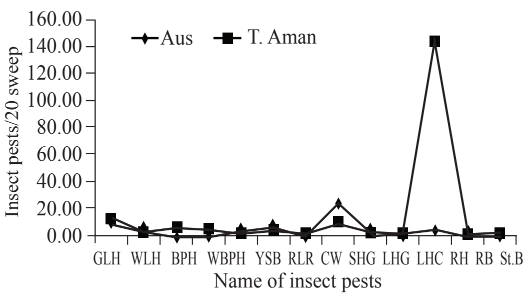


Fig. 2. Incidence of insect pests and natural enemies in rice during Aus and T. Aman 2017 at Sylhet region.

During Aus season damsel fly population was found highest, 13.00/20 sweep followed by Spider, Lady bird beetle (LBB) and carabid beetle (CDB) (5.11, 2.11and 1.22/20 sweep respectively). Brown plant hopper (BPH), white backed plant hopper (WBPH), grasshopper (GH), GLH and yellow stem borer (YSB) were the major insect pests prevailed in all the four regions of Rajshahi, Rangpur, Sylhet and Barishal during Boro 2017-18 season (Fig. 3). But the incidence was below the ETL.

The highest BPH was observed in one location of Moulvibazar district. which ultimately increases the average BPH population in Sylhet region. Brown planthopper, WBPH, GH and GLH infestations were higher in Sylhet region than Rajshahi, Rangpur and Barishal. In Rajshahi region, higher incidence of dark headed borer (DHB) other than yellow stem borer (YSB) occurred at the early and mid tillering stages of rice plant. Among the natural enemies, spider (SPD) was higher in number followed by lady bird beetle (LBB), damsel fly, carabid beetle

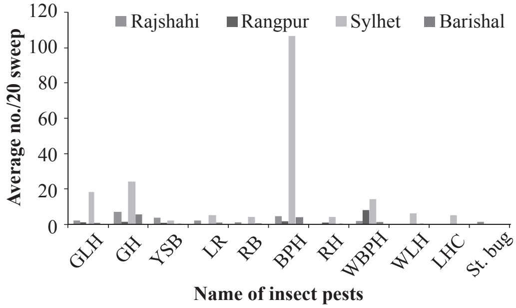


Fig. 3. Incidence of insect pests in different AEZ of Bangladesh during Boro 2017-18.

(CDB) and dragon fly during Boro 2017-2018 season (Fig. 4). Green mirid bug (GMB) and tiger beetle (TB) were found highest (13.0 and 12.0/20 sweep respectively) in Sylhet than other regions. Prevalence of parasitoid and staphylinid beetle was observed in Rajshahi and Barishal.

PI: Md Mosaddeque Hossain, **CI:** Md Nazmul Bari, Md Panna Ali, Md Mir Md Moniruzzaman Kabir, Ms Farzana Nowrin and Ms Sadia Afrin, **PL:** Sheikh Shamiul Haque

Incidence of insect pest and natural enemies in light trap

Rice insect pests and their natural enemies were monitored (through the year) by Pennsylvanian light trap from dusk to dawn throughout the year at BRRI HQ, Gazipur and BRRI RSs. Cumilla, Sonagazi, Barishal, Rangpur, Habiganj and Rajshahi. The total number of insect pests was the highest at Habiganj and followed by Gazipur, Barishal, Rajshahi, Sonagazi, Rangpur and Cumilla. The abundance of GLH, RLF, BPH, WBPH and YSB was observed almost all the seven locations (Fig. 5). The highest number of BPH was observed in November at Habiganj and Gazipur. BPH had an additional peak in April 2018 at Gazipur. The highest peak of YSB was observed at Habiganj in September. In June at Habiganj and October-November in Barishal there was a peak of GLH (Fig. 5).

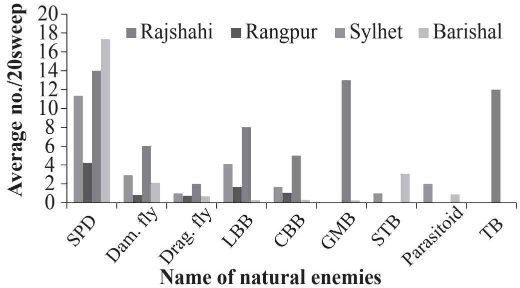


Fig. 4. Incidence of natural enemies of rice insect pest in different AEZ of Bangladesh during Boro 2017-18.

The highest number of natural enemies in light trap was recorded at Habiganj, followed by Gazipur, Barishal, Sonagazi, Rajshahi and Cumilla. No Natural Enemy was in Rangpur station during July 2017 to June 2018 (Fig. 6). Green mirid bug (GMB) population of Gazipur was noticeably higher than those of the six stations (Cumilla, Rajshahi, Barishal, Habiganj, Rangpur and Sonagazi). In November and April two different peaks of GMB were observed in both Gazipur and Barishal. The highest peak of SPD was observed at Sonagazi in November and April (Fig. 6).

PI: Mir Md Moniruzzaman Kabir, **CI:** Dr Md Nazmul Bari, **PL:** Sheikh Shamiul Haque

Impact of climate change on rice arthropods

A hierarchical structure of 22 years on 14 migratory insect species, with three orders of diversity (q = 0, 1, 2) accounted by temporal diversity decomposition framework based on hill numbers. Species diversity showed significant quadratic correlations with short period (month). Species richness increased with monthly average temperature and rainfall, but both the species and heterozygosity decreased with increased temperature showing a linear relationship. While correlations did not exhibit annually at constant pattern due to climate variation and sensitivity of species to temperature, thus leading to a historical hierarchical structure. Only half of ten equivalent species appeared during 10 years increased, indicating that the composition of migratory pool kept relatively constant within 22 years. However, based on historical data, the model predicts that species diversity will be reduced by 2050 (Fig. 7). This study highlights the importance of temporal diversity decomposition to dissect the impact of climate change on the species-environment interactions and may provide guidelines for historical biodiversity research.

PI: Md Panna Ali, **PL:** Sheikh Shamiul Haque

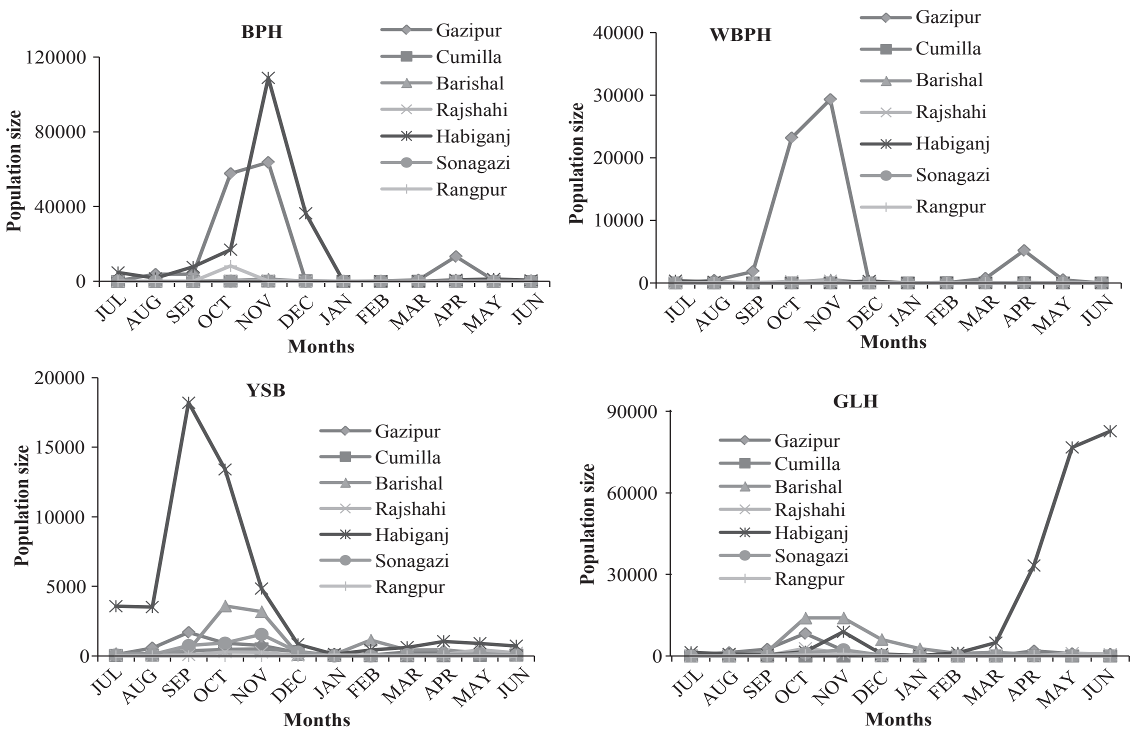


Fig 5. Incidence pattern of major insect pests in light trap, BRRI HQ, Gazipur and regional stations, during July 17- June 18.

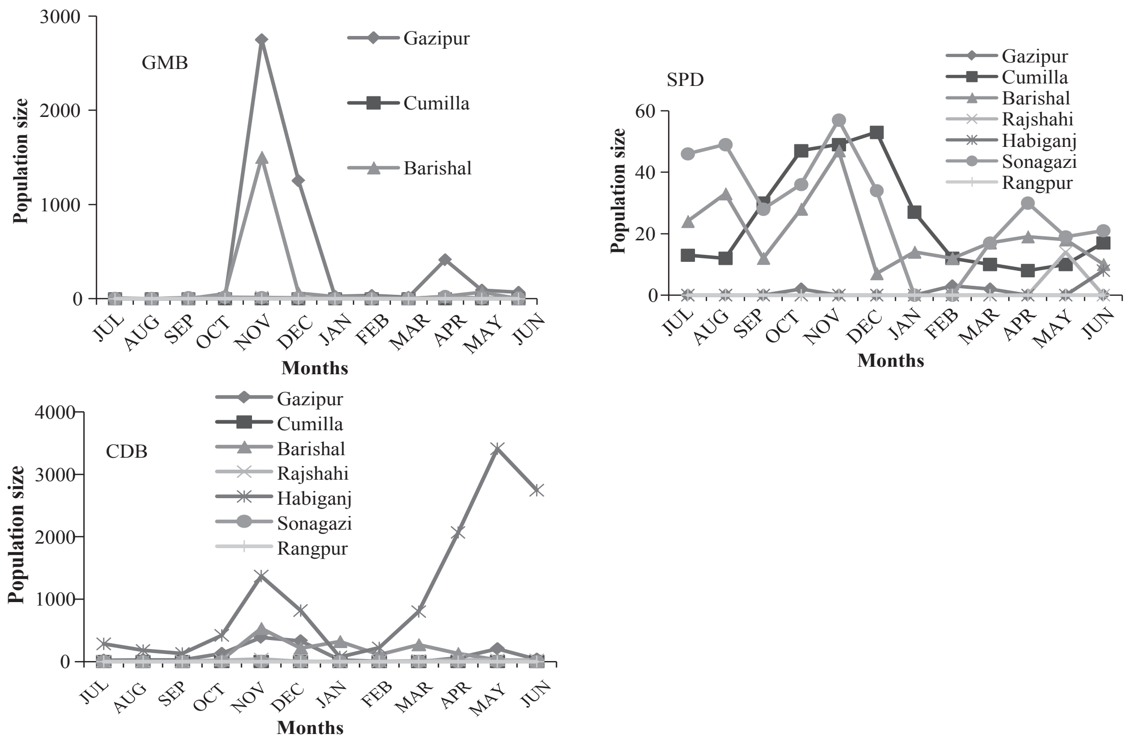


Fig. 6. Incidence pattern of natural enemies of rice insect pest in light trap, BRRI HQ, Gazipur and regional stations, during July 17-June 18.

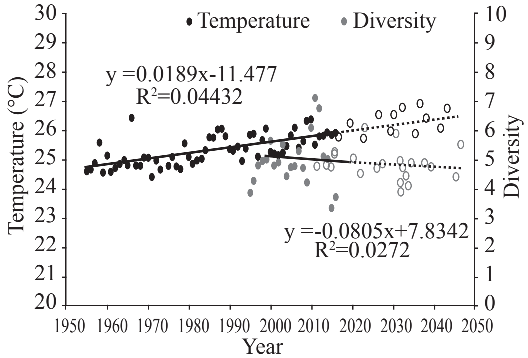


Fig. 7. Prediction of annual temperature and species diversity in Bangladesh with global warming by 2050. (The solid dots and lines are historical data, and empty dots and dash lines are predicted trends).

INTEGRATED PEST MANAGEMENT

Conservation of natural enemies in rice ecosystem

Natural enemies of rice insect pests can be conserved in rice ecosystem through ecological engineering approach. Eco-engineering treated plot showed the highest parasitism activity to the exposed BPH and rice hispa egg in rice field. Rice hispa and BPH egg were parasitized by *Trichogramma zahiri* and *Anagrus spp* respectively (Fig. 8). Severe pest outbreak was not observed in the experimental plot. Moreover, eco-engineering plot reduced 50% key pest population and 75% chemical insecticides from rice field. In addition, no significant yield difference were observed among three times insecticide treated plots (6.58 t ha^{-1}) and eco-engineering (6.73 t ha^{-1}), control (6.48 t ha^{-1}) plot in BRRI dhan58 during Boro season. Moreover the lowest damaged symptom (white head) was observed in eco-engineering plot (Fig. 9). This result indicated that rice can be produced without insecticide using ecological engineering technique.

PI: Md Nazmul Bari, **CI:** Md Panna Ali and Sadia Afrin, **PL:** Sheikh Shamiul Haque

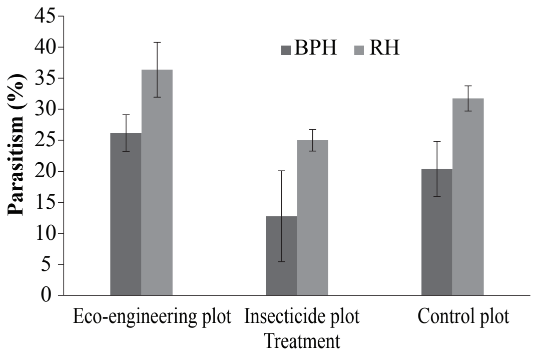


Fig. 8. Effect of treatments on the parasitism (%) of rice hispa and BPH eggs. Egg bait traps were used to determine the parasitism rate in rice field.

CROP LOSS ASSESMENT

Effect of rice leaf folder damage on rice grain yield of BRRI dhan46

The experiment was conducted in BRRI farm, Gazipur. Yield loss due to rice leaf folder was estimated 34.15% in BRRI dhan46 at 35.67% folded leaf condition.

PI: Md Mosaddeque Hossain, **CI:** Mir Md Moniruzzaman Kabir, **PL:** Sheikh Shamiul Haque

EVALUATION OF CHEMICALS AND BOTANICALS AGAINST RICE INSECT PESTS

Test of different insecticides against major insect pests of rice

A total of 115 commercial formulations of insecticides were evaluated against brown planthopper (BPH) and six against rice hispa. One hundred seven out of 115 insecticides were found effective against BPH and all six were found effective against rice hispa.

PI: Md Mofazzel Hossain (Aus), Sadia Afrin (T. Aman) and Md Panna Ali (Boro), **PL:** Sheikh Shamiul Haque

Fumigation action of botanical oils against stored grain insect pests

The experiment was conducted in the field lab of Entomology Division and found that first (24 hrs)

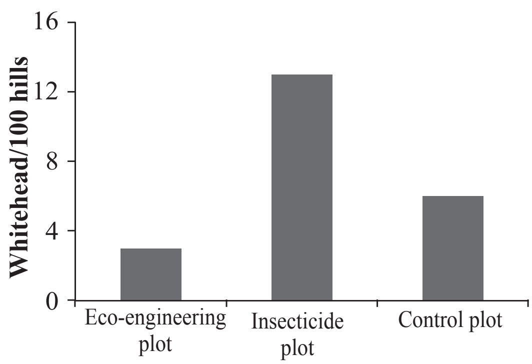


Fig. 9. Effect of treatments on white head development in rice field during T. Aman 2017 in BRRI, Gazipur.

and 2nd exposure (48 hrs) period of rice stored grain insects to mahogany oil fume caused significant mortality to rice weevil and angoumois grain moth compared to the control. Mortality ranges from 51 to 95.67% and 87.14 to 96.82% in rice weevil and angoumois grain moth respectively (Fig. 10). The result of this study indicated that mahogany oil would be an effective product to control stored grain insect pests. After fumigation exposure of grains, panel test was conducted to determine that bitter taste residue remains in the grain or not. Randomly more than 10 people were selected and approached to eat the grain after 48 hrs exposure of fumigation and feel no bitter taste by mahogany oil exposure rice grain. However, more research is required for large scale control.

PI: Md Panna Ali, **CI:** Sadia Afrin, **PL:** Sheikh Shamiul Haque

Reaction of provitamin A enriched GR2-E BRRI dhan29 golden rice introgressed lines to different insect pests under confined field trial condition

GR2-E BRRI dhan29 golden rice and BRRI dhan29 were evaluated under natural infestation at the confined field trial (CFT) site of Bangladesh Agricultural Research Institute (BARI), Gazipur during Boro 2017-18. Prophylactic measures were taken to control insect pests during crop growing season. Four insecticides including Furadan 3G, Virtako 40WG, Malathion 57EC and Dursban 20EC were applied in the trial plot. Insect infestation was very low at the crop establishment stage due to regular application of insecticide. Stem borer infestation was observed from vegetative to reproductive stage. But their level was negligible. No significant differences were observed between the transgenic golden rice lines and non-transgenic BRRI dhan29 (Fig. 11). No unusual insect pest infestation was found in transgenic lines.

PI: Md Panna Ali, **CI:** Md Abdul Kader, **PL:** Sheikh Shamiul Haque

HOST PLANT RESISTANCE

Screening of INGER IRBPHN 2017 rice varieties

A total of 68 INGER IRBPHN 2017 materials were screened against BPH at green house condition to identify resistance sources against major insect pests of rice. A total of nineteen breeding lines showed moderately resistant score (3-5) reaction (Table 1).

PI: Md Mosaddque Hossain, **CI:** Mir Md Moniruzzaman Kabir, **PL:** Sheikh Shamiul Haque

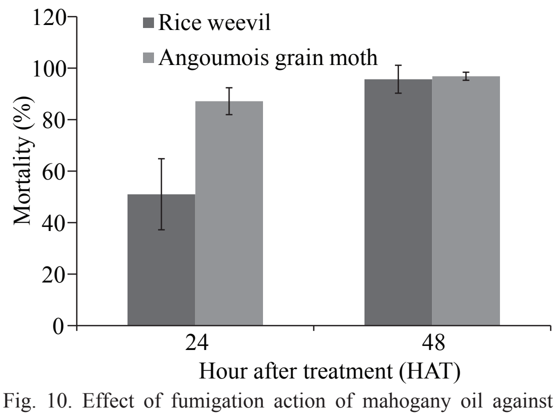


Fig. 10. Effect of fumigation action of mahogany oil against stored grain insect pests conducted in Entomology lab, BRRI, Gazipur.

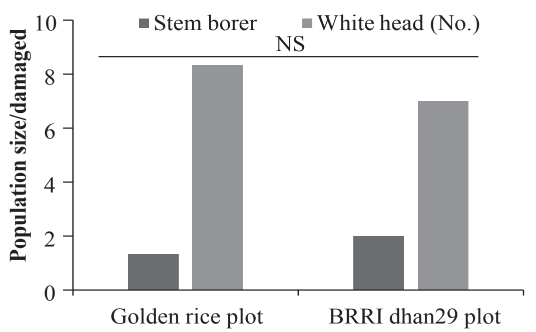


Fig. 11. Number of insects/damaged observed in golden rice and BRRI dhan29 growing plots during Boro 2017-18. Total number of stem borers and white heads observed in field were presented in this figure. NS: Non-significant at the 5% level.

Table 1. Screening of rice germplasm against BPH, entomology greenhouse during Boro 2017-18.

Seed source	No. of entry	Target pest	Promising material	Score
IRBPHN	68	BPH	2017 IRBPHN- 001, 035, 024, 061, 063	3
			2017 IRBPHN- 008,012,015,020, 023, 028, 030,031,036,037,039,046,048 and 2017 IRBPHN- 062	5

Susceptible check: BR3 (for all), Resistant ck: T27A for BPH. Scores were made according to SES. R= resistant (score 0-1), MR= moderately resistant (3-5), Susceptible = >7.

Plant Pathology Division

SUMMARY

Experiments were conducted under seven projects in Plant Pathology Division to manage the rice diseases. Survey and monitoring of rice diseases were conducted in both T. Aman and Boro seasons in Gazipur, Rajshahi, Satkhira, Habiganj, Cumilla, Barishal and Rangpur regions. Disease incidence (DI) and disease severity (DS) data of major rice diseases were recorded following SES. During T. Aman 2017, in Sathkhira district, the disease incidence ranged from 3.5 to 52.93% for brown spot, from 6.26 to 18.36% for sheath blight (ShB) and from 1.77 to 21.77% for Bacterial blight (BB). In Gazipur, average BB (incidence: 61.89% and severity: 4.55), ShB (incidence: 36.97% and severity: 6.49) brown spot (Bs) (incidence: 32.47% and severity: 2.18) were predominantly compared to false smut, sheath rot and narrow brown leaf spot. In Habiganj, brown spot and neck blast disease were prominent compared to other diseases. In Cumilla, among the major diseases, Bacterial blight and sheath blight disease was found all the surveyed plots in Cumilla region. Neck blast disease was observed high in aromatic rice BRRI dhan34 in one location of Sadar Dakkhin only. In Boro, the highest blast disease (90%) was recorded at Mithapukur, Rangpur while the lowest (5-30%) was observed at Sadar upazila. Sheath blight disease was dominant both Mithapukur and Gangachara (15-70%), while least at Sadar Rangpur (3-50%). Bacterial blight disease was present in all the three upazilas of Rangpur ranging from 5-70% having 3-7 disease severity scale. In Boro 2017-18 season, BB (incidence: 24.6% and severity: 2.9) was predominant compared to ShB, brown spot and blast in Gazipur district. In Goadagari, Poba and Tanore under Rajshahi district bacterial blight, brown spot, sheath blight, blast were prevalent over the rice fields on BRRI dhan28, Zira, Minikit, Motazira, Satalaxmizira, BRRI dhan63. Among them, bacterial blight and brown spot were more frequent disease irrespective of varieties across the locations with the incidence of 2-100, 5-100, respectively. Severity ranged from 1 to 9 and 1 recorded with BB and BS, respectively. In Barishal region, BRRI dhan28 and BRRI dhan61 were affected by neck blast disease, whereas BRRI dhan63 affected by leaf blast disease. Two distinct types of false smut balls were identified - orange and olivaceous-greenish-black. Rice false smut contaminated seeds had significantly higher protein content, however, the germination percentage tended to be decreased in contaminated seeds. BRRI dhan49 ranked as highly susceptible by newly developed false smut disease rating scale. The artificial inoculation of false smut disease has been made. However, it needs to validate further. To develop tungro resistance pre-breeding materials, hybridization between tungro resistant (IR69705-1-1-1-3-2, TW-16 and Matatag-1) and tungro susceptible variety (BRRI dhan48, BRRI dhan71 and Swarna) were done to produce different generation (BC_1F_1, BC_2F_1 and BC_3F_1). In addition, for the mapping of QTL in tungro resistant Kumragoir, hybridization was done between Kumragoir and BRRI dhan48 to produce BC_1F_1 generatiom. Primer survey was conducted to find 96 polymorphic markers between the Kumragoir and BRRI dhan48 for QTL mapping. Tungro infected samples were collected from Cumilla, Habiganj, Jhenaidah and Gazipur and successfully detected the presence of both virus particles (RTBV and RTSV) through molecular markers. Fifty upland and 100 zoom rice were screened out against blast disease, only eight upland genotypes and 35 zoom rice showed resistant reaction. Among the tested plant products, neem, mehogoni and dodder plant extraction in ethanol completely (100%) inhibited the mycelial growth of the pathogen. The *Trichoderma* spp. performed good in drought condition for all the tested three varieties e.g. BRRI dhan56, BRRI dhan71 and IR-64. In T. Aman, among 129 advanced breeding lines three entries such as IR10F102, BR9043-11-3-2-2 and IR95817-51-1-1 showed moderate resistant reaction to blast. In Boro season, out of 84 materials five materials such as IR99056-B-B-15, IR101762-1-1-1, IR83484-3B-7-1-1-1, IR87870-6-1-1-1-1-B, and BR8339-6-2-5-2 were moderately resistant to blast disease. For the development of blast resistant varieties using differential system and molecular markers around 20 plants from different crosses harboring target locus were able to select by marker. Fifty rice germplasm were screened against blast in the replicated plots. Among the tested materials four were detected as resistant (score 0-1) which will be tested further and to be confirmed. Introgression of resistant gene *Pi9, Pita2, Pi40* and *Pish* was done in the background of BRRI dhan28, BRRI dhan29

and BRRI dhan63. For the introgression of blast resistant gene in BRRI dhan47, 30 homozygous and 37 heterozygous BC_3F_2 plants having *Pi40* gene were found through marker assisted selection. For the development of bacterial blight resistant varieties, pathogenicity test showed that a number of progenies of BC_2F_1 and BC_1F_1 developed from the different crosses were resistant to the most virulent BB isolate BXO9. A total of 142 F_1 seeds as well as 191 BC_1F_1 seeds were obtained from different crosses for the improvement of BRRI varieties resistance to both blast and bacterial blight diseases. A total of 80 germplasms were screened out against bakanae. Among the three (ACC 562, 621, 652) were found resistant. For the management of sheath blight, among the treatments recommended dose of fertilizer (RDF) with Trichocompost and (75% RDF + 25% vermicompost) positively reduced % RLH whereas other treatments increased % RLH. Yield was also increased at Trichocompost treated plots due to % RLH reduction. Among 15 fungicides, only three fungicides i.e Royal 75 WDG, Tebuplus 75, and Mcvo 75 were successfully controlled rice blast disease (above 80%) in 2017. Twelve fungicides were tested against seedling blight. Six fungicides were found effective to control seedling blight. A total of 37 field demonstrations were conducted in blast prone areas of Gazipur, Rangpur, Dinajpur, Mymensingh, Cumilla and Khulna regions in Boro 2017-18, where BRRI recommended integrated blast management practice reduced approximately 76.13% blast disease compared to farmer's practice, which resulted around 22.72% yield increased.

TRANSFERABLE TECHNOLOGY

Management of false smut disease

To minimize the disease, planting time of T. Aman varieties should be adjusted so that the panicle emergence occurs before mid-October. Avoid seeds from last year's infected field. Follow recommended nitrogen dose.

Management of red eel worm in rice field

Application of Fipronil 3GR (10 kg/ha) group insecticides followed by alternate wetting and drying (AWD) effectively controlled (>80%) red eel worm infestation.

EPIDEMIOLOGY OF RICE DISEASE

Survey and monitoring of rice diseases in selected areas

A survey was conducted in different upazilas of selected districts during T. Aman and Boro 2017-18 to know the present status of different rice diseases under various rice ecosystems. Disease incidence (DI) and disease severity (DS) data of major rice diseases were recorded following SES, IRRI. Sheath blight (ShB), bacterial blight (BB) and brown spot (BS) diseases were prevalent in T. Aman. Early flowering of BRRI varieties especially BRRI dhan28, BRRI dhan50 and BRRI dhan63 in Boro was infected more by neck blast disease over the country. Most of the late flowering Boro varieties were not affected by neck blast.

T. Aman, 2017. Surveys were conducted in Rangpur, Rajshahi, Barishal, Habiganj, Cumilla and Gazipur district covering with three upazila of each mentioned district to know the geographical distribution and severity of different rice diseases. At mature stage, bacterial blight, false smut, brown spot, sheath blight were prevailed over the rice fields on Lal swarna, Guti swarrna, BRRI dhan11, BRRI dhan49, BRRI dhan51, BRRI dhan52. Among them, False smut, bacterial blight, brown spot were more frequent disease irrespective of cultivated variety in that surveyed area. The disease incidence ranges from 2 to 60% for bacterial blight, from 5 to 30% for sheath blight, from 1-10% for brown spot and from 0.5 to 40% for false smut disease. Incidence of false smut disease ranged from 0.5-40 were found predominant in BRRI dhan49. Among the three upazilas of Rajshahi district, the highest disease was recorded at Tanore upazilas especially in swarna and in some hybrid rice varieties, while the lowest disease was recorded at Godagari, Rice sheath blight disease seems to be the major dominant disease in all the three upazila ranges from 10-85% with disease severity 3-7. Blast disease was mostly prevalent at Tanore (10-75%) especially in aromatic rice like BRRI dhan34 and Chinigura type rice. Bacterial blight disease existed in all the three upazilas ranged from 8-70% having disease severity of 3-7 scale. In Cumilla, on average, disease incidence of bacterial blight, sheath blight, blast, false smut and brown spot were 5-80, 5-80, 1-60, 0.1-20 and 10-60 % respectively. Among the major diseases, bacterial blight and sheath blight disease was found in all the surveyed plots of Cumilla region. Neck blast disease was observed high in aromatic rice BRRI dhan34 in one location of Sadar Dakkhin only. In Sathkhira district during T. Aman 2017, the disease incidence ranged from 3.5 to 52.93% for brown spot, from 6.26 to 18.36% for sheath blight and from 1.77 to 21.77% for BB. The study was carried out to investigate the status of different rice diseases in T. Aman season in Sathkhira district in four upazilas namely Tala, Kalaroa, Shyamnagar and Sathkhira sadar. The disease incidence ranged from 3.5 to 52.93% for brown spot, from 6.26 to 18.36% for sheath blight and from 1.77 to 21.77% for BB in this district. The disease was observed for the varieties BRRI dhan10, BRRI dhan28, BRRI dhan34, BRRI dhan49 and Swarna. In T. Aman 2017 season, survey was carried out in different locations to investigate the present status of different rice diseases in different climatic conditions. In Gazipur, average BB (incidence: 61.89% and severity: 4.55), ShB (incidence: 36.97% and severity: 6.49) brown spot (incidence: 32.47% and severity: 2.18 and were prevalent compared to false smut, sheath rot and narrow brown leaf spot.

Boro season 2017-18. Among the three upazilas of Rangpur district, the highest disease was recorded at Mithapukur upazila, while the lowest disease was recorded at sadar. Sheath blight, bacterial blight and blast disease was predominant in all the three upazilas with minimum existence of rice false smut disease. The highest blast disease (90%) was recorded at Mithapur, while the lowest 5-30% was observed at sadar upazilas. Sheath blight disease was dominant in Mithapukur and Gangachara (15-70%), while it was least in sadar (3-50%). Bacterial blight disease was present in all the three upazilas ranging from 5-70% having 3-7 disease severity scale. In four upazilas of Satkhira district namely Tala, Kalaroa, Shyamnagar and Sathkhira sadar and disease was observed for BRRI dhan10, BRRI dhan28, BRRI dhan34, BRRI dhan49 and Swarna. The disease incidence ranged from 3.5 to 52.93% for brown spot, from 6.26 to 18.36% for sheath blight and from 1.77 to 21.77% for BB in this district. In Boro, survey was conducted in three upazilla of Habiganj districts. In Habiganj, brown spot and neck blast diseases were prominent compared to other diseases. Brown spot and neck blast disease incidence and severity were the highest compared to other diseases. In some areas, tungro disease severely affected the rice plant. In Godagari, Poba and Tanore under Rajshahi district bacterial blight, brown spot, sheath blight, blast were prevailed over the rice fields on BRRI dhan28, Zira, Minikit, Motazira, Satalaxmizira, BRRI dhan63. Among them, bacterial blight, brown spot were more frequent disease irrespective of variety across the locations with the incidence of 2-100, 5-100 respectively. Severity ranged from 1 to 9 and 1 recorded with BB and BS respectively. BRRI dhan28 was the predominant variety grown all the locations. In Boro season, average BB was widespread followed by ShB, blast and brown spot. In Boro 2017-18 season, BB (incidence: 24.6% and severity: 2.9) was extensive compared to ShB, brown spot and blast in Gazipur district. In Barishal region, BB, ShB, blast, and brown spot were predominant in rice field. Among the different varieties, BRRI dhan28 and BRRI dhan61 were affected severely by neck blast disease whereas BRRI dhan63 were affected by leaf blast disease.

■ TH Ansari, QSA Jahan, S Akter, M Hossain, MS Mia, MAI Khan, MA Monsur, MR Bhuiyan, MM Rashid, M Ahmed, A Ara, SAI Nihad, R Aktar, HA Dilzahan and MA Latif

Rice false smut (RFSm) disease symptom

In general, smut balls formed in the lower half of the infected panicles. On average, 1 to 2 smut balls would form on infected panicles. Two distinct type of smut balls were identified - orange and olivaceous-greenish-black. Early symptom of the disease showed on an infected panicle in around one week after panicle emergence. After initiation of the symptom, smut balls took 12 days to fully develop. Orange smut balls appeared in all three rice growing seasons – ‘Boro’, ‘Aus’ and early ‘T. Aman’ (during October and early November). Olivaceous greenish-black smut balls only observed in late T. Aman (mid-November onwards) crops. Smut balls formed on the infected panicles batch-by-batch. The final status of the disease in a field was the cumulative incidence of the batches of new smut balls formed on the crop. ■ B Nessa

Newly developed rice false smut disease rating scale

Through consulting seven published disease resistant scoring system for RFSm (FS-Rating), a new system (FS-Rating index) was developed (Table 1): FS-Rating index = [(DI-score × DI-weight) + (DS-score × DS-weight)] / 100, where DI is disease incidence and DS is disease severity expressed as balls / panicle. The value of 'DI-weight' and 'DS-weight' was set as 60 and 40 respectively according to published literature. ■ B Nessa

Field reaction of genotypes to rice false smut resistance

The newly developed false smut-rating index was used to measure field reaction of 23 genotypes. Among the tested genotypes, 'BRRI dhan49' was in the category of 'HS', 'BR11', and 'Gutiswarna' in 'S', 'BR25', 'BRRI dhan32' and 'BRRI dhan52' in 'MS' and 'BRRI dhan39' in 'MR' (Fig. 1).

■ B Nessa

Effects of RFSm contaminated seeds on germination and quality

We compared germination (%) of rice false smut contaminated and clean seeds of 'BRRI dhan49' in 2014, 2015 and 2016 (Fig. 2). The germination of contaminated seeds, compared to clean ones, tended to decrease, but the difference between

Table 1. Rice false smut disease rating scale.

Scale	Level	Level explained	Disease incidence (DI)	Balls/panicle
0	HR	Highly resistant	0	0
1	R	Resistant	1 - 5	1 – 2
3	MR	Moderately resistant	>5 - 10	>2 - 4
5	MS	Moderately susceptible	>10 - 15	>4 - 6
7	S	Susceptible	>15 - 25	>6 - 8
9	HS	Highly susceptible	>25	>8

Field reaction of genotypes to rice false smut resistance.

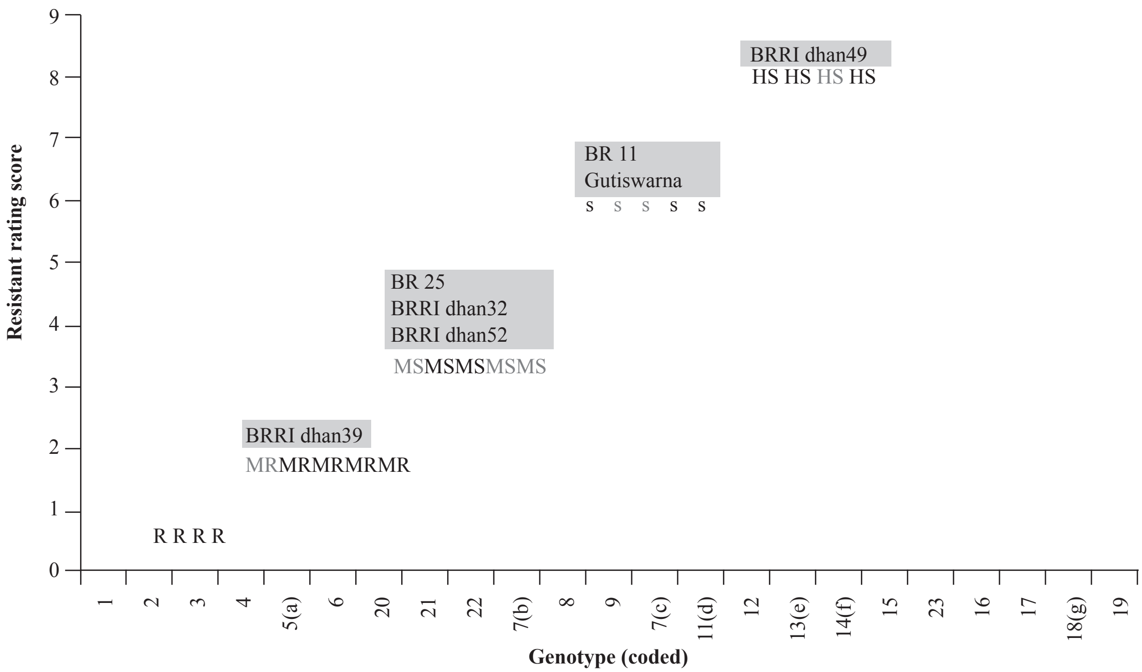


Fig. 1. Field reaction of rice genotypes to false smut resistance.

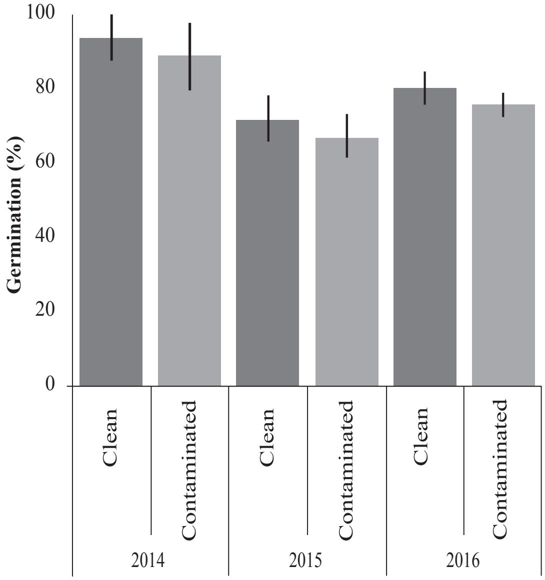


Fig. 2. Comparison of germination (%) of rice false smut contaminated and clean seeds of BRRI dhan49 in 2014, 2015 and 2016.

them in neither years was statistically significant. RFSm contaminated grains tended to produce less head rice than clean ones. The amylase content was significantly lower in contaminated seeds (24.0%) than clean seeds (24.5%), whereas contaminated seeds had significantly higher protein content (9.0%) than clean seeds (8.6%). ■ B Nessa

Development of inoculation technique for false smut disease

The artificial inoculation of false smut disease had been made successful for the first time in Bangladesh (Fig. 3). The technique was very simple. Firstly, isolation was done from freshly collected yellow smut balls within 48 hours on WA media. It took only four days to multiply in pure culture. Then inoculum was prepared by scrabing the pure culture from PSA plate using distilled water. Rice plants were inoculated by spraying the inoculums suspension at booting stage. Inoculated rice plants showed symptom after 21 days of inoculation. ■ B Nessa

PATHOGEN POPULATION STRUCTURES AND BIOLOGY

Isolation and identification of rice kernel bunt pathogens– another emerging rice disease

Kernel bunt is an another emerging disease of T. Aman rice in Bangladesh and was identified based on symptom and spores. ■ B Nessa

Molecular detection of rice tungro virus

To detect rice tungro virus (RTBV and RTSV) through molecular marker; tungro infected samples were collected from Cumilla, Habiganj, Gazipur and Jhenaidah. After collection, rice tungro bacilliform virus (RTBV, a DNA virus) and rice tungro spherical virus (RTSV, a RNA virus) were successfully detected through molecular marker (Fig. 4). The presence of both virus particles were confirmed in the virus infected plant samples of Cumilla, Habiganj, Gazipur and Jhenaidah.

■ SAI Nihad, MA Latif, and M A Rahman

Improvement of differential systems for rice blast disease

To improve the existing differential system for rice blast disease resistance, 210 blast infected samples were collected from 73 hot spots of 10 districts of Bangladesh. We emphasized specially

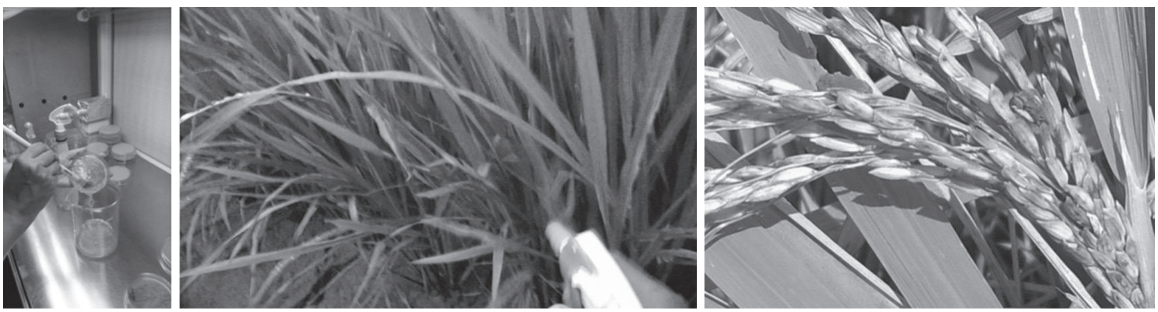
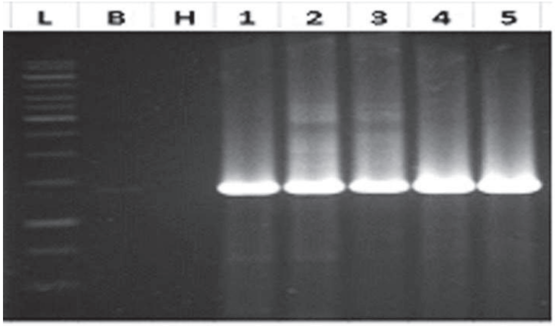


Fig. 3. Artificial inoculation technique of false smut disease.



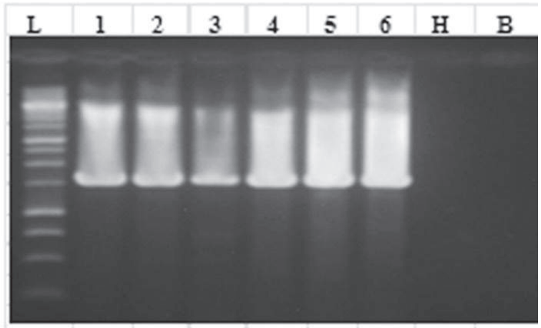


Fig. 4. Detection of rice tungro bacilliform virus a. and rice tungro spherical virus b. through molecular marker (Here, L=1 kb plus ladder, B=Blank (No DNA), H=Healthy, 1 to 5 and 1 to 6 are infected samples)

on BRRI dhan28 infected plot, because now-a-days recurrent blast infection reported in BRRI dhan28. The specific objective of this study was to identify the evolution of new races of blast pathogen that may be responsible for recent blast outbreak in Bangladesh. Ten isolates have already isolated, the rest isolation and preservation of the pathogen is going on. Pathogenicity test against differential varieties harboring 23 blast resistance genes will be done very soon.

■ Khan, MAI, MR Bhuiyan, MM Rashid, TH Ansari, MA Latif, MA Ali and Y Fukuta

Identification of existing races/pathotypes of *Xanthomonas oryzae* pv. *oryzae* and study on its diversity during T. Aman 2017

An experiment was conducted to identify a standard differential set of isolates of *X. oryzae* pv. *oryzae* (*Xoo*) and to know the diversity of *X. oryzae* pv. *oryzae* through morphological and genetical studies. Virulence diversity based on 13 NILs and 14 pyramid lines, the isolates of *Xoo* were polymorphic for virulence on 13 NILs. Six isolates were shown virulent to all these resistant (*R*) genes tested in this study. The results showed that 12 *Xoo* pathotypes/races were existed in Bangladesh. The genes *Xa1, Xa2, Xa3, Xa4, Xa7, Xa10, Xa11* and *Xa14* did not show any resistant reactions against any of the isolates tested. The *R* genes *xa5, Xa8, xa13*, *Xa21* and *Xa23* showed 9 to 95% resistance frequency among the isolates. Only *Xa21* gene showed resistant reactions (95%) to maximum isolates.

■ MM Rashid, MA Latif, HA Dilzahan, MAI Khan and MR Bhuiyan

Identification of potential bio-control agents and formulations of bio-pesticides against bakanae disease

Forty bio-controlling bacteria, six *Trichoderma spp,* and four plant active ingredients (neem seed, neem leaf, mehogoni seed and dodder plant extraction in ethanol) have been identified to inhibit mycelial growth of bakanae causing pathogen. Among the tested plant products, neem leaf, mehogoni seed and dodder plant extraction in ethanol completely (100%) inhibited the mycelial growth of the pathogen. Identified bio-control agents will be confirmed following molecular method for documentation and future use. Furthermore, isolated active ingredient materials from plant products will be tested singly or in combination with bio-control agents to find out effectiveness against bakanae disease in field condition. Thus, effective plant active ingredients will be identified and used to formulate bio-pesticide single or in accordance with the effective bio-control agent/s.

■ QSA Jahan

Effect of drought tolerant microbes (*Pseudomonas* spp and *Trichoderma* spp.) on drought response of rice

Two drought tolerant varieties (BRRI dhan56 and BRRI dhan71) were collected from GRS Division, BRRI HQ, Gazipur and a drought susceptible check variety IR64 was collected from Plant Pathology Division, BRRI, Gazipur in T. Aman 2017. At the same time five *Trichoderma* isolates (T_1, T_2, T_3, T_4 and T_5) were isolated from different soil samples of Gazipur district. Five isolates of *Trichoderma spp* along with control were tested in each drought treatment for their ability to enhance drought tolerance in rice plants. Before planting the treated seeds with five isolates were prepared according to

IRRI guidelines. Ten plants per pot were maintained for each treatment combinations including control. Moisture was maintained by applying 100 ml of water per pot every alternate day until plants attained the age of five weeks and at this point drought treatments were given by altering the water cycle. Watering was stopped for subsequent days for each drought treatment, which included 4, 7, 10 and 13 days drought stress (DDS), while control seedlings were continued to watering every alternate day. Subsequent to drought treatment application, observations were recorded on wilting and physiological responses of rice plants. After 13 days of water stress it was found that *Trichoderma* spp was variety specific in terms of drought tolerant activity. In variety IR64 (drought susceptible), T_1, T_3 and T_5 yielded good result after 13 days water stress compared to control (non inoculated with any *Trichoderma* spp). At the same time T_3 and T_5 showed very good tolerant activity in variety 56 whereas, T_1 and T_3 performed well in variety BRRI dhan71. From this trial, it was observed that T_3 is the unique *Trichoderma* spp for all the tested three varieties for performing good drought tolerant activity. For confirmation of result the trial will be evaluated further.

■ QSA Jahan and MA Latif

DISEASE RESISTANCE AND MARKER ASSISTED SELECTION STUDIES

Gene pyramiding for bacterial blight (BB) resistance (BAS project)

In this study, BRRI dhan28, BRRI dhan29, CN6 and BRRI dhan58 were used as recipient parents. IRBB57, IRBB58, IRBB60, IR64 (*Pi9*), US2 (*Pb1*), STRASA 3 and STRASA 4 were used as donor parents. Phenotyping and genotyping were applied for suitable plant selection. Table 2 presents the result. Pathogenicity results showed that a number of progenies of BC_2F_1 and BC_1F_1 developed from the crosses were resistant to the most virulent BB isolate BXO9.

■ M A Latif, M K Hassan, A K M S Islam, M A I Khan

Screening of rice germplasm against blast disease (KGF Project)

The objective was to find out new sources of resistance of blast from upland rice and zoom rice. Fifty upland and 100 zoom rice were screened out and only eight upland genotypes and 35 jhum rice showed resistant reaction. Artificial inoculation was done in the control condition. Data were taken after 10 days of inoculation. Suceptible check US2 and LTH showed highly sensitive reaction and scored 5 (JIRCAS scoring system). The resistant germplasm showed 0-1 score. Genotyping of phenotypically resistant jhum rice germplasm were done through marker assisted selection (MAS). Among the identified resistant materials, two materials were amplified with the gene based marker pBA14 and pBA8 (Fig. 5).

Rain fed low land native germplasm was screened during Boro season in the blast screening hub (field), BRRI, Gazipur. Fifty rice germplasm were screened in the replicated plots. Mixed isolates were used for inoculation. Artificial inoculation was done in the screening plots. All the susceptible checks in the border lines and separate rows inside the testing materials showed highly susceptible reaction and scored 4-5. Data were taken at 15 days

Table 2. Development of BB resistant materials from the crosses of BRRI varieties and bacterial blight resistant pyramid lines of IR24.

Recipient/Recurrent	Donor		Present status
	Designation	Target *R* gene	
BRRI dhan29	IRBB57	*Xa4, xa5, Xa21*	21 seeds of BC_2F_1
BRRI dhan29	IRBB58	*Xa4, xa13, Xa21*	29 seeds of BC_3F_1
CN6	IRBB60	*Xa4, xa5, xa13, Xa21*	109 seeds of BC_2F_1
BRRI dhan28	IRBB57	*Xa4, xa5, Xa21*	27 seeds of BC_1F_1
BRRI dhan28	IRBB60	*Xa4, xa5, xa13, Xa21*	82 seeds of F_1
BRRI dhan28	IRBB58	*Xa4, xa13, Xa21*	6 seeds of F_1
BRRI dhan28	ST3	*xa13, Xa2, Xa23*	99 seeds of F_1
BRRI dhan28	ST4	*xa13, Xa2, Xa23*	4 seeds of F_1
BRRI dhan29	ST4	*xa13, Xa2, Xa23*	5 seeds of F_1
BRRI dhan58	ST3	*xa13, Xa2, Xa23*	85 seeds of F_1

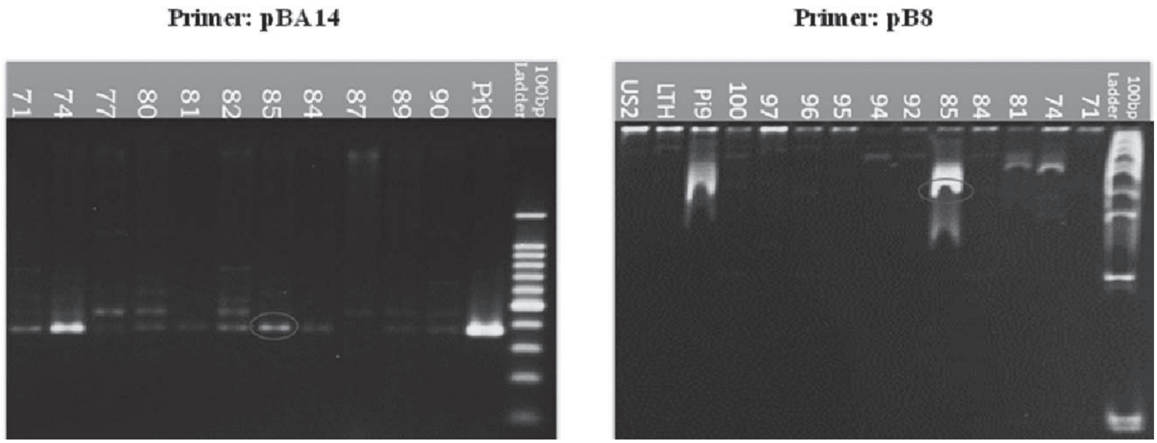


Fig. 5. Identification of *Pi9* gene in zoom rice by molecular markers.

after inoculation. Among the tested materials, four were detected as resistant (score 0-1), which will be tested further and to be confirmed.

■ M Tuhina-Khatun, M Ahmed, TH Ansari

Evaluation of advanced breeding lines against blast disease

An investigation was carried out in rice blast nursery of Plant Pathology Division to identify resistant genotypes against blast disease. Two hundred and thirteen advanced breeding lines along with standard susceptible check (US2) and resistant check BRRI dhan33 were screened against blast (P*yricularia oryzae*) pathogen. Twenty-one-day-old seedlings were used as test materials. Spore suspension of virulent isolate maintaining @ 10^5 spores/ml were used for inoculation. The inoculated plants were incubated for 24 hrs in dew chamber. Data were recorded at seven days after inoculation following SES, IRRI (0-9 scale). In T. Aman, 136 advanced breeding lines along with check materials were screened to identify the resistance sources against blast disease (*Pyricularia oryzae*). Three entries such as IR10F102, BR9043-11-3-2-2 and IR95817-51-1-1 showed moderate resistance to blast. Again, in Boro season, out of 84 materials, five such as IR99056-B-B-15, IR101762-1-1-1, IR83484-3B-7-1-1-1, IR87870-6-1-1-1-1-B, and BR8339-6-2-5-2 showed moderate resistance to blast disease.

■ MR Bhuiyan, R Akter, HA Dilzahan, MAI Khan, TH Ansari, MA Latif

Development of pre-breeding materials of tungro resistance

To introgress tungro resistant gene in high yielding variety, parent materials were grown during Aman and Boro season of 2017-18. Five set of parents with seven days interval were grown for the synchronization of flowering among the parents. Seeding was starting from 14 July 2017 in Aman season and for Boro season it was starting from 6 December 2017. In T. Aman, six crosses were made whereas in Boro season six crosses were made among the parents. Heterozygosity of the populations was confirmed through using respective marker. After confirmation crossing was done to make next generation (Tables 3 and 4).

■ SAI Nihad, MA Latif, TH Ansari and QSA Jahan

Linkage and QTL mapping of tungro resistance in rice (KGF Project)

To identify QTLs with linked marker for tungro resistance in rice landrace Kumragoir; three sets of parents (Kumragoir and BRRI dhan48) were planted with seven days interval for flowering synchronization for hybridization. After successful crosses, F_1 and consecutively BC_1F_1 seeds were produced. A total of 250 SSR primers were surveyed and 84 primers (Fig. 6) were found polymorphic between two parents. GLH was collected from the rice field of BRRI and reared in a cage (80 cm × 45 cm × 45 cm) for virus acquisition and transmission. Tungro virus particles (RTBV and RTSV) were detected through using molecular marker.

■ MA Latif, SAI Nihad and MA Rahman

Table 3. List of crosses and number of seeds for respective cross (Aman 2017).

Generation	Cross	No. of seed
BC3F1	BRRI dhan48*Matatag-1	47
BC3F1	BRRI dhan48*IR69705-1-1-1-4-2	49
BC3F1	BRRI dhan71*TW-16	67
BC1F1	Swarna* Matatag-1	72
F1	BRRI dhan71*Sonahidmota	12
F1	BRRI dhan71*Shadamota	9

Table 4. List of crosses and number of seeds for respective cross (Boro 2017-2018).

Generation	Cross	No. of seed
BC4F1	BRRI dhan48*Matatag-1	52
BC4F1	BRRI dhan48*IR69705-1-1-1-4-2	24
BC4F1	BRRI dhan71*TW-16	62
BC2F1	Swarna*Matatag-1	7
BC1F1	BRRI dhan71*Sonahidmota	11
BC1F1	BRRI dhan71*Shadamota	10

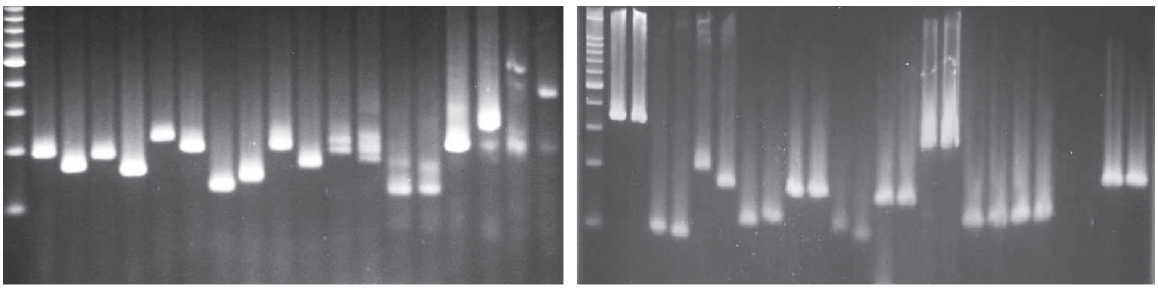


Fig. 6. Primer survey for finding polymorphic primers between Kumragoir and BRRI dhan48.

Development of blast resistant varieties using differential system and molecular markers

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 with the collaboration of JIRCAS, Japan in 2014. Different sources of *Pi9*, *Piz-t*, *Pish*, *pi21* and *Pb1* were used as donor. Around 200 plants of BC2F2 population of each cross, were cultivated in Boro 2017-18 season at BRRI farm, Gazipur. Plant selections using linked marker have already completed at the laboratory of Plant Pathology Division, BRRI, Gazipur. Around 20 plants from each cross harboring target locus were able to select by marker. The selected materials will be advanced up to BC2F6 by modified RGA system.

■ Khan, MAI, MR Bhuiyan, MM Rashid, TH Ansari, MA Latif, MA Ali and Y Fukuta

Evaluation of blast resistant *Pi9* gene derived line at blast hot spot

Blast resistant *Pi9* gene derived line were evaluated at seven blast hot spots [Nilphamari (2), Kurigram, Bogura, Satkhira, Khulna (2)] of Bangladesh in Boro 2017-18. There were no blast infection in *Pi9* gene derived line whereas adjacent plot of BRRI dhan28 was affected severely by neck blast disease. The growth duration and yield performance of *Pi9* derived line and BRRI dhan28 were 142-145 days and 5.8 to 6.1 t/ha respectively. Farmers preferred this line by seeing its good phenotypic appearance and yield performance.

■ Khan, MAI, MR Bhuiyan, MM Rashid, TA Ansari, MA Latif, MA Ali and Y Fukuta

Purification of Jira by pure line selection

Three Jira cultivar were collected from Jashore, Rajshahi and Bogura and cultivated it in BRRI farm, Gazipur following head to row method. The purified seeds named HR(Path)-Jira-Rajshahi, HR(Path)-Jira-Bogura and HR(Path)-Jirashail-Jashore were handed over to the GRS Division, BRRI, Gazipur for necessary action.

■ Khan, MAI, MR Bhuiyan, MM Rashid, TA Ansari, MA Latif, MA Ali and Y Fukuta

Screening of INGER materials against blast disease

A total of 150 INGER materials were screened against three differential blast isolates. Among them five materials were found resistant. These materials are needed to confirm again in blast nursery where natural blast infection occurs regularly.

■ Khan, MAI, M Khatun, MR Bhuiyan, MM Rashid, TH Ansari and MA Latif

Screening of rice germplasm and breeding lines against bacterial blight (BB) disease during T. Aman 2017

A total of 331 materials (150 rice germplasm, four Biotech advaced breeding lines, 20 PYT, 10 SYT, 13 PQR (ALART), 52 RYT, 55 OT, six ZER, one ALART, three resistant check and 17 susceptible checks) were screened against bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) pathogen. The experiment was conducted under field conditions using artificial inoculation during T. Aman 2017 season. Among the 150 tested germplasm, none of the materials was found resistant to BB. However, four resistant (BR9138-4-4-5-5-P2, BR9138-4-4-5-5-P3, BR7959-10-1-1, BR8545-5-5-2-7-2), 23 moderately resistant materials were obtained from 161 breeding materials against BB. The resistant checks were also showed resistant to BB. The highly resistant to resistant materials further need to confirm in the next season by artificial inoculation. It is suggested that highly resistant to resistant materials are recommended for further breeding programme.

■ MM Rashid, T Ferdous, MA Latif and M Khalequzzaman

Screening of INGER materials against Bacterial blight disease of rice during T. Aman 2017

A total of 136 materials (101-168 and 201-268) including two resistant (IRBB60, IRBB65) and two susceptible checks (BR11, BRRI dhan49) were tested against BB. The experiment was conducted under field condition using artificial inoculation during T. Aman 2017 season. A total of 12 INGER materials showed resistant reaction against major BB isolates tested in this study. The resistant checks also showed resistant to BB and susceptible checks were also showed highly susceptible reaction.

■ MM Rashid, T Ferdous, A Ara, MA Latif, MAI Khan and MR Bhuiyan

Evaluation of pre-breeding materials against bacterial blight (BB) disease of rice during Aus and Aman 2017

During Aus 2017 season 28 genotypes showed highly resistant and 67 genotypes exhibited resistant reaction against the virulent *Xoo* isolates among the 102 tested rice genotypes. In T. Aman 2017 season, 102 rice genotypes were again evaluated using two major virulent *Xoo* isolates. Twelve genotypes showed highly resistant and 48 showed resistant reaction against the *Xoo* isolates. This variation in disease reaction might be due to seasonal variation of the isolates. Because the isolates used in this study during both seasons were collected from the BB diseased samples of T. Aman season. The resistant checks were also showed resistant to BB and susceptible checks

Table 5. Number of F_1 seeds produced from crossing between different parents and backcrossing.

Recurrent parents	Gene introgressed	Progeny	No. of seed
BRRI dhan28	*Pi9*	BC_4F_1	159
	Pi40	BC_4F_1	89
	Pish	BC_1F_1	5
	Pita2	BC_1F_1	19
BRRI dhan29	*Pi9*	BC_1F_1	206
	Pi40	BC_1F_1	12
	Pita2	BC_4F_1	149
BRRI dhan63	*Pi40*	BC_1F_1	42
	Pita2	BC_4F_1	274

were also showed highly susceptible reaction. It is suggested that highly resistant to resistant materials showed in the T. Aman season are recommended for further breeding program.

■ MM Rashid, MA Latif, MAI Khan and MR Bhuiyan

Introgression of blast resistant genes into Boro rice

Introgression of monogenic resistant gene *Pi9, Pita2, Pi40* and *Pish* was done in the background of BRRI dhan28, BRRI dhan29 and BRRI dhan63. Seeds produced in different crossing, and backcrossing generations are mentioned in the following Table 5 during T. Aman 2017.

BC_3F_4 generation. A total of 13 BC_3F_3 plants with *Pi9* allele were selected from the cross between BRRI dhan28 and IRBL-9W in T. Aman 2017 season. These materials have grown again in Boro 2017-18 and BC_3F_4 materials selected. BC_3F_3 plants were selected from a cross/backcross between BRRI dhan63 and *Pita2* in the last T. Aman season. The selected plants will be grown in T. Aman 2018.

■ TH Ansari, M Ahmed, M Tuhina-Khatun, MAI Khan, MS Rahman and MA Raman

Introgression of blast resistant gene into BRRI dhan47

For the development of blast resistant variety, a cross was made between blast susceptible BRRI dhan47 and resistant variety harboring *Pi9* gene. A total of 30 homozygous and 37 heterozygous BC_3F_2 plants having *Pi40* gene were found through marker assisted selection.

■ MT Islam, MA Latif and MA Ali

Table 6. List of crosses and number of seeds for respective cross (Aman 2017).

Generation	Cross	No. of seed
F_1	BRRI dhan29*IRBB58	382
F_1	BRRI dhan29**Pi9* (US)	104
F_1	BRRI dhan29**Pi9* (IR64)	56
F_1	BRRI dhan29* *Pb1* (US)	153

Table 7. List of backcrosses and number of seeds for respective cross (Boro 2017-18).

Generation	Cross	No. of seed
BC_1F_1	BRRI dhan29*IRBB58	304
BC_1F_1	BRRI dhan29*Pi9 (US)	178
BC_1F_1	BRRI dhan29*Pi9 (IR64)	22
BC_1F_1	BRRI Dhan29* Pb1 (US)	148

Screening of rice germplasms against bakanae disease

A total of 80 germplasms were screened against bakanae disease. Three accessions (ACC 562, 621, 652) were found resistant.

■ QSA Jahan

Gene pyramiding of bacterial blight and blast resistance genes into the genetic background of BRRI dhan29

To introgress bacterial blight (BB) and blast resistant genes in high yielding variety; parent materials were grown during Aman 2017 and Boro 2017-18. Four set of parents with seven days interval were grown for the synchronization of flowering among the parents. Seeding was done starting from 14 July 2017 in Aman season and for Boro season it was from 17 December 2017. In Aman 2017 four crosses were made to obtain F_1 seeds whereas in Boro season four backcrosses were made among the parents (Tables 6 and 7). Heterozygosity of the populations was confirmed through using respective marker. After confirmation crossing was done to make next generation.

■ A K M S Islam, M A Latif, M L Hassan

Table 8. List of crosses and number of seeds for respective cross, Aman 2017.

Generation	Cross	No. of seed
F_1	BRRI dhan28*IRBB58	15
F_1	BRRI dhan28*IRBB65	16
F_1	BRRI dhan28*Pi9 (US)	9
F_1	BRRI dhan28*Pi9 (IR64)	12
F_1	BRRI dhan28*Pb1	11
F_1	BRRI dhan58* Pi9 (US)	23
F_1	BRRI dhan58* Pi9 (IR64)	29
F_1	BRRI dhan58* Pb1	27
	Total	142

Table 9. List of backcrosses and number of seeds for respective cross, Boro 2017-18.

Generation	Cross	No. of seed
BC_1F_1	BRRI dhan28*IRBB58	42
BC_1F_1	BRRI dhan28*IRBB65	10
BC_1F_1	BRRI dhan28*Pi9 (US)	14
BC_1F_1	BRRI dhan28*Pi9 (IR64)	32
BC_1F_1	BRRI dhan28*Pb1	10
BC_1F_1	BRRI dhan58* Pi9 (US)	25
BC_1F_1	BRRI dhan58* Pi9 (IR64)	26
BC_1F_1	BRRI dhan58* Pb1	32
	Total	191

Improvement of BRRI dhan28 and BRRI dhan58 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 Aman 2017 and Boro 2017-18 (Tables 8 and 9). Four set of parents with seven-days interval were grown for the synchronization of flowering among the parents. Seeding was starting from 14 July 2017 in Aman season and for Boro season it was starting from 17 December 2017. In Aman 2017, crosses were made to obtain F1 seeds whereas in Boro season backcrosses were made among the parents. Heterozygosity of the populations was confirmed through using respective marker. A total of 142 F1 seeds as well as 191 BC1F1 seeds were obtained from different crosses, and further crossing will be carried out to make next generation.

■ MR Bhuyian, A K M S Islam, M A I Khan, M A Latif

DISEASE MANAGEMENT

Evaluation of new chemicals against blast disease

An experiment was conducted at BRRI west byde farm, Gazipur and BRRI RS, Barishal under natural condition to find out effective chemicals against rice blast disease. Susceptible variety BRRI dhan34 was used as test variety. Twenty-three new fungicides were tested with one standard check (Trooper) and one diseased control treatment. Artificial inoculation was done at 28 days after seeding. Among the 15 fungicides, only three i.e Royal 75WDG, Tebuplus75, and Mcvo75 were successfully controlled rice blast disease (above 80%) in 2017.

■ MR Bhuiyan, M Hossain, MAI Khan, T H Ansari and MA Latif

Evaluation of fungicides against rice seedling blight during Boro 2017-18 (NATP 2)

The experiment was conducted to find out effective chemicals against the disease rice seedling blight. Naturally tray seedlings are affected severely during seedling raisng in Boro season. Twelve fungicides were tested as seed treating fungicides with standard check (Amister Top). Seeds were treated firs, sown and grown until 26 days after sowing following standard protocol as followed/suggested by Plant Pathology Division, BRRI. Disease incidence and seedling characters were investigated. Six fungicides were found effective to control seedling blight.

■ T H Ansari, M Ahmed and MA Monsur

Judicial application of selected fungicides for neck blast disease management

To find out the neck blast disease efficiently and economically, two selected fungicides Nativo and Trooper were applied in two growth stages of rice plant such as booting and flowering with the recommended doses of 0.6 and 0.8 g/L water, respectively. BRRI dhan34, a popular aromatic rice variety but susceptible to blast, was used as test variety. This experiment was conducted in farmers' field of Jashore, Khulna, Rangpur and Barishal as well as in experimental plots of BRRI, Gazipur. Results suggested that application of Trooper at the initial stage of flowering is the best way of neck blast disease management (91.3% disease reduction) followed by Nativo application at booting stage (83.5% disease reduction). Application of Trooper in booting stage also inhibited neck blast disease, but at later stage disease was appeared at the base of panicle that did not affect grain yield significantly.

■ Mohammad Ashik Iqbal Khan, Md Rejwan Bhuiyan, Md Mamunur Rashid and M A Latif

Evaluation of silver nano-particles against bacterial blight disease

To evaluate the silver nano particle against BB disease, commercial formulation (MONOSI Harbal) was applied for both preventive and curative measurers on BRRI dhan28. Effect on grain filling was also evaluated. Due to low disease pressure in both control and inoculated plots, effects of silver nano particle on BB disease management could not be determined. Moreover, in *in vitro* condition, we did not find any growth suppressive effect of commercial formulation of Ag nano particle (MONOSI Harbal) up to 1000 ppm concentration.

This study suggested that pure nano particles should be tested first against rice pathogen in *in vitro* condition.

■ Mohammad Ashik Iqbal Khan, Rumana Akhter, Md Asaduzzaman, Md Mostak, Md Rejwan Bhuiyan, Md. Mamunur Rashid and M A Latif

Management of sheath blight disease utilizing *Trichoderma harzianum*

Compost was prepared in T. Aus 2017 in net house; Plant Pathology Division, BRRI, Gazipur. Culture of *Trichoderma* spp was grown in grided corn seeds in laboratory condition. The culture was mixed with dry water hyacinth, cow dung, and urea solution. Water hyacinth and cow dung were dried under intense sunlight for seven days (42 hours). The composting materials were placed in layers in a pit (1m × 1m ×1m) in ratio of water hyacinth: Cow dung: *Trichoderma* inoculum: 3: 1: 0.25. Urea solution (10%) was used for rapid decomposing. The pit was covered with polythene sheet to avoid excessive rain water. Water was sprayed with sprinkler in every week up to four weeks and inverted the composting mixtures for better decomposition. The composting materials were covered with polythene sheet and locked the outer side of the polythene sheet with mud until compost prepared to use. The compost was prepared within 6-7 weeks. After compost preparation, it was used in farmers' fields in variety BRRI dhan70 to find the efficacy of this compost in reducing sheath blight disease. A total of six treatments–T_1 (75% RDF + 25% poultry litre), T_2 (RDF with DAP), T_3 (RDF with Trichocompost), T_4 (75% RDF + 25% vermicompost), T_5 (RDF) and T_6 (Control without fertilizer) were set up at the same time adjacent to the compost trial for comparison. All six treatments were replicated thrice in RCB design. Data were collected on % RLH and yield (t/ha) in treated plots versus in farmers practice plots. Among the treatments T_3 (RDF with Trichocompost) and T_4 (75% RDF + 25% vermicompost) positively reduced % RLH whereas other treatments increased % RLH. Yield was also increased higher at Trichocompost treated plots due to % RLH reduction and addition of nutrients.

■ QSA Jahan, KA Bhuiyan and MA Latif

TECHNOLOGY DISSEMINATION

Integrated management of blast disease for enhancing rice production in relation to climate change

A series of activities including field demonstrations, training, field day, distribution of leaflets and workshop were performed to increase skill and awareness of farmers, pesticide dealers, sub assistant agriculture officer (SAAO) and other extension personnel on 'Rice blast disease and its management'. A total of 37 field demonstrations were conducted in blast prone areas of Gazipur, Rangpur, Dinajpur, Mymensingh, Cumilla and Khulna regions in Boro 2017-18, where BRRI recommended integrated blast management practice reduced approximately 76.13% blast disease compared to farmer's practice which resulted around 22.72% yield increased. A total of 15 batches of training were successfully completed in six different regions of Bangladesh where 308 farmers, 77 pesticide dealers and 105 SAAO acquired knowledge on rice blast disease and its management at field level. Five field-days on rice blast disease and its management were conducted at five different regions of Bangladesh in Boro 2017-18 where 500 farmers as well as SAAOs of the respective upazila, agricultural extension officer, upazila agriculture officer, deputy director of the district and scientists were present in the occasion. A regional workshop on rice blast disease in aromatic rice and its management was held in BRRI RS, Rajshahi. Around 100 participants including farmers, SAAO, agricultural extension officer, upazila agriculture officer and deputy directors of the Rajshahi region attended the workshop. Moreover, 10,000 copies of leaflets on `Rice blast disease and its integrated management' were published with the financial assistance of the project, which were circulated among farmers with the help of DAE personnel those were aimed at creating awareness on rice blast disease and its successful management.

■ MR Bhuiyan, MM Rashid, M Tuhina-Khatun, B. Nessa, MA Monsur, MAI Khan, S Akter, MS Mian, QSA Jahan, T H Ansari and MA Latif

Rice Farming Systems Division

SUMMARY

Cropping pattern survey initiated in 2015 was completed in all upazilas of Bangladesh during 2016. A total of 316 cropping patterns along with their coverage were identified throughout the country. Boro-Fallow-T. Aman was the most dominant cropping pattern covering 27% of net cropped area. Top five cropping patterns were found exclusively rice based covering 51% of the net cropped area. Land use, cropping intensity, district wise distribution of most dominant cropping pattern and diversity index of crops and cropping patterns were also identified.

Fertilizer dose for T. Aman-Mustard-Boro cropping pattern was determined through omission plot technique. Individual crop-based recommended doses were higher than that of system-based recommendation for all the three tested crops.

An experiment on evaluation of establishment method of different crops of Mustard-Boro-T. Aman cropping pattern in medium highland ecosystem was initiated in Rabi 2016. After completion of first year experiment, no significant difference was observed in case of weed biomass and rice equivalent yield for establishment method or tillage system except water requirement of the pattern.

An on-farm trial was conducted to evaluate mulching material and mulching method on pit crop of sweet gourd in saline prone area. Mulching with rice straw increased the yield and economic return of sweet gourd.

Among the tested crops under different establishment methods sweet gourd established in pit performed better at Dacope, Khulna whereas dibbled sown sunflower was more profitable, which was followed by sweet gourd in Amtali, Barguna.

In some shallow flooded area, Aman rice is cultivated as relay crop with the preceding jute in Rabi-Jute-Aman (relay) cropping pattern. Some newly developed Aman rice varieties and fertilizer options were tested to improve the yield of the cropping pattern. BRRI dhan73 and BRRI dhan72 was as good as the check BRRI dhan39. Higher fertilizer dose produced more yield than the farmer's practice.

Two exotic date palm orchards were established to evaluate its performance as homestead agro forestry at BRRI HQ and Mujibnagar Complex, Meherpur. In 2017, dates were harvested for the first time from six plants. Intercropping of black gram with date palm gave an additional yield of 860 kg/ha.

On-farm trials of premium quality rice varieties under CSISA Phase III project was conducted in four farmers' fields in Chuadanga under Jashore Hub during T. Aman season 2017. Six varieties released by BRRI and BINA were evaluated in the farmers' field. BRRI dhan49 produced the highest yield (4.56 t/ha) followed by BRRI dhan75 (3.90 t/ha) under drought stress.

On-farm trial of integrated weed management options in transplanted Aman rice during T. Aman season 2017 was conducted in six farmers' fields in each of Faripur and Jashore Hub. Ten weed management options were evaluated to find out effective and economic weed management option. From this trial it was found that Mefecanet + Bensulfuron methyl followed by one mechanical weeding effectively controlled weeds and thereby reduced labour requirement and subsequently weeding costs.

SURVEY AND MONITORING

Survey on cropping patterns of Bangladesh

The climate and environment of Bangladesh are diversified. As a result lots of crops are cultivated in this country. In the arable land, crops are cultivated in annual sequence. The yearly sequence and spatial arrangement of crops or crops and seasonal fallow of a given area is known as cropping pattern (CP). CP indicates the proportion of areas under different crops in a given time. Climate, environment, resources and socioeconomic conditions determine the CP in an area. CP brings appropriate crops and management in appropriate space and time. Improved formation of CP helps boost sustainable agriculture production. CP allows increase in intensity and hence total production in a year as well. Thus identification of CPs with their scope of improvement by proper management is very important for sustainable improvement of agricultural production system. Information on CP in a locality as well as in national level plays a vital role in making policies. However, on this vital element of agriculture, information is not enough. Thus the present study was undertaken to investigate agricultural land use and CP createing data base on it across the whole country with a view to exploring the potential of CPs in future from these information. Specific objectives of the study were to:

Create database of existing cropping pattern in different regions of Bangladesh

Explore the scope of improvement of existing cropping pattern

The study was conducted following two steps.

1. Collection of secondary information, analysis of data and find out the mismatch of data, if any, among themselves and any query regarding the data.
2. Conduct stakeholder consultation workshop to verify and validate mismatch data with query and finalize data.

Data used in this study were collected from DAE. In the first step, secondary information of crops, their coverage from each upazila was collected from records of DAE by physically visiting DAE offices in each district. Another set of data on CP, their area coverage for the year, 2014 were also collected from each upazila through a semi-structured questionnaire filled up by Upazila Agriculture Officer. Those two sets of data were analyzed. After data analysis usually there were some mismatches among two sets of data and were also some information that needed further clarification. In the second step to purify and finalize those data and collect relevant other information, stakeholder consultation workshops were arranged in 64 districts separately. DD and district level all concern officers of DAE and from upazila level UAO, AEO, UAA, SAPPO, SAAO of respective upazila and team of investigators (researchers) attended the workshop. After discussion, the data were finalized. The whole study was conducted from August 2015 to November 2016, throughout the country. Thus the data used for final analysis were the overviewed data. The CP for the present study with its coverage means the proportion of areas under different CPs in each upazila in 2014.

Data analysis

Collected data were analyzed using Micro Soft Excel programme. Tally, addition, average and descriptive statistics were used for presentation of data. Based on these data, tables were constructed and discussed accordingly. Crop diversity index was calculated by using the following equation described by Kshirsagar *et al*. (1997).

$$CDI_i = 1 - \sum_{j=0}^{n} \left(\frac{a_{ij}}{A_i} \right)^2$$

Where, CDI_i: Crop diversity index

a_{ij}: Area planted to the jth crop in the ith location

A_i: Total area planted under all crops

The index is zero for a land area growing only one crop. It approaches unity as the level of diversity increases.

Many striking results were revealed when data were analyzed. District-wise common land use pattern of Bangladesh as represented by annual crop area, single cropped area (SCA), double cropped area (DCA), triple cropped area (TCA), quadruple cropped area (QCA), others, net cropped area (NCA) and cropping intensity (CI) related data were analyzed. DCA dominated in different districts in comparison to SCA or TCA except in Nrayanganj, Pirojpur, Sirajganj, Sunamganj, Tangail and Rangamati. Those districts have more low lying areas except Rangamati. Therefore, single Boro CP dominated in those districts. Whereas in Rangamati, single season *jhum* cultivation was dominated. QCA was extremely low in most of the districts. It was highest in Bogura followed by Naogoan and then Jashore. As QCA was very low, it contributed less to the CI. However, the region which had more TCA, consequently had greater CI. TCA was the highest in Bogura district followed by Naogoan and then Dinajpur. Bogura district had the highest CI followed by Kushtia, Laxmipur and Thakurgoan districts. The lowest CI was found in Sunamganj followed by Rangamati and Gopalganj. Sunamganj and Gopalganj are *haor* and low lying areas where scope of crop cultivation is only possible in Rabi season and in Rangamati, a hilly region, only *jhum* crops are grown in one season. AC production was the highest in Tangail, which was followed by Natore and then Rangamati. These districts produced more banana, papaya, turmeric, ginger etc. NCA of the country was more than eight million hectares. Mymensingh had the highest NCA followed by Dinajpur and Naogoan. Increased NCA might be because of increased geographical area of the districts and increased arable areas as well. The country's average indicated that DCA was more than the sum of AC, SCA, TCA and QCA and more than twice of the SCA or TCA, separately. QCA was quite negligible which was 0.22% of the NCA. The average CI was 200%.

In Bangladesh 316 CPs were found excluding the very minor ones. Boro-Fallow-T. Aman was the most dominant CP that occupied 26.92% of the NCA. Whereas the last CP was the Barley-Fallow-Fallow occupied only 0.0002% of the NCA. There had been many more CPs, with quite low coverage were not considered in the list. Those CPs were kept in 'Other' category where only summation of all of their coverage was considered. The most dominant CP, Boro-Fallow-T. Aman occupied 26.92% of NCA of Bangladesh. That CP occupied significantly higher percentage of NCA than that of its next following CP, Boro-Fallow-Fallow which occupied less than half of the percentage of NCA of Boro-Fallow-T. Aman. The next three CPs were Fallow-Fallow-T. Aman, Boro-Aus-T. Aman and Fallow-Aus-T. Aman respectively. Those five CPs occupied 50.86% of the NCA. Interestingly, the results unveiled that no other crop than rice was included in the top five CPs. It indicates the overwhelming domination of rice culture in Bangladesh. All other CPs including 'Other' category, that could be few hundreds, constituted the rest 49% of NCA. The most dominant CP, Boro-Fallow-T. Aman was present in 426 upazilas out of 486 upazilas. It was found that higher the percentage of NCA occupied by a CP greater the presence of the CP in different upazilas.

If a single one CP is considered, its geographical distribution also produce valuable information. Table 1 presents district-wise distribution of the most dominant CP, Boro-Fallow-T. Aman. This CP generally occupies medium high land area. Maximum area under this CP was in Mymensingh district was 1,88,650 hectares of land which was followed by Dinajpur district with 1,38,400

Table 1. Distribution of the most dominant Boro-Fallow-T. Aman cropping pattern and area coverage in Bangladesh, 2014-15.

District	Area (ha)	% of district NCA	% coverage of the pattern in the country
Mymensingh	188650	65.13	8.18
Dinajpur	138400	49.99	6.00
Netrakona	98300	49.22	4.26
Gaibandha	96670	63.87	4.19
Naogaon	96400	35.59	4.18
Tangail	84000	36.04	3.64
Kurigram	83500	55.91	3.62
Rangpur	81300	46.39	3.53
Jashore	80700	42.48	3.50
Bogura	80200	36.10	3.48
Jamalpur	75300	46.83	3.27
Sherpur	69000	68.62	2.99
Nilphamari	65300	53.70	2.83
Jhenaidaha	54900	39.26	2.38
Chattogram	46420	23.19	2.01
Thakurgaon	45050	30.36	1.95
Lalmonirhat	44600	45.12	1.93
Sunamganj	43100	16.12	1.87
CoxBazar	42400	49.66	1.84
Satkhira	40950	33.72	1.78
Kishoreganj	40300	20.17	1.75
Cumilla	38710	18.71	1.68

Table 1. Continued.

District	Area (ha)	% of district NCA	% coverage of the pattern in the country
Sirajganj	38200	20.82	1.66
Bhola	35650	19.13	1.55
Sylhet	34200	16.27	1.48
B.Baria	34010	24.39	1.47
Panchagarh	32400	31.70	1.41
Narsingdi	31500	43.60	1.37
Barishal	31050	19.59	1.35
Chuadanga	28800	32.56	1.25
Feni	28800	40.04	1.25
Gazipur	27100	31.74	1.18
Natore	25490	18.85	1.11
Narail	24950	33.73	1.08
Maulvibazar	24650	19.34	1.07
Rajshahi	22400	13.40	0.97
Magura	20800	27.44	0.90
Lakshmipur	20200	20.22	0.88
Khulna	19870	15.64	0.86
Bagerhat	19600	17.26	0.85
Joypurhat	19200	24.46	0.83
Habiganj	19070	11.32	0.83
Kushtia	17900	15.60	0.78
Chandpur	14690	15.97	0.64
Chapainawabganj	14100	11.71	0.61
Noakhali	12460	6.28	0.54
Meherpur	9800	18.12	0.42
Khagrachhari	9570	21.59	0.42
Pabna	8650	4.69	0.38
Pirojpur	6540	7.95	0.28
Faridpur	6080	4.34	0.26
Jhalakati	5450	10.50	0.24
Rajbari	5450	7.17	0.24
Bandarban	5170	12.69	0.22
Rangamati	4660	10.67	0.20
Gopalganj	2900	2.56	0.13
Narayanganj	2200	5.54	0.10
Dhaka	2040	2.99	0.09
Madaripur	1800	2.16	0.08
Patuakhali	1670	0.79	0.07
Shariatpur	1455	1.87	0.06
Manikganj	980	1.05	0.04
Barguna	350	0.35	0.02
Bangladesh	2306005	26.92	100.00

hectares of land. This CP was practiced in 63 districts. However, in Munshiganj, there was no Boro-Fallow-T. Aman CP. Because, T. Aman was extremely rare in that district. The lowest area under this CP was in Borguna. In Mymensingh, this CP occupied about 65.13% of its NCA. In Mymensingh, the area under this CP was 8.18% of its total area of the country.

Table 2 presents district-wise total number of CPs, total number of crops, diversity index of CPs and crops. Cumilla had the highest number of CPs of 117 which was followed by Kushtia of 116 and then Jashore 101. The maximum number of 30 crops was cultivated in Munshiganj which was followed by the four districts viz, Cumilla, Faridpur, Manikganj and Noakhali each of which cultivated 28 crops. Pabna had the highest CP diversity followed by Rajshahi and then Kushtia.

To explore the potential of CPs, it is necessary to integrate the available technologies into it to increase the total yield. Identification of major CPs and exploring their potential is important. Increasing production through utilizing fallow period in CP can create scope for sustainable improvement of agricultural production system. This study gives us better opportunity to explore these areas.

■ SM Shahidullah, MA Muttaleb, M Ibrahim, A Khatun, MH Rashid, MR Dewan, MK Quais, S Pramanik, N Parvin, ABMJ Islam, MA Zaman, BJ Shirazy, ABM Mostafizur, M Nasim and A Saha

DEVELOPMENT OF FARMING SYSTEMS (CROPPING SYSTEM) AND COMPONENT TECHNOLOGIES FOR DIFFERENT ECOSYSTEMS

Determination of fertilizer dose for Mustard-Boro-T. Aman cropping pattern

The experiment was conducted at the BRRI experimental farm, Gazipur during T. Aman 2017 to Boro 2018 with the inclusion of mustard in the

Table 2. Crop and cropping pattern diversity and cropping intensity of different districts in Bangladesh, 2014-15.

District	No. of identified cropping pattern	No. of crop	Diversity index for cropping pattern	Crop diversity index	C.I. (%)
B.Baria	62	18	0.757	0.883	165
Bagerhat	53	20	0.848	0.921	161
Bandarban	49	24	0.953	0.963	138
Barguna	29	17	0.868	0.939	218
Barishal	74	20	0.911	0.955	192
Bhola	61	25	0.933	0.972	228
Bogura	96	27	0.803	0.925	248
Chandpur	74	22	0.880	0.945	190
ChapaiN.ganj	62	18	0.944	0.975	217
Chattogram	63	25	0.826	0.924	180
Chuadanga	48	23	0.867	0.945	224
Cumilla	117	28	0.868	0.932	210
CoxBazar	44	22	0.725	0.856	197
Dhaka	67	25	0.889	0.937	196
Dinajpur	75	22	0.723	0.889	228
Faridpur	96	28	0.942	0.972	225
Feni	34	22	0.777	0.879	183
Gaibandha	52	23	0.583	0.807	210
Gazipur	47	26	0.801	0.880	161
Gopalganj	57	25	0.643	0.824	146
Habiganj	46	21	0.827	0.916	170
Jamalpur	77	22	0.762	0.898	220
Jashore	101	25	0.799	0.920	225
Jhalakati	40	21	0.891	0.944	189
Jhenaidaha	76	26	0.833	0.931	223
Joypurhat	45	19	0.697	0.879	267
Khagrachhari	47	23	0.900	0.929	151

Table 2. Continued.

District	No. of identified cropping pattern	No. of crop	Diversity index for cropping pattern	Crop diversity index	C.I. (%)
Khulna	52	21	0.839	0.922	159
Kishoreganj	91	21	0.694	0.852	156
Kurigram	78	25	0.673	0.854	214
Kushtia	116	26	0.955	0.982	240
Lakshmipur	44	21	0.878	0.945	240
Lalmonirhat	44	22	0.750	0.897	223
Madaripur	57	24	0.910	0.967	204
Magura	55	26	0.878	0.980	251
Manikganj	75	28	0.917	0.958	212
Maulvibazar	47	20	0.819	0.894	168
Meherpur	40	21	0.932	0.973	239
Munsiganj	38	30	0.835	0.915	177
Mymensingh	71	24	0.562	0.779	199
Naogaon	90	23	0.848	0.936	221
Narail	37	21	0.850	0.932	210
Narayanganj	45	27	0.800	0.906	158
Narsingdi	54	23	0.753	0.861	181
Natore	68	22	0.939	0.972	210
Netrokona	54	20	0.603	0.746	160
Nilphamari	59	21	0.695	0.875	224
Noakhali	49	28	0.892	0.953	178
Pabna	90	29	0.970	0.987	230
Panchagarh	65	24	0.862	0.938	216
Patuakhali	51	22	0.893	0.951	203
Pirojpur	50	24	0.858	0.930	162
Rajbari	50	26	0.937	0.971	234
Rajshahi	99	27	0.964	0.984	221
Rangamati	41	25	0.944	0.954	128
Rangpur	70	22	0.768	0.907	227
Satkhira	62	22	0.840	0.923	193
Shariatpur	72	25	0.905	0.963	178
Sherpur	44	20	0.522	0.785	213
Sirajganj	100	30	0.891	0.950	206
Sunamganj	52	24	0.506	0.656	123
Sylhet	38	21	0.820	0.894	151
Tangail	89	29	0.842	0.922	204
Thakurgaon	50	23	0.887	0.955	240
Bangladesh	315	48	0.896	0.952	200

transition period between T. Aman and Boro rice under T. Aman–Mustard–Boro cropping pattern to determine the fertilizer dose through omission plot technique. There were four treatments: i) NPK, ii) – N, iii) –P and iv) –K. The variety BRRI dhan57, BARI shorisha-14 and BRRI dhan28 were used for T. Aman rice, mustard and Boro rice respectively. Recommended management practices were followed for rice and non-rice crops. The results showed that the grain yields of T. Aman, mustard and Boro varied from 3.03 to 4.08 t/ha, 0.24 to 0.77 t/ha and 3.56 to 7.23 t/ha, respectively. The grain yields of all the tested crops were significantly influenced by the treatments. Cropping system based fertilizer recommendation (CSFR) for the tested crops have been calculated after completion of second year experiment. The required doses of N, P, K under CSFR for T. Aman, Mustard and Boro were 47.3, 2.71 and 24 kg/ha; 94, 22 and 36 kg/ha; and 116.2, 9.8 and 26.2 kg/ha, respectively whereas the individual crop based fertilizer recommended (ICFR) doses were 69, 10 and 41 kg/ha; 138, 36 and 50 kg/ha; and 119.6, 19.4 and 60 kg/ha respectively. Apparently the individual crop based recommended doses were higher compared to system based recommendation for all the tested crops under T. Aman-Mustard-Boro cropping systems. However, the experiment should be executed one more year for valid conclusion.

■ A Khatun

Evaluation of non-rice crop establishment methods for sustainable crop production in saline areas

A field experiment was conducted in two locations over two years (2016-17 and 2017-18) during Rabi season at Dacope, Khulna and Amtali, Barguna to evaluate the performance of selected crops under different crop establishment methods. In both the locations the experiment was carried out in a randomized complete block design with four replications. Sunflower, maize, sweet gourd and water melon were taken as experimental crops. Two establishment methods were considered viz (a) Dibbling for sunflower and maize and (b) Pit for sweet gourd and water melon. Fertilizers were applied as per recommendations. Pits were made properly for sweet gourd and water melon. Pit to pit and line to line distance was 2 m. Manure and basal dose of fertilizer was applied during pit preparation. Seedlings were prepared in the poly-bag and 16-20-day-old seedlings were transplanted in pit. Intercultural operations were done as and when necessary for all crops. Sunflower produced statistically similar yield (1.96-2.53 t/ha) over the year and locations. The highest maize yield (8.51 t/ha) was found at Dacope, Khulna. The yield difference was insignificant over the years at same location but significant over different locations. The average yield of maize was 8.46 t/ha and 7.62 t/ha in Dacope, Khulna and Amtali, Barguna respectively while the national average yield of maize is about 10 t/ha (BBS, 2017). The yield of sweet gourd also varied significantly over the locations in every year. The highest yield (13.5 t/ha) was found at Dacope, Khulna during 2017-18 (Table 5). The average yield of sweet gourd was 12.08 t/ha and 8.58 t/ha at Dacope, Khulna and Amtali, Barguna, respectively. Those yields were much lower than the national average yield (20-25 t/ha) of sweet gourd under recommended condition. The highest yield (7.53 t/ha) of watermelon was at Amtali, Barguna during 2017-18, which was also much lower than the national average (18-22 t/ha). Based on the maize equivalent yield (MEY) sweet gourd produced the

Table 3. Yields of T. Aman, Mustard and Boro under Mustard–Boro –T. Aman cropping system, BRRI, Gazipur, 2017–18.

Treatment	T. Aman		Mustard		Boro	
	Grain yield (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)	Stover yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)
NPK	4.08	5.86	0.77	2.01	7.23	8.60
– N	3.03	4.69	0.24	0.64	3.56	4.23
– P	3.91	5.60	0.61	1.49	6.79	7.64
– K	3.91	5.71	0.69	1.27	6.47	7.79
CV(%)	3.5	1.8	7.5	9.4	6.0	26.9
$LSD_{0.05}$	0.26	0.19	0.09	0.25	0.74	3.68
F-value for treatment	**	**	**	**	**	NS

**Significant at the 0.01 probability level.

Table 4. Cropping system based fertilizer recommendation for T. Aman, Mustard and Boro, BRRI, Gazipur, 2017-18.

Required nutrients (kg/ha)	T. Aman		Mustard		Boro	
	ICFR	CSFR	ICFR	CSFR	ICFR	CSFR
N	69	47.3	138	94	119.6	116.2
P	10	2.71	36	22	19.4	9.8
K	41	24	50	36	60	26.2

Table 5. Yield of different crops under different establishment methods at Dacope, Khulna and Amtali, Barguna during 2016-17 to 2017-18.

Year	Crop yield	Dibbled sunflower (T_1) Dacope	Amtali	Year wise avg. (t/ha)	Dibbled maize (T_2) Dacope	Amtali	Year wise avg. (t/ha)	Sweet gourd in pit (T_3) Dacope	Amtali	Year wise avg. (t/ha)	Water melon in pit (T_4) Dacope	Amtali	Year wise avg. (t/ha)
2016-17	Yield (t/ha)	2.31a	1.96a	2.13a	8.42a	7.54b	7.98a	10.66ab	8.3b	9.48a	4.33b	7.53a	5.93
	MEY*	7.24	6.14	6.67	8.42	7.54	7.98	8.53	7.19	7.86	5.77	10.03	7.90
2017-18	Yield (t/ha)	2.29a	2.53a	2.41a	8.51a	7.70b	8.12a	13.5a	8.86b	11.18a	5.39ab	4.12b	4.76
	MEY	7.18	7.92	7.55	8.51	7.70	8.12	10.8	7.67	9.24	7.18	5.49	6.34
Location wise avg. (t/ha)	Yield (t/ha)	2.30a	2.25a	2.28a	8.46a	7.62b	8.04a	12.08a	8.58b	10.33a	4.86a	5.82a	5.34
	MEY	7.20	7.04	7.12	8.46	7.62	8.04	9.66	7.43	8.55	6.48	7.76	7.12

Price :*Sunflower@ 47 Tk/kg, Maize@ 15 Tk/kg, Sweet gourd@ 12 Tk/kg, Watermelon@ 20 Tk/kg. *Maize equivalent yield (MEY).
* Lettering is done for individual crop yield not for MEY.

highest MEY (9.66 t/ha) followed by dibbled maize at Dacope (Table 5). The lowest MEY (6.48 t/ha) was observed at Dacope, Khulna for watermelon. Although the national average yield of sweet gourd and watermelon was higher than the experimental yields, but it should be mentioned here that sweet gourd and watermelon were cultivated under drought and salinity stress where the land remains fallow during Rabi season.

■ A B M Mostafizur, M Nasim and A Saha

Economic analysis

Economic analysis indicated that sweet gourd was the most profitable crop followed by sunflower at Dacope (Table 6). On the other hand, sunflower was the most profitable crop followed by sweet gourd at Amtali (Table 7).

Evaluation of different mulching techniques for pit crops under saline condition

An experiment was conducted to evaluate mulching material and mulching method for pit crops at Dacope, Khulna and Amtali, Barguna during Rabi season (2016-17 and 2017-18). The experiment was carried out in a randomized complete block design with four replications. Sweet gourd was taken as experimental crop. Five experimental treatments were considered viz, (a) No mulch (control), (b) Rice straw at the top of the pit, (c) Rice husk at the top of the pit (d) Rice straw at bottom and the top of the pit and (d) Mulching with polythene sheet. Manure and basal dose of fertilizer was applied during pit preparation. Pit to pit and line to line distance was 2m. Seeds were sown in the poly-bag and 16-20-day-old seedlings were transplanted in pit. Necessary intercultural operations were done as and when necessary. The yield of sweet gourd varied significantly for different mulch materials over the years and locations. During 2016-17, mulching with rice straw and mulching with rice husk produced significantly higher yield (13.47 t/ha and 13.05 t/ha, respectively) over all other treatments at Dacope, Khulna (Table 8). Location-wise average yield indicates that when rice straw was used as mulch material at the bottom and above the pit then sweet gourd produced significantly higher yield than the other treatments.

Although the national average yield of sweet gourd is higher, it is remarkable that sweet gourd was cultivated under salinity and water stress conditions, where the land remains fallow during Rabi season. Mulching with rice straw treatment was the most profitable followed by mulching with rice straw at bottom and above the pit at Dacope (Table 9). On the other hand, mulching with rice straw at bottom and above the pit treatment was the most profitable at Amtali, Barguna (Table 10).

Improvement of relay cropping of Aman with jute in Rabi-Jute-Relay Aman cropping pattern in flood prone ecosystem

Major jute growing cropping pattern in Bangladesh is Rabi-Jute-T. Aman. However in the flood prone

Table 6. Economics of dry season crops at Dacope, Khulna, 2016-17 to 2017-18.

Crop	Total cost (Tk)	Total paid-out cost (Tk)	Imputed cost (Tk)	Gross benefit (Tk)	Gross income (Tk)	Net income (Tk)
Sunflower	97,858	79,414	18,444	108,775	29,361	10,917
Maize	117,842	82,254	35,588	126,900	44,646	9,058
Sweet gourd	97,158	74,818	22,340	134,960	60,142	37,802
Watermelon	119265	91,578	27,687	106,920	15,342	− 12,345

Price: Sunflower@ 47 Tk/kg, Maize@ 15 Tk/kg, Sweet gourd@ 12 Tk/kg, Watermelon@ 20 Tk/kg.

Table 7. Per hectare cost and return of dry season crops in Amtali, Barguna, 2016-17 to 2017-18.

Crop	Total cost (Tk)	Total paid-out cost (Tk)	Imputed cost (Tk)	Gross benefit (Tk)	Gross income (Tk)	Net income (Tk)
Sunflower	96,546	77,826	18,720	118,750	40,924	22,204
Maize	111,085	76,964	34,121	114,300	37,336	3,215
Sweet gourd	89,928	71,328	18,600	111,540	40,212	21,612
Watermelon	114,342	88,987	25,355	116,400	27,413	2,058

Price: *Sunflower@ 48 Tk/kg, Maize@ 15 Tk/kg, Sweet gourd@ 13 Tk/kg, Watermelon@ 20 Tk/kg.

Table 8. Effect of mulching on the yield of sweet gourd at Dacope, Khulna and Amtali, Barguna during 2016-17 and 2017-18.

Treatment	2016-17		2017-18		Location wise avg. (t/ha)	
	Dacope	Amtali	Dacope	Amtali		
	Yield (t/ha)	Yield (t/ha)	Yield (t/ha)	Yield (t/ha)	Dacope	Amtali
No mulch (Control)	7.47 de	7.53de	4.71e	5.11e	6.09	6.32
Mulching with rice straw	13.47a	10.70abc	6.58de	8.34cd	10.02	9.52
Mulching with rice husk	13.05a	6.77de	6.44de	6.63de	9.75	6.7
Mulching with rice straw (bottom and above the pit)	11.94bc	11.2abc	8.24cd	10.70abc	10.09	10.95
Mulching with polythene sheet	6.98de	9.03bcd	7.23de	10.80abc	7.12	9.92
LSD			3.00			
CV			24.42			

Table 9. Per hectare cost and return of sweet gourd under different mulching condition, Dacope, Khulna, 2016-17 to 2017-18.

Crop	Total cost (Tk)	Total paid-out cost (Tk)	Imputed cost (Tk)	Gross benefit (Tk)	Gross income (Tk)	Net income (Tk)
No mulch (Control)	94,815	71,865	22,950	73,080	1,215	−21,735
Mulching with rice straw	105,215	77,244	27,971	120,240	42,996	15,025
Mulching with rice husk	106,158	78,818	27,340	117,000	38,182	10,842
Mulching with rice straw at bottom and above the pit	108,648	80,055	28,593	121,080	41,025	12,432
Mulching with polythene sheet	112,294	83,693	28,601	85,440	1,747	−26,854

Sweet gourd price: 12 Tk/kg.

Table 10. Per hectare costs and returns of sweet gourd under different mulching condition, Amtali, Barguna, 2016-17 to 2017-18.

Crop	Total cost	Total paid-out cost	Imputed cost	Gross benefit	Gross income	Net income
No mulch (Control)	92,810	70,865	21,945	82,160	11,295	−10,650
Mulching with rice straw	104,015	76,244	27,771	114,240	37,996	10,225
Mulching with rice husk	105,198	77,217	27,981	87,100	9,883	−18,098
Mulching with rice straw at bottom and above the pit	107,698	79,565	28,133	131,400	51,835	23,702
Mulching with polythene sheet	110,734	82,193	28,541	119,040	36,847	8,306

Sweet gourd price: 12 Tk/kg.

areas flood water makes T. Aman cultivation difficult after jute. In some flood prone areas, flood water intrudes late and its depth remains shallow. In these areas farmers follow an adaptive management practice and can grow Aman rice after jute. In this practice, one month before the final harvest of jute, lean and thin jute plants are sorted out and harvested. At that time Aman rice seeds are direct seeded as relay crop. After about one month or so, when jute is finally harvested, the relay sown Aman rice seedlings are fertilized by top dressing and field is weeded out. After that, usually flood water intrudes in these areas and reaches an average height of two feet. By this time Aman rice is tall enough to survive in flood water damage. In this system, farmers generally use Aman varieties, BRRI dhan33, BRRI dhan39 etc. However, there are many other short duration newly released photo insensitive Aman varieties and their performance in this system is not known. At the same time, fertilizer management for the relay Aman is not standardized as well. With this view in mind this experiment was undertaken to find out the best performing Aman varieties and fertilizer management options for the relay Aman with jute.

Five newly released Aman varieties were used in this trial viz, 1. BRRI dhan75, 2. BRRI dhan73, 3. BRRI dhan72, 4. BRRI dhan71 and 5. BRRI dhan39 (check).

In another trial four doses of fertilizer were used viz., 1. 30-14-12-8-1, 2. 25-12-10-7-1, 3. 20-10-8-7-1 and 4. 20-10-8-0-0 (urea-TSP-MoP-gypsum-zinc sulphate, kg/bigha). In this trial Aman rice varieties were BRRI dhan39.

The trials were conducted in the farmers' fields each in six dispersedly replicated fields in Bhanga, Faridpur in 2017. Aman seeds were broadcast as relay with jute, one month before the harvest of jute during 28 June to 4 July, 2017. Just after the harvest of jute, after about one month of Aman sowing all fertilizers together were top dressed. Aman was harvested during 26 October to 4 November 2017.

The highest yield was produced by BRRI dhan39 (check), however it was statistically similar to that of BRRI dhan73 and BRRI dhan72 (Table 11). BRRI dhan71 produced the lowest yield. Among the fertilizer dose, the highest amount of fertilizer i.e., 30-14-12-8-1 kg/bigha of urea-TSP-MOP-gypsum-zinc sulphate produced the highest yield (Table 12). However, this dose produced statistically similar yield to that of 25-12-10-7-1 kg/bigha of urea-TSP-MoP-gypsum-zinc sulphate. The other two doses produced lower yield and the lowest yield was found in farmer's practice. The results indicated that higher fertilizer dose produced higher yield than the farmer's practice.

Evaluation of crop establishment methods in Mustard-Boro-T. Aman cropping pattern in medium highland ecosystem

An experiment was conducted during Boro 2016-17 and T. Aman 2017 at the experimental farm BRRI, Gazipur to find out the effect of establishment method in Mustard-Boro-T. Aman cropping pattern. The treatments were, single pass unpuddled Boro rice -conventional Aman rice-mustard (T_1), conventional Boro rice-single pass unpuddled Aman rice-Mustard (T_2), Single pass unpuddled Boro rice-single pass unpuddled Aman rice-mustard (T_3) and conventional Boro rice-conventional Aman rice-mustard (check). Single pass unpuddled rice transplanted using transplanter machine was compared with conventional transplanted rice. The seeds of BRRI dhan28 and BRRI dhan57 were used in Boro and Aman season respectively. In case of

Table 11. Performance of some Aman varieties as relay crop with jute in Rabi-Jute-Relay Aman cropping pattern in flood prone areas, Bhanga, Faridpur, 2017.

Aman variety	Aman yield (t/ha)
BRRI dhan75	3.11
BRRI dhan73	3.72
BRRI dhan72	3.23
BRRI dhan71	2.87
BRRI dhan39	3.63
CV (%)	12.58
LSD	0.502

Table 12. Fertilizer management options practiced in relay Aman with jute in Rabi-Jute-Relay Aman cropping pattern in flood prone areas, Bhanga, Faridpur, 2017.

Fertilizer dose (Urea-TSP-MoP-gypsum-zinc sulphate, kg/ha)	Aman yield (t/ha)
30-14-12-8-1	3.91
25-12-10-7-1	3.65
20-10-8-7-1	3.13
20-10-8-0-0 (Farmer's practice)	2.97
CV (%)	5.99
LSD	0.282

M Nasim.

single pass unpuddled rice transplanting, land was cultivated by only one ploughing and laddering. On the other hand, conventional method (ploughing and laddering) was followed in case of conventional rice transplanting. For hand transplanting 30-day-old seedlings were used at Boro season and 18-day-old seedlings were used in Aman season. The plots were fertilized by BRRI recommended fertilizer dose. Other cultural practices were also done as per recommendation. Prior to start of the experiment, soil of the experimental plots was analyzed to know the initial fertility status by collecting samples at 0-15 cm depth. Table 13 presents the initial status of the soils**.**

Both of the establishment methods conventional Boro rice-single pass unpuddled Aman rice-mustard (T_2) and conventional Boro rice-conventional Aman rice-mustard (T_4) required significantly higher amount of water (11,19,503 liter/ha and 11,78,424 liter/ha respectively) followed by single pass unpuddled Boro rice-conventional Aman rice-mustard (T_1) (9,15,957 liter/ha). Comparatively lower amount of water (7, 65,976 liter/ha) was required in single pass unpuddled Boro rice- single pass unpuddled Aman rice-mustard (T_3) establishment method. It indicates that T_2 and T_4 treatment are congenial for saving underground water and ultimately reduce irrigation cost (Table 14).

The highest REY (12.84 t/ha) was found in single pass unpuddled Boro rice-conventional Aman rice-mustard (T_1) establishment method followed by T_4 (12.57 t/ha). But there were no significant difference of REY among the establishment methods (Table 15).

Table 13. Initial soil status of the experimental plots, BRRI, Gazipur 2016.

Soil depth (cm)	Soil properties					
	pH	% organic matter	Total N (%)	Available P (ppm)	Exchangeable K (meq/100g)	Available S (ppm)
0-15	6.65	2.28	0.102	3.82	0.094	6.77

Table 14. Amount of water applied in each pattern, BRRI, Gazipur 2016-17.

Establishment method	Water required (liter/ha)
Single pass unpuddled Boro rice-conventional Aman rice-mustard (T_1)	9,15,957 ab
Conventional Boro rice-single pass unpuddled Aman rice-mustard (T_2)	11,19,503 a
Single pass unpuddled Boro rice-single pass unpuddled Aman rice-mustard (T_3)	7,65,976 b
Conventional Boro rice-conventional Aman rice-mustard (check) (T_4)	11,78,424 a
CV (%)	13.92
SE	113100

In a column, means followed by different letters differ significantly at the 5% level by DMRT.

On-farm trials of newly released premium quality T. Aman rice varieties

An on farm experment was conducted with newly released T. Aman premium quality rice varieties to identify suitable varieties in the drought prone Gangetic river flood plain in Chuadanga.

The tested varieties in the trials include BRRI dhan49, BRRI dhan70, BRRI dhan73, BRRI dhan75 and BINA dhan-17. BRRI dhan34, popularly grown aromatic rice, was also included as check variety.

Location and description. The trial was conducted in four farmers' fields in Chuadanga district during T. Aman (Kharif-2) season 2017. Each farmer's field was around 1300 m^2 (about 33 decimal) and each farmer's field was considered as one replication. Seed bed sowing was done during 1 July to 3 July and transplanting was done during 2-4 August 2017. Best Management Practices (BMP) were followed in all the treatments.

BRRI dhan49 produced the highest yield of 4.56 t/ha followed by BRRI dhan75 (Table 16). The lowest yield of 2.25 t/ha was obtained from BINA dhan-17. The yield of BRRI dhan34 was also low which was only 2.31 t/ha. Panicles m^{-1} also followed the same trend, BRRI dhan49 produced the highest 378 panicles m^{-1} followed by BRRI dhan75 which produced 340 panicles m^{-1}. Unlike yield and panicles m^{-1} the grains panicle^{-1} was the highest, 197 panicle^{-1} in BRRI dhan34 followed by BRRI dhan73 (154 panicle^{-1}). Overall yield was low due to severe drought in Chuadanga. The participating farmers were interviewed for their perception about the varieties grown in their fields. Table 17 shows their perception about the varieties.

On-farm evaluation of integrated weed management options in transplanted Aman rice

An on farm experiment was conducted to integrate pre-emergence herbicide with either mechanical or post-emergence herbicide or hand weeding or both mechanical and post emergence herbicide to better control weeds in transplanted Aman rice, to increase rice yield and reduce weed control cost. The following treatments were used in this experiment.

Treatments: Weed control options

T_1. Farmer's practice (Usual weeding practice of farmers known through interview)	T_6. Post emergence herbicide - Penoxsulam fb 1 HW
T_2. Pre-emergence herbicide - Pendimethaline (Panida) followed by 1 Hand weeding (HW)	T_7. Superclean fb Matrix fb 1 HW
T_3. Pre-emergence herbicides - Mefecanet + Bensulfuron methyl (Super-clean) fb 1 HW	T_8. Superclean fb Penoxsulam fb 1 HW
T_4. Superclean fb 1 Mechanical weeding (MW)	T_9. 1 MW fb 1 HW
T_5. Post emergence herbicide - Bispyribac sodium (Matrix) fb 1 HW	T_{10}. Weed free

Table 15. Yield of mustard, Boro and T. Aman rice and REY under different establishment methods of cropping pattern, BRRI, Gazipur, 2016-17.

Establishment method	Yield (t/ha)			REY (t/ha)
	Mustard	Boro	T. Aman	
Single pass unpuddled Boro rice-conventional Aman rice-mustard (T_1)	0.80	6.31	3.74	12.84 NS
Conventional Boro rice-Single pass unpuddled Aman rice-Mustard (T_2)	0.90	5.71	2.70	11.81 NS
Single pass unpuddled Boro rice-Single pass unpuddled Aman rice-Mustard (T_3)	0.90	5.50	3.17	11.81 NS
Conventional Boro rice-Conventional Aman rice-Mustard (check) (T_4)	1.02	5.78	3.24	12.57 NS
CV (%)				10.57
SE				1.06

NS = Not significant.

Table 16. Grain yield and yield contributing characters of premium quality rice varieties in Aman 2017, Chudanga, Jashore hub.

Variety	Panicle/m_2	Grain/Panicle	1000 GW (g)	Yield (t/ha)
BRRI dhan34	312ab	197a	11.12d	2.31b
BRRI dhan70	276bc	113c	21.0bc	3.56a
BRRI dhan73	221c	154b	26.0a	2.40b
BRRI dhan75	340ab	117c	21.0c	3.90a
BRRI dhan49	378a	116c	21.0bc	4.46a
BINA dhan17	200c	118c	22.0b	2.25b
LSD	80.98	13.88	1.15	1.03
CV %	12.26	4.45	2.45	14.28

Table 17. Farmer's perception regarding premium quality rice varieties.

Variety	Farmers' perception
BRRI dhan34	Grain quality is good, but poor yield, lodging and neck blast are major problem. Crop duration is also high.
BRRI dhan49	Satisfied with yield, grain quality and duration
BRRI dhan70	Satisfied with yield, grain quality and duration
BRRI dhan73	Poor yield and lodging
BRRI dhan75	Satisfied with yield, grain quality and duration
Bina dhan-17	It was very early and faced severe drought during flowering. Poor yield.

A. Saha.

Location and description. The trial was conducted in six farmers' fields in each of Faripur and Jashore hub during T. Aman season 2017. Each farmer's field was around 1,300 m^2. Each farmer's field was considered as one replication. The variety BRRI dhan49 was used in both the hubs. Weeds were controlled as per treatment. Crop management practices other than weed control were done following the BRRI recommended management practices.

Table 18 shows grain yield, labour uses and weed control costs of different weed control options. Across different weed control options grain yield differences were insignificant in Jashore hub, while it was significant in Faridpur hub. In Faridpur hub the highest yield of 5.7 t ha^{-1} was obtained from T_4 which was similar to those from T_3, T_5 and T_{10} treatments and in Jashore hub the yield varied from 4.63-4.89 t ha^{-1}. Weed control option having pre-emergence herbicide Mefecanet + Bensulfuron methyl (Superclean) followed by one mechanical weeding (T_4) required the lowest number of labourers (6 md/ha in Faridpur and 9 md/ha in Jashore) for weeding as well as the lowest weeding cost (42 US $ /ha in Faridpur and 58 US $ /ha in Jashore) in both the hubs. The highest labour cost for weeding as well as the highest total cost for weeding was found in completely weed free treatment (T_{10}) in both the hubs. As compared to farmer's practice (T_1) total weeding cost was reduced in T_4 treatment by 70% in Faridpur and 66% in Jashore hub, while it was increased respectively, by 48% and 35% treatment in those hubs in T_{10}. The results of T. Aman 2017 revealed that Mefecanet + Bensulfuron (Superclean) methyl followed by one mechanical weeding (T_4) gave the highest yield with minimum weeding cost. While the results of T. Aman 2016 (Tables 19 and 20) revealed that Mefecanet + Bensulfuron methyl followed by either Bispyribac sodium (T_7) or Penoxsulam (T_8) followed by one hand weeding effectively controlled weeds and thereby reduced labor requirement and subsequently weeding costs. In both the years herbicide cost was minimum in T_3, T_4 and T_5 treatments.

DEVELOPMENT OF HOMESTEAD AGROFORESTRY SYSTEM

Performance of exotic date palm (*Phoenix dactylifera*) in homestead agro-forestry systems

Good quality date palm has special utility in our country and is totally imported from exotic source. Exotic date palm varieties can be introduced and evaluated in our local situation. Therefore, an

Table 18. Effect of different weed control options on labor use for weeding, cost of weeding and grain yield, in Aman 2017 at Jashore and Faridpur.

Treatment	Grain yield (t/ha)		Labor use (md/ha)		Total weeding cost (TK)		Increase (-) /decrease (+) of TCW (%)	
	Jashore	Faridpur	Jashore	Faridpur	Jashore	Faridpur	Jashore	Faridpur
T_1	4.63	5.2	32	25	13600	11040	-	-
T_2	4.79	5.1	17	16	8960	8480	34	23
T_3	4.78	5.6	14	13	6560	6080	52	45
T_4	4.82	5.7	9	6	4640	3360	66	70
T_5	4.84	5.6	16	13	7040	5920	48	46
T_6	4.65	5.0	17	14	8560	7280	37	34
T_7	4.89	5.0	11	15	5680	8000	58	28
T_8	4.85	5.0	11	15	6640	9040	51	18
T_9	4.87	5.5	22	14	8640	5520	36	50
T_{10}	5.05	5.6	46	41	18320	16320	-35	-48
$LSD_{0.05}$	NS	0.6	4.52	2.66	22.7	13.3		

Table 19. Effect of different weed control options on labor use for weeding, cost of weeding and grain yield, Faridpur hub, Aman 2016.

Weed control option	Grain yield (t/ha)	Labour use (md/ha)	Herbicide cost** (Tk/ha)	Total cost of weeding (TCW)** (Tk/ha)	Increase (-) /decrease (+) of TCW (%)
T_1	3.5 ± 0.4	10 ± 1	1120	3680	
T_2	3.6 ± 0.3	6 ± 1	2800	4560	- 24
T_3	3.5 ± 0.4	6 ± 1	1040	2800	25
T_4	3.6 ± 0.4	5 ± 1	1040	2560	31
T_5	3.5 ± 0.3	7 ± 1	1040	2000	46
T_6	3.6 ± 0.4	6 ± 0	1920	1680	53
T_7	3.7 ± 0.4	3 ± 0	2080	960	74
T_8	3.6 ± 0.4	3 ± 0	2960	880	75
T_9	3.6 ± 0.4	9 ± 0	0	1840	50
T_{10}	3.7 ± 0.3	15 ± 2	0	4480	- 22

Table 20. Effect of different weed control options on labour use for weeding, cost of weeding and grain yield, Jashore hub, T. Aman 2016.

Weed control options*	Grain yield (t/ha)	Labour use (md/ha)	Herbicide cost (Tk/ha)	Total cost of weeding (TCW) (Tk/ha)	Increase (-) /decrease (+) of TCW (%)
T_1	4.3 ± 1.3	37 ± 14	1120	12240	
T_2	4.1 ± 1.1	21 ± 14	2800	9280	24
T_3	4.3 ± 1.1	26 ± 11	1040	8880	28
T_4	4.0 ± 1.0	33 ± 11	1040	10960	11
T_5	3.9 ± 1.0	33 ± 6	1040	11040	10
T_6	3.9 ± 1.0	36 ± 7	1920	12640	- 3
T_7	4.4 ± 1.1	16 ± 3	2080	6800	45
T_8	4.3 ± 1.0	18 ± 3	2960	8400	31
T_9	4.3 ± 1.2	53 ± 10	0	15760	- 29
T_{10}	4.4 ± 1.3	60 ± 14	0	17920	- 46

experiment was undertaken to develop agro-forestry system with exotic date palm to increase the system productivity and income of the farmers

Collected seeds of 10 varieties of *Phoenixdactylifera viz*, Azwah, Ambar, Mabrum, Bohtan, Khalas, Makhtum, Sukkary, Lu-Lu, Shahia and Shagri were sown in nursery bed in 2013. Six-month-old seedlings were transplanted in 3m × 3m spacing. Two orchards were established, one at BRRI Head Quarter with 500 saplings and other one at Mujibnagar Comolex, Mujibnagar, Meherpur with 1100 saplings. A regular irrigation and fertilizer and weed management schedule was followed. Suckers of selected plants (true-to-type) has been used for further propagation and field plantation. Black gram was integrated with the date plants in 2017. BARI Mash-2 variety was broadcast sown @ 60 kg/ha seed on 18 september and was harvested on 5 December.

In 2016-17, 30 male and 14 female plants were identified. Out of 14 female plants successful harvest was done from 6 plants. Number of fruits varied from 150- 200 per bunch and fruit size varied from 13-17 gm per fruit intercropped black gram gave and additional yield 860 kg/ha.

■ SM Shahidullah

Agricultural Economics Division

SUMMARY

Socio demographic factors like, family size and income, easy access to extension services and better market demand along with higher yield potential, good appearance and good eating quality had significant and positive influence to adopt a variety. Surveyed farmers of Mymensingh district opined that performance of newly released BRRI varieties could not satisfy their expectation. Even though seeds of those varieties, which performed a bit better in the local demonstrations, their supply was not sufficient.

In T. Aman season, among all Indian rice varieties, Gutiswarna was leading cultivar covering 39% area in Rangpur region, and in Dinajpur, it was31% followed by Swarna5 (5%). Most of the farmers continued to cultivate Gutiswarna due to its suitability in all types of lands; higher yield performance, better taste and quality straw. Due to some extent earliness of Gutiswarna, which facilitated to cultivate the next crop (Rabi crops) also popularized it in both Rangpur and Dinajpur regions. In Boro season, Zira (71%) was the most dominant variety in Naogaon district due to yield advantage, good grain quality, lucrative price, required low intensive care, less susceptible to insects and diseases, high demand to the millers.

In Aus season, overall adoption of modern varieties was 91% of which BRRI varieties' coverage was about 66%. BRRI dhan48 ranked the top position (17%) in terms of area coverage followed by BRRI dhan28 (15%). In T. Aman season, overall adoption of BRRI varieties was apparently low (48%); however, adoption of those varieties in some regions namely Khulna, Faridpur, Cumilla, Sylhet were substantially high (60-83%). BRRI dhan49 (11%) and BR11 (7%) were mostly adopted BRRI varieties in T. Aman season. Total adoption of Indian varieties in T. Aman season was 22% while it was 43-58% in some regions. Overall adoption of modern varieties in Boro season was about 99%, of which coverage of BRRI varieties was about 70%. BRRI dhan28 and BRRI dhan29 were the most dominant varieties; jointly covered 61% of total areas in Boro season. BRRI dhan48 produced the highest yield (4.01 ton/ha) in Aus season whereas in T. Aman season, BRRI dhan49 was the top yielder (4.62 ton/ha), followed by BRRI dhan52 (4.56 ton/ha). BRRI dhan29 was the top yielder (6.43 ton/ha) followed by BRRI dhan58 (6.03 ton/ha) and BRRI dhan63 (5.78 ton/ha) in Boro season. Average yield of hybrids was 7.27 ton/ha whereas BRRI developed hybrids yielded 7.63 ton/ha in Boro season.

In Boro season, yield was higher due to better cropping environment, good management practices and use of better genotypes, consequently secured higher gross return. However, in T. Aman season gross and net return was higher due to lower costs of production and better market price. Overall, rice cultivation was profitable at current years' yield and price in terms of gross income and only the T. Aman and Aus rice was profitable in terms of net income.

Based on the performance of T. Aman rice in the trial plots in 2017-18, BRRI dha76 was the most preferred variety in Dacope due to its potentiality of transplanting in the fields with over a feet depth of water as well as less or no infestation of disease and long panicle with large number of grains. On the other hand, BRRI dhan54 was the most preferred variety at Amtali because of higher yield and early maturity. It matured about 25-40 days earlier than the check varieties. In addition, it matured in a time when food scarcity prevailed in the region. BRRI dhan77 was the second most preferred variety in Amtali mainly because of suitability of planting in stagnant water, matured for harvesting after drainage out of stagnant water and its long panicle indicated higher yield potential.

Price transmission scenario was asymmetric from farm to retail level both in long and short run. An increase in the farm price led to rapid increase in the wholesale and retail prices. However, a decrease in farm price did not decrease in wholesale and retail price at the same rate. That means the processors (wholesalers/millers) enjoy a certain advantage over primary producers (farmers) and retailers enjoy a certain advantage over processors. Also, final consumers are more likely to experience a decrease in their surplus from a price increase rather than to experience an increase in their surplus from a price decrease at the upstream.

The support price policy creates a positive change in producer surplus of US$ 1,981 million, which is substantially higher than the consumer surplus (US$–1,785 million) in the intervened

years. Furthermore, the result shows that if the subsidized price policy is implemented, the price variation by 1.38% can be reduced and the change in consumer surplus (US$ 1,501 million) obtained in the intervened years. To adapt with the unavoidable climate change and eliminate the number of victims of food insecurity, public food policy is necessary even if it becomes costly.

CONSTRAINTS TO ADOPTION OF BRRI RELEASED MODERN RICE VARIETIES: A POLICY OPTION

Bangladesh Rice Research Institute (BRRI) has so far developed 92 HYV rice varieties including six hybrids which made outstanding contribution towards attainment of rice sufficiency in Bangladesh. Out of 92 varieties, few mega varieties were popularized and adopted in different seasons which contributed the lion's share of rice production; but the yield performance of these varieties is now under decreasing trend due to different biotic, abiotic and socio-economic constraints. As a result, acreage under BRRI varieties especially in Aman season continues to decline and farmers shifted their choice to cultivate other than BRRI varieties which is a misfortune and threat for rice sector as a whole. Under such a situation, an in-depth study was designed to explore the underlying reasons of adoption and dis-adoption of BRRI varieties at the field level with the following objectives to:

- Investigate the positive and negative traits of BRRI released rice varieties;
- Assess the factors affecting slow adoption of BRRI released rice varieties at the farm level; and
- Develop a diffusion model for curtailing adoption lag period.

Farm level data were collected through farmers' group discussion (FGD) followed by face to face interview method in Mymensingh district during 2017-18. A total of 1,950 sample farm households of which, Aus-390, T. Aman-780, and Boro-780 growers respectively were surveyed and interviewed with pre-tested semi structured questionnaire. Both descriptive and inferential statistics were used to analyze the data for achieving the set of objectives of the study.

Drivers and constraints of adoption of rice

Ausseason : Most of the farmers preferred BRRI dhan28 in Aus season for shorter growth duration, less pests attack, better grain quality and higher market price, though it's a recommended variety for Boro season. BRRI dhan48 is a higher yield potential, lodging resistant and higher market demanded variety which seed is easily available from DAE. Even though it's an early matured variety, birds' attack is much lesser due to erect flag leaf. On the other hand, BR26 is popular to the farmers for higher yield potentiality, less number of unfiled grains and maintaining seeds for the next season from their harvest. However, farmers repeatedly reported that insect-pests infestation is comparatively high in BR26 as large areas remains fallow in Aus season and cooked BR26 rice becomes soft or decomposed within a short time.

Aman season. Major drivers of adopting BRRI dhan49 in Mymensingh are better yield performance, medium slender grain so that good taste to eat, higher market demand as well as shorter growth duration compared to BR11, which is suitable for three crops cropping patterns (e.g., T. Aman/wheat/rabi-Aus rice). In addition, farmers get liquid cash from selling quality straw of BR49, which is harvested a bit earlier. However, infestation of false smut (although, most cases scale of occurrence remains below the economic threshold level), susceptibility to leaf folder, brown plant hopper, caterpillar and even neck blast diseases are the widespread concerns and bottlenecks of further dissemination of this variety. Besides, to some extent susceptibility to lodging, lack of availability of seed at local market, higher attack of birds due to early maturity hindered the adoption of this variety. Furthermore, few farmers also opined that BINA dhan-7 is more suitable for three crops pattern than BRRI dhan49 due to shorter growth duration.

Good yield potential, medium slender grain and better market demand, less susceptible to pest and insect, no lodging despite cultivating in the low laying area, higher tillering ability even in the field with stagnant water, good yield despite moisture stress at maturity stage are the key considerations of continuing cultivation of BR22. However, lack of availability of seed, high susceptibility to brown plant hopper and higher infestation of caterpillar in case of foggy weather and longer growth duration are the main causes of low adoption of the variety at farmers' fields.

Highly suitable in natural flash flood condition, medium slender grain, good taste and better market demand are the key criteria for adoption of BRRI dhan51. However, susceptible to stem borer, rice hispa, neck blast, brown plant hopper and also lack of availability of seed are the factors responsible for lower adoption of this variety.

Higher yield potentiality than local aromatic rice, good taste, better market price; consequently higher profitability as well as higher demand for straw which is preferred by cattle are the key criteria for adoption of BRRI dhan34. The drawbacks of this variety are susceptibility to neck blast, stem borer and high brown plant hopper attack.

Farmers reported that major reasons of substantial adoption decrease of BR11 are susceptible to sheath blight, leaf blight and ufra diseases as well as brown plant hopper, gall midge and stem borer, etc. Moreover, poor yield performance (due to incomplete emerge of panicle) in late transplanting and in cold stress the case while farmers are unable to transplant on time due to shifted delay of rainfall is also an important driver of decreasing adoption of BR11. In addition, less number of effective tillers and low demand of grain at market because of bold grain is also affected the adoption of BR11. However, farmers have been continuing cultivation of the variety as the variety gives higher yield than that of available other varieties under good seasonal conditions (no biotic and abiotic stress) and better agronomic and pest management practices. Besides, tillering ability in anaerobic condition, good eating quality, availability of household seeds and lack of access to seeds of newly released BRRI varieties are also the important factors of continuing cultivation of both the biotic and abiotic susceptible variety, for instance BR11.

Farmers grow BR10 due to higher yield potential, more number of tillers per hill, though the productivity of this variety frequently affected by cold and drought due to longer growth duration as well as attack of birds and rats. Similarly, tolerance to natural flash floods, higher number of effective tiller, suitability to late planting in low laying and flood affected areas are the reasons of adoption of BRRI dhan52. Farmers reported that susceptibility to BLB, blast and BPH along with longer growth duration; lower market price and lack of availability of seed are the key of low adoption of the variety.

Boro season: Good yield potential and shorter growth duration, less irrigation requirement and maturity before monsoon, which ease threshing and drying of grain and straw, are the important criterion of higher adoption of BRRI dhan28 in Mymensingh. Besides, higher milling out turn, medium slender grain and good eating quality which ensured good market price as well as availability of seed at local market were the key drivers of higher adoption of BRRI dhan28. Moreover, cattle like the straw of this variety much as their feed; because the quality of straw remains good as the harvesting ended almost before the rain. However, due to severe infestation of neck blast, some of the respondents suspected that adoption of this variety may decrease substantially in near future. Furthermore, adulteration even in the BADC supplied seed, lower yield potentiality than newly released varieties, lodging proneness in case of rain at maturity stage, more unfiled grain and susceptibility to gall midge are also critical constrains of BRRI dhan28. So, the farmers are eagerly looking for a suitable variety as replacement of BRRI dhan28.

Higher yield potentiality, medium bold grain, good taste and higher market demand, less infestation of neck blast including other pests, no shattering and lodging problems are the major reasons of continuing cultivation of BRRI dhan29. Longer growth duration; for which there is higher chances to affect this crop by extreme weather events (e.g., rain, hail storm and strong wind) and (ii) maturity during monsoon that hampered harvest and post-harvest activities (e.g., harvesting, threshing and drying) and increase post-harvest losses also are the main negative concern about BRRI dhan29. Moreover, higher cost of production due to longer growth duration; especially, irrigation and other input costs, lower milling out turn and higher rate of unfilled grain are also the cause of decreasing popularity of the variety.

Delayed flowering of BRRI dhan58, which can avoid neck blast infestation and escape adverse consequences of extreme weather events, requires less urea compared to BRRI dhan29. It is called lodging resistant with the profuse tillering capacity and suitable for transplanting in the low laying area (one seedling per hill) that requires lesser amount of seed. Its good taste and higher market demand secures better price for the producers. However, the variety is sensitive to cold and several grains of top of the panicle remain unfilled. Application of higher doses of urea delays flowering and reduces yield as well. Respondents expected that adoption of this variety may rapidly increase if seed season is guaranteed as per demand.

In spite of some positive traits such as strong stem, no shattering, good eating quality and good yield, farmers are about to stop cultivating BR14 as its long awn is injurious for health during threshing, winnowing and drying, low demand and price of the grain at market as well as availability of better variety such as BRRI dhan28 and BRRI dhan29 are the major reasons of substantial adoption decrease of this variety. Despite potentiality to give higher yield and less prone to sterility, farmers are about to stop cultivating BR26 as the cooked rice of the variety becomes soft and decomposed within a short time.

Good yield potential, slender grain, good taste to eat, higher market price are the criteria of cultivating BRRI dhan50; however, adoption of the variety is low mainly due to lack of seed as well as higher shattering rate in the field, low milling outturn and unsuitability of milling in the non-rubber hauler mills. BRRI dhan68 gave lower yield at trial plots than that of existing varieties even under the farmers' practice. Cooked rice of BRRI dhan69 becomes soft after a short while and is the main reason of less adoption of the variety despite having some important positive traits such as higher yield potential, medium fine grain and no lodging problem even in heavy and strong wind.

Diffusion pathway of BRRI variety

Farmers in the group discussion reported that performance of newly released varieties could not satisfy their expectation. Furthermore, seeds of those varieties, which performed a bit better in the local demonstrations, their supply was not sufficient as BADC and other private sector seed traders produced only most dominant and popular varieties which had widespread acceptance to the growers. BADC and private seed traders noted that lack of information regarding the location specific demand of particular variety in different seasons was an important factor for insufficient supply of newly released varieties. It is also the case that BADC, only the public organization could not fulfil the huge demand of rice seed for the whole country. In this regard, BADC personnel and private seed traders suggested that ensuring availability of breeder's seeds and information regarding actual demand for location specific variety seed are very important to enhance adoption of the newly released potential varieties at farmers' field (Fig. 1).

Socio demographic factors like, family size and income, easy access to extension services and better market demand along with higher yield potential, good appearance and good taste to eat had significant and positive influence to adopt a variety. In this regard, farmers considered the drivers that profoundly influenced the adoption decisions having performance of a variety in terms of yield, profitability, and tolerance in biotic and abiotic stresses, easily available of good quality seeds, better quality of milled and cooked rice and ensured market demand. Besides, BADC and other private seed traders informed that they were not much updated about the demand of location specific particular popular variety for different seasons.

Recommendations

Most of the actors (BADC, private traders, extension personnel) of rice seed value chain strongly recommended that commercial cultivation of seed by the progressive farmers' could be a vital strategy to ensure quality seed supply to the farmers as a whole. In this regard, identification and selection of interested farmers for developing private seed entrepreneurship and providing them training on production and storage is indispensible. On the other hand, large scale demonstration of potential variety in selected region is essential for rapid diffusion. Expert personnel and key informants suggested the following strategies, which would be effective to reduce adaptation lag of the newly release varieties:

- Large scale demonstration of potential selected varieties in particular region which is suitable to cultivate it.
- Arrangement of field-days with participation of farmers of the entire community along with the private seed traders showing them performance and potentiality of the variety. It will be useful to-

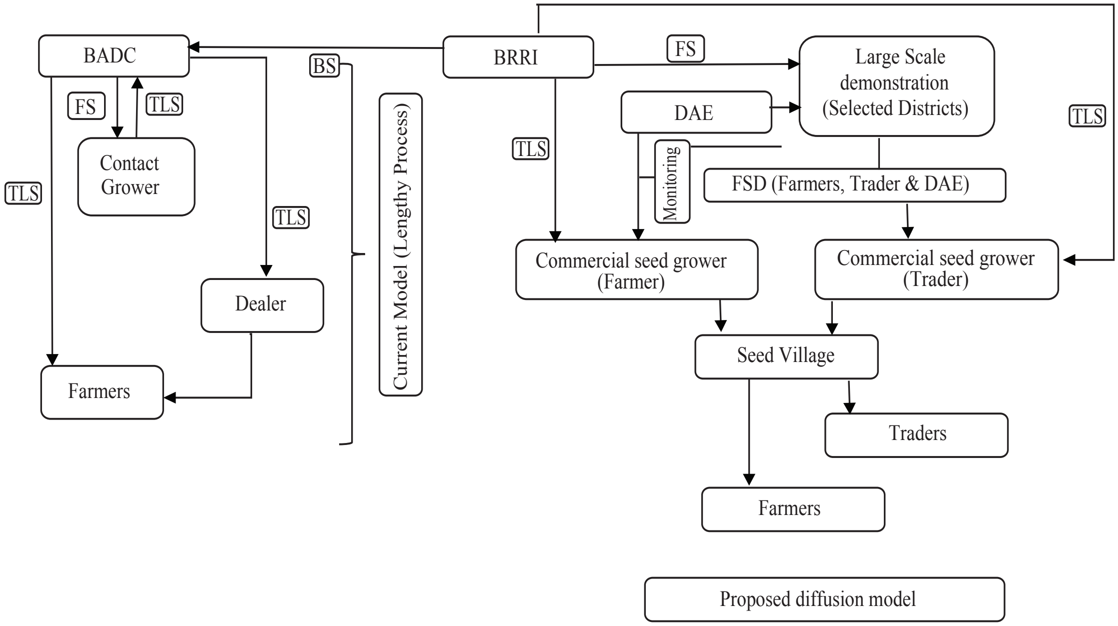


Fig. 1. Rapid diffusion pathway of newly BRRI released rice varieties.

- Identify farmers and private traders who are interested to produce seed commercially.
- Provide them hands on training on seed to seed rice production package and seed storage techniques.
- Deliver 'technical know-how' support to them for seed production for 2-3 years through on farm trial which would enhance expertise of farm household's skill to develop private seed entrepreneurship.

■ Providing region and season specific rice production manual and wide spread circulation to the farmers and extension personnel at the field level.

■ Development and wider scale dissemination of modern rice production technology based on APPS to farmers and extension personnel.

■ Development of leaflet/stickers on traits and special characteristics of newly BRRI released varieties and its wide scale circulation to farmers, extension personnel and private traders to be familiar with those.

■ MAB Siddique, MS Islam, MJ Kabir, MA Salam, MA Islam, MI Omar, MAR Sarkar, MC Rahman, A Chawdhury, MS Rahaman and L Deb

EVALUATION OF THE PROPENSITY OF INDIAN RICE VARIETIES ADOPTION IN SELECTED AREAS

Rice, the staple food crop in Bangladesh is being cultivated all over the country in Aus, Aman and Boro seasons which produced 36.19 MT of clean rice during 2017-18 and it secure the food demand for 163 million people. Similar to other parts of the country, Rangpur and Rajshahi region is also unique habitat for rice cultivation where HYV, traditional, different types of hybrids and Indian rice varieties are grown. Though, the farmers of this region started to cultivate Indian rice varieties since 1995, these are getting popularity and replacing domestic cultivars overnight. To address the emerging concern regarding dropout of native rice cultivars across the border region and to uncover the underlying causes of cross-border adoption of Indian varieties, the present study was an attempt and also to satisfy the at heart curiosity regarding the actual scenario of Indian rice varieties in Bangladesh with the following objectives to:

■ Determine area coverage of Indian rice varieties in the study areas;

■ Find out the specific reasons for cultivating those varieties.

In order to fulfill the purpose of the study, the areas which are densely concentrated with Indian rice variety's coverage; namely, Dinajpur and Rangpur for *Swarna* (T. Aman) and Naogaon district for *Zira* (Boro) was selected purposively. Intensive field surveys combined with a number of focus group discussion (FGDs) were conducted to generate necessary data during 2017-18.

Scenario of domestic and indian rice varieties in T. Aman season

Adoption of BRRI and Indian rice variety was about 46% and 42% in Rangpur and 47% and 48% in Dinajpur region, respectively during T. Aman season of 2017-18. Among Indian varieties, adoption of GutiSwarna was the highest (39%) followed by swarna5. It was observed that Indian varieties were popular in Badarganj (51%), Mithapukur (44%), Pirganj (72%) and Taraganj (46%) upazilas due to higher yield potential, stable market price and apt to fit in the cropping patterns. On the other hand, farmers of the rest of the upazilas still prefer BRRI released varieties and other MVs in T. Aman season. Notably, *Guti* Swarna was dominant in terms of area coverage in Badarganj (49%), Gangachora (23%), Mithapukur (38%), Pirganj (72%) and Taraganj (36%) upazilas of Rangpur district. Similarly, area coverage of BR11 in Kaunia (31%), Metropoliton (28%), Pirgacha (29%) and sadar (44%) upazilas was still higher.

Among BRRI varieties BRRI dhan34, a fine grain cultivar with excellent aroma occupied the highest (42%) area in Dinajpur region due to higher market price and good quality straw that might be the major drivers of widest cultivation of this variety; despite few negative traits like susceptible to false smut, strong lodging problem, vulnerable to drought and temperature. Despite so old variety BR11still had good coverage (18%) in Rangpur region; though, its popularity shifting downward due to highly susceptible to sheath blight and less market price (Table 1 and 2).

Reasons for adopting Indian rice varieties

Most of the farmers remarked in a voice that the Indian rice varieties (especially, different types of Swarna in T. Aman season) are short duration, less insect-pest infestation, higher yield potential, good grain quality which secured lucrative market price, required lower intensive care, etc. They also added that they could easily maintain Swarna seed for next season. All the aforesaid traits are highly convincing factors to adopt Swarna in the surveyed areas. Most of the farmers continue to cultivate Gutiswarna having desirable traits such as better taste, suitable for all types of land, higher yield and good quality straw, drought resistant as well as high milling out-turn. Somewhat earliness of Gutiswarna facilitates the cultivation of Rabi crops.

Scenario of domestic and Indian rice varieties in Boro season

All of the Boro rice areas were covered by modern varieties with limited varietal diversificationin in Naogaon district where area coverage of BRRI developed varieties, hybrids and Indian varieties were about 22, 5 and 73 percent respectively. Among recently cultivated rice varieties, Zira (71%) was the most dominant Boro varieties followed by BRRI dhan28 (15%), and BRRI dhan29 (5%). It was observed that, all upazilas of the district were dominated by Zira except Bodalgachi. Nevertheless, BRRI it is still popular variety (48% of total areas) in Bodalgachi upazila of Naogaon district (Table 3). It's noted that most of the farmers produce BRRI dhan28 for their home consumption only and Indian varieties for commercial purposes.

Most of the farmers continued to cultivate *Gutiswarna* due to its suitability in all types of lands; higher yield performance, better taste and quality straw, drought resistance as well as higher milling outturn. Due to some extent earliness of Gutiswarna, which facilitated to cultivate the next crop (Rabi crops) also popularized it in both Rangpur and Dinajpur regions. Likewise; Swarna5, a higher yield potential short duration popular variety, which ensured better market price due to medium slender grain, has no shattering as well as lodging problem induced the farmers to grow it. All of the aforesaid traits were highly convincing factors to adopt *Gutiswarna* and Swarna5 in the surveyed areas.

BRRI dhan49 and BRRI dhan52 are gradually getting popularity in both Rangpur and Dinajpur regions where BRRI dhan49 seemed to be a better option of substituting *Gutiswarna* for desirable

Table 1. Adoption status (% area) of T. Aman rice varieties in Rangpur district, 2017-18.

Variety	*Upazilas									Rangpur
	1	2	3	4	5	6	7	8	9	
BR11	1.02	22.72	31.35	28.33	16.38	28.51	3.01	44.07	3.02	17.61
BRRI dhan33	0.18	4.18	3.49	0.12	1.97	1.75	1.41	0.96	4.02	1.93
BRRI dhan34	11.30	0.65	-	0.04	0.62	0.50	-	0.58	2.01	1.78
BRRI dhan39	0.18	6.40	0.26	0.08	0.03	0.70	0.20	-	5.41	1.24
BRRI dhan49	6.54	3.00	6.99	12.32	5.05	7.00	1.61	4.81	2.01	5.18
BRRI dhan51	2.04	9.14	3.23	4.93	1.36	0.25	4.22	2.89	3.02	3.24
BRRI dhan52	7.16	15.93	10.48	17.24	14.47	28.51	5.02	5.77	6.04	12.91
All BRRI Varieties	29.90	67.75	57.60	66.79	40.99	67.85	15.72	62.10	28.00	45.85
Mamunswarna	2.04	-	-	-	-	-	-	-	7.19	0.68
Parija	-	-	3.93	-	-	-	-	-	-	0.27
Ranjitswarna	0.31	-	-	2.87	5.73	-	-	-	3.52	1.74
Gutiswarna	48.77	23.37	29.21	25.74	38.25	24.17	72.43	28.87	35.52	38.92
All Indians	51.12	23.37	33.14	28.61	43.98	24.17	72.43	28.87	46.24	41.62
ACI	-	0.57	0.17	0.16	1.09	-	0.60	0.19	2.52	0.59
Dhanigold	7.29	1.64	1.75	0.21	0.68	2.25	2.41	0.38	1.51	2.10
Hira-2	0.87	0.78	0.35	0.29	1.04	0.50	0.80	0.38	0.60	0.72
Other Hybrids	4.21	3.02	2.01	1.8	6.06	0.5	1.01	2.9	15.6	3.82
All Hybrids	12.37	6.01	4.28	2.46	8.87	3.25	4.82	3.85	20.23	7.23
All other MVs	6.42	2.61	4.54	1.89	5.10	4.03	4.42	4.46	5.53	4.44
All MVs	99.81	99.74	99.56	99.75	98.95	99.30	97.39	99.28	100	99.14
All LVs	0.19	0.26	0.44	0.25	1.05	0.70	2.61	0.72	-	0.86

*Rangpur upazilas: 1.Badarganj, 2. Gangachora, 3. Kaunia, 4.Metropoliton, 5.Mithapukur, 6.Pirgacha, 7.Pirganj, 8.Sadar and 9.Taraganj.

Table 2. Adoption (%) status of T. Aman rice varieties in Dinajpur district, 2017-18.

Variety	1	2	3	4	5	6	7	8	9	10	11	12	13	Av.
BR11			1.48		1.32			0.55			0.71			0.34
BRRI dhan34	17.71	9.97	54.52	15.43	34.9	58.9	33	20.3	21	6.99	1.43	46.59	43.56	31.09
BRRI dhan49	1.55	10.7	1.9	1.4	1.02	10.2		8.72	2	5.8	0.57	1.05	4.68	4.33
BRRI dhan51		29.5	3.76	8.07	1.28	3.59	6.1	0.09	0.3	24.3	0.86	1.64		7.35
BRRI dhan52		1.04	2.14	6.15	0.51	4.21	4.8		2.6	2.54	0.57	1.55		1.97
BRRI dhan56		0.72	0.07	1.29	0.13				0.6	1.62	0.57	0.18	0.8	0.45
BRRI dhan57		0.3	0.05	0.28					0.4	1.21		0.18		0.17
BRRI dhan62		0.24	0.08	2.6	0.38		0.9		0.2	0.24	0.43	0.23		0.37
All BRRI varieties	19.26	52.5	64.9	40.37	39.7	77	45	29.7	28	42.7	5.13	52.09	49.04	46.58
Hybrid	1.43	8.19	0.36	3.23	0.81	0.68	3.6	2.13	3.8	1.24	8.2	5.23	2.86	3.21
GutiSwarna	45.3	35.2	15.73	27.18	42.1	0.18	43	19.7	30	54.7	47.34	42.09	20.87	30.77
Kotrapari		1.27	0.78							0.66				0.29
Mamun					1.73			3.4	2.5		1.57		1.92	0.66
Nepali swarna			0.79		6.71						35.86		3.79	2.92
Ranjit	1.69	1.67	3.94	4	1.58			13.9	8.5		0.72	0.18		2.07
Sampakatari	2.26		0.27			3.49	3.3							0.76
Sonamukhi		0.13	2.14			7.2	5.5						1.92	1.56
Suman swarna			6.25	15.66										1.71
Swarna-5	29.77				1.49			20.1	27				16.12	5.44
Indian	79.03	38.2	3	54.8	53.6	17.6	52	68	68	55.4	85.93	42.27	44.63	47.93
Local	0.29	0.03	4.07	0.27	2.51	3.9		0.26		0.75	0.03			1.16
Other_MV		1.07	0.68	1.34	3.39	0.78	0.2		0.1		0.71	0.41	3.46	1.13
Grand total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: Name of different upazilas: 1= Birampur, 2= Birganj, 3= Birol, 4= Bochaganj, 5= Chirirbandar, 6= Sadar, 7= Fulbari, 8= Ghoraghat, 9= Hakimpur, 10= Kaharul, 11= Khansama, 12= Nawabganj, 13= Parbatipur.Source: DAE.

Table 3: Adoption status (% area) of Boro varieties in Naogaon district, 2017-18.

Variety	*Upazilas											Naogaon
	1	2	3	4	5	6	7	8	9	10	11	
BRRI dhan28	8.56	48.23	5.40	27.41	10.13	25.52	3.89	22.27	8.33	2.77	6.68	15.17
BRRI dhan29	20.32	0.95	3.74	1.05	0.36	5.21	0.21	3.65	4.17	3.74	22.28	4.76
All BRRI varieties	30.05	57.37	17.12	29.25	12.83	32.67	8.20	29.31	13.81	6.59	32.14	22.41
Khato-10	4.71	2.92	-	1.86	1.97	1.39	-	-	-	0.87	-	1.36
Parija	-	-	0.48	0.41	0.98	-	1.47	-	-	-	-	0.40
Zira	51.07	41.02	75.09	61.85	84.94	54.43	90.27	67.77	76.19	90.6	67.62	70.71
All Indians	55.78	41.02	75.57	64.12	85.93	55.82	91.73	69.53	76.19	91.4	67.62	72.66
All other MVs	-	0.04	-	-	-	-	-	0.62	1.07	0.04	-	0.12
All Hybrids	14.17	1.57	7.31	6.62	1.24	11.50	0.07	0.55	8.93	1.93	0.24	4.81
Grand Total	100	100	100	100	100	100	100	100	100	100	100	100

Naogaon upazilas: 1. Atrai, 2.Bodalgachi, 3.Damirhat, 4.Manda, 5.Mohadebpur, 6.Naogaon Sadar, 7.Niamatpur, 8.Patnitala, 9.Porsha, 10.Raninagar and 11.Sapahar.

traits such as earliness, lodging resistance, medium slender grain and longer panicle size, etc. However, occurrence of severe false smut, sheath blight, and low market demand become a critical barrier toward widespread adoption of BRRI dhan49. BRRI dhan52 could compete with Indian varieties in the low land for bearing the submergence tolerance trait.

It was observed that all upazilas, except Bodalgachi of this district was dominated by Zira, which was due to yield advantage, grain quality, required low intensive care, less susceptible to insects and diseases, high demand to the millers and lucrative prices. Nevertheless, BRRI dhan28 is still popular variety covering 48% areas in Bodalgachi upazila. It's noted that most of the farmers produce BRRI dhan28 for their home consumption only and Indian varieties for commercial purposes.

Following policy measures may be considered for rapid replacement of Indian varieties in the study areas:-

- Rice scientists must consider the preferences of the rice value chain actors and agro-climatic conditions of the border regions in the process of variety development. In this regard, short to medium growth duration higher yield potential, biotic and abiotic stress resistance along with good market demand of the variety should be considered;
- Effective block demonstration, proper extension services and ensuring availability of good quality seed to the farmers may help to escalate rapid dissemination of BRRI varieties in the border region of Bangladesh. In this regard, a bunch of desirable region-specific suitable rice varieties must be provided to the farmer's hand in order to replace Indian varieties.
- Scientists may also purify and select pure lines of the existing popular Indian varieties and release those as notified crop for Bangladeshi growers.

■ MAB Siddique, MS Islam, MJ Kabir, MA Salam, MA Islam, MI Omar, MAR Sarkar, MC Rahman, A Chawdhury, MS Rahaman and L Deb

FARM LEVEL ADOPTION AND EVALUATION OF MODERN RICE CULTIVATION

Rice is the staple food in Bangladesh. It provides about 55 and 75% of total protein and calorie of daily human diet (Siddique et al., 2016). About 75% of total cropped area is devoted to rice cultivation in the country. Bangladesh Rice Research Institute has developed 92 high yielding rice varieties along with six hybrids for different rice production environments. Most of the varieties are cultivated by the farmers of Bangladesh, but the adoption rate of these MVs differs substantially in different regions and seasons. Specific objectives of the study were as follows:

- Determine region-wise adoption rate of rice varieties in different regions and seasons; and
- Assess yield of diverse rice varieties in different regions and seasons.

Multistage random sampling technique was adopted in selecting the sample farmers. First, 35 in Aus season, 46 in T. Aman and 48 districts in Boro were selected on the basis of different adoption level from 14 agricultural regions of Bangladesh. One upazilla from each district was selected for each season. In total, sample size was 4,140 of which, Aus, T. Aman, and Boro farmers were 1,356, 1,328 and 1,456 respectively. The selected farmers were interviewed using a pretested semi-structured questionnaire. Descriptive statistics were used to achieve the set objectives.

Season-wise Adoption of modern rice varieties

Aus season. The overall adoption rate of modern rice varieties in Aus season was about 91% of which the coverage of BRRI developed varieties was about 66%. Among all the BRRI varieties, BRRI dhan48 ranked the top position (17%) in terms of area coverage followed by BRRI dhan28 (15%) and BR26 (7%). In Aus season, coverage of other MVs, Indian and hybrid were about 15, 6 and 5% respectively. Results also revealed that, area coverage of traditional varieties was about 9% in this season (Table 4).

T. Aman season. Although, overall adoption of BRRI varieties was apparently low (48% of total areas) in T. Aman season. However, of those varieties was substantially higher (ranges between 60-83% of total area) in some regions (region 6, 7, and 10-14). Although, overall adoption of BRRI dhan49 was higher about 11% of total area; whoever, adoption of the varieties in the some regions, such as Bogura (19%), Mymensingh (23%) and Dhaka (36.9%), was notable. Similarly, overall adoption of BR11 was only about 7% of total T. Aman area but the variety is still a very popular one in Rangamati (28%) and Sylhet (19%) region. Besides, overall adoption of BRRI dhan34 was only about 4% of total T. Aman area; however; the variety occupied considerable areas of the season in Dinajpur (27%) and Bogura (8.27%). Likewise, an overall adoption of Indian rice varieties was about 22% of total areas and adoption of those varieties was very high (43-58% of total areas) in Rangpur, Dinajpur, Bogura, Rajshahi and R5= Jashore region. Overall adoption of modern varieties (MVs) in T. Aman season was about 79%.This result indicates that there is still have some room of rising rice production through increasing adoption of MVs in T. Aman season (Table 5).

Boro season. The adoption of modern rice varieties (MVs) was about 99% of total Boro areas, of which 70% was BRRI varieties. BRRI dhan28 and BRRI dhan29 were the most dominant Boro varieties, covered about 61% of Boro areas in 2017-18. Among the recently released BRRI varieties, BRRI dhan50 has become a popular variety (12% of total areas) particularly in region five. Besides, adoption of BRRI dhan58 was notable in region ten (9% of total areas) and region three (3% of total). Similarly, adoption rate of BRRI dhan47 was 11% of total Boro areas in region seven. On the other hand, overall adoption of hybrids and Indian varieties was 16% and 11% respectively. Nevertheless, adoption

Table 4. Adoption (%) of different Aus rice varieties by agricultural regions of Bangladesh, 2017-18.

Variety	Reg1	Reg2	Reg3	Reg4	Reg5	Reg6	Reg7	Reg8	Reg9	Reg10	Reg11	Reg12	Reg13	Reg14	BD
BR21	0	0	0	16.16	0.07	0	0.01	0	0	0.02	2.17	1.94	9.31	6.38	4.74
BR26	0.7	0.29	1.56	2.68	10.51	8.76	2.39	4.55	16.96	6.11	7.73	1.99	22.32	11.86	6.86
BRRI dhan28	47.83	47.32	3.89	19.6	11.35	12.23	0.07	0.58	21.51	27.64	5.31	2.89	17.97	18.32	14.98
BRRI dhan48	19.67	3.46	44.21	9.37	30.27	17.88	16.27	9.66	25.73	15.81	10.42	3.31	19.01	31.74	17.28
Other BRRI	7.89	1.85	9.26	9.38	7.45	12.32	40.42	3.98	10.15	37.51	41.7	12.26	27.71	23.09	22.12
BRRI total	76.09	52.91	58.93	57.21	59.64	51.19	58.85	18.77	74.36	87.1	67.32	22.38	96.32	91.4	65.98
All Hybrid	21.79	27.2	6.51	2.95	14.1	4.98	0.48	1.79	0	4.56	4.61	5.64	0.16	0	4.97
All Indian	0	0	18.1	13.01	9.21	10.08	0.1	0	0	0.18	8.44	0.82	0.31	0	5.73
Other MVs	2	18.91	16.35	20.61	16.83	9.74	40.21	0.34	23.45	7.18	1.93	1.3	0.7	5.11	14.69
All MVs	100	98.92	99.89	93.78	99.78	75.99	100	20.9	97.81	99.01	82.31	30.15	97.48	96.51	91.38
Grand Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: R = Region, R1= Rangpur, R2= Dinajpur, R3= Bogura, R4 = Rajshahi, R5= Jashore, R6= Khulna, R7= Barishal, R8= Faridpur, R9 Mymensing, R10= Cumilla, R11= Chattogram, R12= Rangamati, R13= Dhaka, R14 = Sylhet and BD=Bangladesh, Source: Field survey, 2017-18.

of Indian varieties was very location specific, for example, adoption of Indian variety Zira was higher in region four (53%), followed by region three (16%). Moreover, adoption of Indian variety locally known as Miniket was higher in region three (17.44% of total area), followed by region five (16% of total area) region two (9%) (Table 6).

Yield of modern rice varieties

Tables 7, 8 and 9 present per hectare yield performance of modern rice varieties in different seasons and agricultural regions of Bangladesh.

Aus season. In Aus season, BRRI dhan48 produced the highest yield (4.01 ton/ha) and BRRI dhan28 and BRRI dhan55 ranked the second and third position with an average yield of 3.94 ton/ha and 3.86 ton/ha respectively. The yield of hybrid was also higher (5.01 ton/ha) compared to the Indian varieties (3.91 ton/ha) in this season. Average yield of all MVs in Aus season was 4.10 ton/ha (Table 7).

T. Aman season. Among BRRI varieties, BRRI dhan49 was the top yielder (4.62 ton/ha), followed by BRRI dhan52 (4.56 ton/ha) and BR11 (4.54 ton/ha) in T. Aman season whereas average yield of hybrid was 5.37 ton/ha. The productivity of Indian variety was 4.26 ton/ha. Average yield of BRRI varieties was 4.30 ton/ha and the overall yield of modern varieties (MVs) in this season was 4.52 ton/ha (Table 8).

In Boro season among all BRRI varieties, BRRIdhan29 was the top yielder (6.43 ton/ha) followed by BRRI dhan58 (6.03 ton/ha) and BRRI dhan63 (5.78 ton/ha). Average yield of hybrid was 7.27 ton/ha whereas BRRI hybrid yielded 7.63 ton/ha in this season (Table 9). Average yield of Indian varieties was 5.64 ton/ha and the overall yield of modern varieties in Boro season was about 6.05 ton/ha.

■ MAB Siddique, MS Islam, MJ Kabir, MA Salam, MA Islam, MI Omar, MAR Sarkar, MC Rahman, A Chawdhury, MS Rahaman and L Deb

ESTIMATION OF COSTS AND RETURN OF MV RICE CULTIVATION AT THE FARM LEVEL

Economic decisions are primarily concerned with the most profitable level of input use in the production process. The viability of a technology mostly depends on its cost and return. Therefore, it is indispensable to know the cost and return of rice cultivation where farmers used different types

Table 5. Adoption (%) of different T. Aman rice varieties by agricultural regions of Bangladesh, 2017-18.

Variety	Reg1	Reg2	Reg3	Reg4	Reg5	Reg6	Reg7	Reg8	Reg9	Reg10	Reg11	Reg12	Reg13	Reg14	BD
BR11	12.49	0.31	3.7	1.16	0.58	7.02	7.3	2.45	8.29	2.33	8.2	27.54	10.2	19.38	7.11
BR22	0	0	0.79	0	0.46	1.1	3.26	0	1.66	26.97	10.46	4.84	5.72	7.18	4.21
BR23	0.02	0	0	0.01	1.2	18.8	4.12	0.01	0.5	2.79	6.76	0.35	0.19	2.03	2.75
BRRI dhan33	1.73	0.07	0.97	0.96	3.23	0.52	0.14	22.89	0.62	0.27	0.71	9.82	0.24	0	1.29
BRRI dhan34	1.92	27.36	8.27	6.5	0.19	0.09	0.11	0.49	3.53	0.41	0.04	0	0.58	1.17	4.04
BRRI dhan49	3.13	4.06	19.08	8.27	12.48	8.5	0.8	4.8	23.09	10.19	8.2	14.35	36.9	17.8	11.41
BRRI dhan51	2.51	1.99	1.28	4.44	2.29	0.61	0.78	1.67	2.69	1	2.12	1.09	2.03	3.53	2.08
BRRI dhan52	7.04	1.47	1.06	1.18	1.39	1.98	5.02	2.94	2.85	1.42	4.08	0.97	1.48	4.11	3.11
Other BRRI	6.23	1.63	2.75	3.35	13.88	21.62	11.31	33.44	11.56	17.54	21.35	23.94	10.53	15.88	11.75
BRRI total	35.08	36.88	37.89	25.9	35.7	60.26	32.85	68.67	54.81	62.94	61.94	82.87	67.87	71.08	47.76
All hybrid	5.21	3.81	1.81	0	3.34	0.24	0.03	0.59	1.53	0.01	0.45	0.94	0.17	0	1.47
All Indian	52.11	52.7	42.87	58.43	48.9	5.04	1.82	0.14	1.96	0.91	2.78	1.73	2.53	0.36	21.69
Local	2.98	2.2	3.93	9.04	0.67	30.07	63.17	21.42	23.9	33.79	25.75	6.54	12.97	25.84	21.19
Other MVs	4.62	4.4	13.49	6.64	11.39	4.38	2.13	9.17	17.8	2.35	9.07	7.92	16.46	2.71	7.9
All MVs	97.02	97.8	96.07	90.96	99.33	69.93	36.83	78.58	76.1	66.21	74.25	93.46	87.03	74.16	78.81
Grand Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: R = Region, R1= Rangpur, R2= Dinajpur, R3= Bogura, R4 = Rajshahi, R5= Jashore, R6= Khulna, R7= Barishal, R8= Faridpur, R9 Mymensing, R10= Cumilla, R11= Chattogram, R12= Rangamati, R13= Dhaka, R14 = Sylhet and BD=Bangladesh, Source: Field survey, 2017-18.

Table 6. Adoption (%) of different Boro rice varieties by agricultural regions of Bangladesh, 2017-18.

Variety	Reg1	Reg2	Reg3	Reg4	Reg5	Reg6	Reg7	Reg8	Reg9	Reg10	Reg11	Reg12	Reg13	Reg14	BD
BRRI dhan28	44.33	36.75	24.2	26.98	45.3	57.01	10.83	15.3	43.35	38.45	27.27	36.05	28.08	32.9	34.8
BRRI dhan29	20.18	21.6	20.84	5.78	2.07	0.43	18.35	37.69	28.06	35.89	14.29	10.67	63	39.26	26.25
BRRI dhan50	0.6	1.39	0.42	1.39	12.46	1.15	0.72	1.51	0.29	0.76	1.08	1.6	0.64	0.51	1.78
BRRI dhan58	1.62	1.42	3.07	0.09	0.45	0.15	0.29	2.3	1.85	9.19	1.37	0.49	1.41	2.1	2.14
Other BRRI	3.77	6.96	3.66	3.65	3.4	1.86	15.6	3.41	7.46	5.77	17.62	11.43	1.54	3.09	5.03
BRRI total	70.51	68.12	52.21	37.9	63.68	60.6	45.78	60.21	80.99	90.05	61.63	60.23	94.67	77.85	70.00
All hybrid	28.65	10.24	9.63	4.83	7.73	35.11	31.09	28.74	17.04	9.25	32.69	38.61	4.5	20.91	15.62
All Indian	0.32	15.27	35.36	52.87	25.74	1.5	0.07	0	0.14	0.1	0.2	0.32	0.06	0	11.24
Other MVs	0.37	6.37	1.86	4.4	2.85	2.26	17.05	7.99	1.64	0.48	5.48	0.83	0.11	0.43	2.57
All MVs	99.83	100	99.05	100	100	99.47	93.99	96.94	99.81	99.88	100	100	99.34	99.19	99.42
Grand Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: R = Region, R1= Rangpur, R2= Dinajpur, R3= Bogura, R4 = Rajshahi, R5= Jashore, R6= Khulna, R7= Barishal, R8= Faridpur, R9 Mymensing, R10= Cumilla, R11= Chattogram, R12= Rangamati, R13= Dhaka, R14 = Sylhet and BD=Bangladesh, Source: Field survey, 2017-18.

Table 7. Yield (t/ha) of different Aus rice varieties by agricultural regions of Bangladesh, 2017-18.

Variety	Reg1	Reg2	Reg3	Reg4	Reg5	Reg6	Reg7	Reg8	Reg9	Reg10	Reg11	Reg12	Reg13	Reg14	BD
BR21				4.22	3.86		4.15			3.88	3.32	4.12	3.94	3.39	3.77
BR26	3.68	3.66	3.5	3.84	3.87	3.71	3.69	3.48	3.52	3.67	3.72	3.41	3.77	3.49	3.67
BRRI dhan28	4.25	4.12	3.67	4.31	3.97	3.75	3.58	3.17	3.79	4.06	3.66	4.72	4.28	3.47	3.94
BRRI dhan48	4.24		4.15	4.69	4.14	3.76	3.75	3.23	4.06	4.42	4.15	4.49	4.02	3.67	4.01
Other BRRI	4.09	3.65	3.38	4.31	3.95	3.54	3.52	3.34	3.83	3.79	3.68	4.06	3.91	3.50	3.73
BRRI varieties	4.09	3.81	3.54	4.29	3.97	3.61	3.56	3.36	3.75	3.86	3.68	4.1	4.0	3.52	3.79
All Hybrid	5.42	4.61	4.24	5.55	4.84	4.91	5.03	4.51		4.37	5.61	5.18	4.55		5.01
All Indian			3.72	4.2	3.92	4.17	3.81			3.62	3.7	3.62	3.63		3.91
Local		2.89	2.29	2.2	2.09	2.42		2.1	2.19	2.32	1.82	2.2	2.17	1.74	2.1
Other MVs	3.81	3.72	3.57	4.05	3.95	3.35	3.31	3.48	3.89	3.48	3.81	3.98	4.28	3.22	3.7
All MVs	4.44	4.05	3.77	4.52	4.17	4.01	3.93	3.78	3.82	3.83	4.20	4.22	4.12	3.37	4.10
Grand Total	4.76	4.16	3.63	4.33	4.25	3.8	3.72	2.81	3.43	3.6	3.42	3.43	3.73	2.87	3.73

Note: R = Region, R1= Rangpur, R2= Dinajpur, R3= Bogura, R4 = Rajshahi, R5= Jashore, R6= Khulna, R7= Barishal, R8= Faridpur, R9 Mymensing, R10= Cumilla, R11= Chattogram, R12= Rangamati, R13= Dhaka, R14 = Sylhet and BD=Bangladesh, Source: Field survey, 2017-18.

Table 8. Yield (t/ha) of different T. Aman rice varieties by agricultural regions of Bangladesh, 2017-18.

Variety	Reg1	Reg2	Reg3	Reg4	Reg5	Reg6	Reg7	Reg8	Reg9	Reg10	Reg11	Reg12	Reg13	Reg14	BD
BR11	4.34	4.5	4.87	4.67	4.73	4.76	4.33	4.61	4.58	4.37	4.43	4.64	4.39	4.55	4.54
BR22	4.01		4.22		4.93	4.57	4.34		4.44	4.19	4.41	4.36	4.14	4.24	4.32
BR23	3.56			4.66	4.27	4.75	4.37	3.51	4.15	4.11	4.41	3.92	3.89	4.3	4.2
BRRI dhan33	3.76	4.38	4.89	5.16	4.05	4.45	4.31	4.32	3.93	4	4.14	4.43	4.17		4.24
BRRI dhan34	3.89	3.5	3.95	3.35	3.85	4.01	3.93	3.82	3.48	3.61	3.89		3.65	3.74	3.75
BRRI dhan49	4.14	4.48	5.04	4.79	4.98	4.62	4.49	4.95	4.52	4.46	4.5	4.75	4.62	4.44	4.62
BRRI dhan51	4.16	4.61	4.87	5.22	4.68	4.32	4.42	4.39	4.23	4.09	4.55	4.31	4.33	4.32	4.45
BRRI dhan52	4.29	4.58	5.17	5.02	4.87	4.59	4.44	4.8	4.37	4.18	4.55	4.77	4.36	4.32	4.56
Other BRRI	3.99	4.26	4.46	4.49	4.39	4.36	4.21	4.63	4.15	4.06	4.18	4.35	4.11	4.19	4.26
BRRI varieties	4.02	4.3	4.63	4.59	4.48	4.43	4.26	4.47	4.19	4.09	4.23	4.39	4.19	4.23	4.3
Hybrid_BRRI	4.78							6.01							5.7
All hybrid	5.04	5.14	5.37		5.76	5.82	5.46	6.01	5.26	5.67	5.83	6.35	5.43		5.37
All Indian	4.26	4.47	4.9	5.05	4.47	4.19	3.27	4.18	3.8	3.19	4.28	3.77	3.21	3.85	4.26
Local	2.55	2.97	2.62	2.78	2.41	2.54	2.45	2.55	2.56	1.98	2.49	2.6	2.35	2.58	2.45
Other MVs	3.96	4.01	4.65	3.88	4.59	4.56	4.09	4.67	4.03	4.04	4.03	3.97	3.99	4.17	4.16
All MVs	4.32	4.48	4.89	3.38	4.83	4.75	4.27	4.83	4.32	4.25	4.59	4.62	4.21	3.06	4.52
Grand Total	3.99	4.35	4.42	4.28	4.4	3.42	3.22	3.86	3.61	2.9	3.59	4.26	3.48	3.51	3.68

Note: R = Region, R1= Rangpur, R2= Dinajpur, R3= Bogura, R4 = Rajshahi, R5= Jashore, R6= Khulna, R7= Barishal, R8= Faridpur, R9 Mymensing, R10= Cumilla, R11= Chattogram, R12= Rangamati, R13= Dhaka, R14 = Sylhet and BD=Bangladesh, Source: Field survey, 2017-18.

of technologies. Moreover, through the cost and return analysis researcher and planners can get indication in developing a technology which will help the farmers in increasing return and reducing cost. Thus, the present study has been undertaken to assess the profitability of rice cultivation in the country with the following specific objectives to:

- Determine the level of inputs used in MV Aus, MV T. Aman and MV Boro rice cultivation;
- Estimate the cost of MV rice cultivation in different seasons; and
- Evaluate the profitability of MV Aus, MV T. Aman and MV Boro rice cultivation at the farm level.

Multistage random sampling technique was adopted to select farmers from all agricultural regions of Bangladesh. Farm level data on input use pattern, prices of inputs and outputs and yields were collected from 80, 136, 127 farmers for the Boro, T. Aman and Aus season respectively. Thus, in total respondents were 343 rice growing farmers. Data were collected through face to face interview using a structured questionnaire. Mainly, descriptive statistical technique was applied to analyse the data and tabular technique was used to present the results.

Profitability. Per hectare yield of Boro rice (5,883 kg) was higher followed by T. Aman rice (4,621 kg) and T. Aus rice (4,262 kg). Despite higher yield per hectare, gross margin of MV Boro rice (Tk. 21,391) was lower than that of MV T. Aman rice (Tk. 47,704) and MV T. Aus rice (Tk. 29,803) (Table 11). It can be noted that the farmers obtained higher return from T. Aman and T. Aus rice due to low production cost and higher farm gate price of paddy, BCR on cash cost basis of T. Aman was higher (1.8) followed by T. Aus (1.5) and Boro (1.2) (Table 10).

■ MAB Siddique, MS Islam, MJ Kabir, MA Salam, MA Islam, MI Omar, MAR Sarkar, MC Rahman, A Chawdhury, MS Rahaman and L Deb

PREFERENCE ANALYSIS OF T. AMAN RICE VARIETIES IN THE COASTAL AREAS

Preference analysis (PA) is a process, used by social and biological scientists to identify the best suited new crop varieties for large scale dissemination in the farmers' fields. The specific objective of the study was: to identify the most preferred T. Aman rice varieties in the areas.

The study area was Pankhali village of Dacope, Khulna and Kallanpur village of Amtali, Barguna. BRRI conducted trials on different T. Aman rice varieties under ACIAR and KGF funded a collaborative project. The preference analysis was carried out based on the performance of T. Aman season 2017/18.

Preference outcomes: Pankhali, Dacope

Table 11 presents preference score of WS rice varieties in Pankhali village. BRRI dhan76 was he most preferred variety to farmers in Dacope followed by check variety BR23. BRRI dhan73 was ranked as the least preferred variety in the village.

Table 9. Yield (t/ha) of different Boro rice varieties by agricultural regions of Bangladesh, 2017-18.

Varieties	Reg1	Reg2	Reg3	Reg4	Reg5	Reg6	Reg7	Reg8	Reg9	Reg10	Reg11	Reg12	Reg13	Reg14	BD
BRRI dhan28	5.27	5.6	5.98	6.11	6.07	5.85	5.75	6.15	5.08	5.52	5.33	5.42	5.81	4.73	5.68
BRRI dhan29	6.69	6.32	6.78	7.12	6.67	6.21	6.14	6.88	6.17	6.09	5.76	6.07	6.85	5.02	6.43
BRRI dhan50	5.38	5.38	5.74	5.84	6.13	5.72	6.07	5.92	5.45	5.51	5.38	5.08	5.71	4.6	5.63
BRRI dhan58	5.66	6.32	6.4	6.48	6.35	5.62	5.99	6.4	5.59	5.89	5.68	5.51	6.43	4.93	6.03
Other BRRI	5.31	5.88	5.76	6.17	6.03	5.68	5.74	6.12	5.39	5.43	5.47	5.30	5.81	4.74	5.57
BRRI varieties	5.42	5.89	5.73	6.24	6.18	5.72	5.81	6.2	5.44	5.6	5.45	5.32	6.06	4.78	5.73
All hybrid	7.23	6.83	7.55	7.45	7.02	7.14	7.47	7.89	7.03	7.30	6.96	6.78	7.34	5.33	7.27
All Indian	5.45	5.86	5.83	6.2	5.88	5.85	4.63	4.48	4.48	5.07	4.75	4.69	4.54	0	5.64
Other MVs	5.3	5.52	5.57	5.77	6.04	5.71	5.59	6.08	5.33	5.3	5.32	4.66	5.8	4.75	5.55
All MVs	5.85	6.03	6.17	6.42	6.28	6.11	5.88	6.16	5.57	5.82	5.62	5.36	5.94	3.72	6.05
Grand Total	6.51	6.39	6.65	6.72	6.51	6.42	6.46	6.39	6.12	6	6.17	6.09	5.97	5.05	6.27

Note: R = Region, R1= Rangpur, R2= Dinajpur, R3= Bogura, R4 = Rajshahi, R5= Jashore, R6= Khulna, R7= Barishal, R8= Faridpur, R9 Mymensing, R10= Cumilla, R11= Chattogram, R12= Rangamati, R13= Dhaka, R14 = Sylhet and BD=Bangladesh, Source: Field survey, 2017-18.

Table 10. Per hectare cost and return of MV rice cultivation in different seasons in Bangladesh, 2017-18.

Items	Aus	Aman	Boro
Total costs (BDT/ha)	83,398	89,686	121,499
Total paid-out cost costs (BDT/ha)	61,749	59,367	90,324
Total imputed cost (BDT/ha)	21,649	30,319	31,175
Yield (kg/ha)	4,262	4,621	5,883
Market value of paddy (BDT/ha)	85,240	94,731	102,953
Market value of straw (BDT/ha)	6,312	12,340	8,762
Gross benefit (BDT/ha)	91,552	107,071	111,715
Gross margin (BDT/ha)	29,803	47,704	21,391
Net return (BDT/ha)	8,154	17,384	-9,785
Unit price of grain (BDT/kg)	20.0	20.5	19.5
Unit cost of production (BDT/kg)	19.6	19.4	20.7
BCR (cash cost basis) (Undiscounted)	1.5	1.8	1.2
BCR (full cost basis) (Undiscounted)	1.1	1.2	0.92

Source: Authors' calculation.

Farmers voted for BRRI dhan76 because of taller height of seedling, long panicle with large number of glossy colour medium bold grain (250-350), higher yield (5.3 t/ha) than the check BR23 (4.3 t/ha) and Shadamota (3.2 t/ha). Besides, it matured after drained out the stagnant water from the fields, less or no lodging susceptibility and less susceptible to pest such as no BLB infestation despite rainfall at reproductive phase. It had no infestation of other insects and diseases despite no pesticides application; and rat was unable to cut the panicle due to taller plant height. These were also the important criteria of preferring BRRI dhan76. Farmers reported drawbacks about BRRI dhan76 included less tillering capacity, apprehension of lodging as the plants are too tall, longer growth duration might be the barrier of timely Rabi crops planting, shattering of the over matured rice.

Farmers voted for BR23 mainly because of medium height of the plant with less/no lodging, higher littering capacity even in the anaerobic condition, good yield despite late planting after harvesting Aus rice and planting in the low to medium low areas, ensured market demand and higher price, good eating quality, matured for harvesting after drained out stagnant water from fields, less susceptible to lodging, less pest infestation.

Preference outcomes: Kalnanpur, Amtali

BRRI dhan54 was the most preferred variety at Amtali followed by BRRI dhan77. Similarly, BBRI dhan73 ranked as least preferred variety in Amtali (Table 12). Farmers voted for BRRI dhan54 because of higher yield than local check varieties. Besides, the variety is matured for harvesting about 25-40 days earlier than the check varieties after drainage out the stagnant water from fields. In addition, the variety is ready for harvesting at food and feed scarce period so that price of both grain and straw is higher even at harvesting season. Besides, farmers liked it as they get adequate turnaround time for planting dry season crops within the optimum planting period, had less pest infestation, good eating quality, more tillers per hill and long panicle with cylindrical bold grain.

Farmers voted for BRRI dhan77 mainly because of its environmental suitability particularly its taller height of seedling which is suitable for planting in the fields with about a feet depth stagnant water and matured for harvesting after drainage out stagnant water. Besides, long panicle with large number of grain producing higher yield is an important criterion of preference. In addition, the variety was less susceptible to pest and lodging. On the other hand, major causes of rejecting BRRI dhan73 was included fewer tillers per hill, less number of grains per panicle so that expected low yield, shorter growth duration so that matured for harvesting before drained out the stagnant water in the fields. Farmers gave negative vote for BRRI dhan76 mainly because of less tillering ability resulting low yield. Additionally, taller plant height also considered as negative trait in apprehension

Table 11. Preference score for T. Aman rice varieties in Pankhali, Dacope, 2017.

Variety	Preference score					Rank
	Male	Female	Farmer	Scientist	Total	
BRRI dhan76	0.225	0.167	0.308	0.300	0.215	1
BR23	0.083	0.067	0.117	0.100	0.080	2
BR11	-0.150	-0.133	-0.217	-0.150	-0.145	3
Baran	-0.117	-0.067	-0.150	-0.150	-0.105	4
BRRI dhan73	-0.042	-0.033	-0.058	-0.100	-0.045	5

Table 12. Preference score for T. Aman rice varieties in Kalnanpur, Amtali, 2017.

Variety	Preference score					Rank
	Male	Female	Farmer	Scientist	Total	
BRRI dhan54	0.138	0.109	0.13	0.143	0.131	1
BRRI dhan77	0.113	0.094	0.10	0.214	0.125	2
Sornogota	0.050	0.031	0.04	0.000	0.036	3
BR23	0.013	0.000	0.01	-0.107	-0.012	4
BR11	-0.038	0.000	-0.02	-0.179	-0.048	5
BRRI dhan76	-0.075	-0.094	-0.08	0.071	-0.060	6
Vojon	-0.075	-0.031	-0.06	-0.143	-0.071	7
BRRI dhan73	-0.125	-0.109	-0.12	0.000	-0.101	8

Source: Authors' calculation

of lodging susceptibility because rain with ghastly wind is usual phenomenon in November in the coastal areas of Bangladesh.

■ MJ Kabir, M Moniruzzaman and MAB Siddique

VERTICAL PRICE TRANSMISSION OF RICE IN BANGLADESH

The food grain marketing chains in developing countries tend to be long and complex because of the involvement of many small-scale intermediaries. In case of Bangladeshi rice market, unreliable evidence and casual observation supports the idea of price asymmetry. Specifically, it is widely believed that price increases emanating at the farm or wholesale level are quickly passed on in terms of higher prices at the wholesale or retail level, but at farm or wholesale price decreases do not lead to similar price decreases at the wholesale or retail level. With this in mind, this study intends to investigate whether the widely held perception of asymmetric price transmission actually exists or not. Thus we have to examine the vertical price transmission along with the rice supply chain of Bangladesh.

Fluctuation or variability of price in the rice market was examined with ARDL model expressed as below:

$$\Delta y_t = \alpha_0 + \rho y_{t-1} + \theta x_{t-1} + \gamma z_t + \sum_{j=1}^{p-1} \alpha_j \Delta y_{t-j} + \sum_{j=0}^{q-1} \pi_j \Delta x_{t-j} + e_t \quad (1)$$

Where z_t is a vector of deterministic regressors (trends, seasonals, and other exogenous influences, with fixed lags) and e_t is an iid (independent and identically distributed) stochastic process. Table 13 presents the findings of asymmetric ARDL model estimation including both short- and long-term dynamics. The $WALD_{LR}$ tests the null hypothesis of long run symmetry and the $WALD_{SR}$ tests the null hypothesis of short run symmetry. The null hypotheses of long run and short run symmetry are rejected at 1% significance level. It means that there are short and long run asymmetric effects of wholesale and farm rice prices on retail price in Bangladesh. The co-integration test (F_{PSS}) rejected the null hypothesis of no co-integrating relationship between farm, wholesale, and retail price series. That means the price series are correlated. An increase or decrease in the farm price led to increase or decrease in the wholesale and retail prices. The long-term coefficients of the NARDL model indicated that the effect of positive and negative changes in wholesale price (L_W^+ and L_W^-) on retail price were statistically significant at the 5% level. But, the sizes of the coefficients were not similar to each other. The long-term coefficient of the positive farm price change (L_F^+) was 0.635 and statistically significant at the 10% level. The coefficient of negative farm price change (L_F^-) was neither as large as the coefficient of positive farm price change (L_F^+) nor significant. So, these findings indicate that optimal model for the price transmission from farm to retail through wholesale level along the Bangladesh rice supply chain should include asymmetric relation both in the short run and long run. The error correction term (ECT) result showed that about 19.33 percent of the gap between long run equilibrium value and the actual value of the dependent variable (retail price) has been corrected monthly. Its speed of adjustment towards long run equilibrium was 19.33 percent monthly.

■ MC Rahman and MAB Siddique

WELFARE EFFECT OF ADAPTATION POLICY FOR RICE PRICE VARIATION UNDER CLIMATE CHANGE

The present study attempts to measure the changes in surplus and net social welfare of the climate adaptation policy using the surplus approach, in particular "to what extent do the producers and consumers actually benefit from the aforesaid policy," in the era of climate change. This study evaluates the change in the social welfare effects of the adaptation policy using a partial equilibrium model. Data on rice production was gathered from the Bangladesh Bureau of Statistics (BBS, 2014).

Table 13. Results of the asymmetric ARDL model estimation.

Asymmetric ARDL Model			
Variable	Coefficient	Standard error	t-statistic
	1.6387***	0.3193	5.1315
	-0.1825***	0.0352	5.1925
	0.1720***	0.0514	3.3449
	0.1281***	0.0429	2.9863
	0.1159*	0.0695	1.6684
	0.0813*	0.0415	1.9571
	0.6089***	0.0675	9.0164
	0.1842**	0.0828	2.2247
	-0.1347*	0.0794	-1.6973
	-0.1614**	0.0785	-2.0553
	0.2334**	0.1155	2.0214
= 9.1349***			= 0.9426**
= 5.2162**			= 0.7020**
= 0.6351*			= 0.4452
= 18.466***			= 9.282***
Diagnostics			
ECT = -0.1933***			JB = 6.90
ARCH = 0.0091			LM = 1.9567
CUSUM = S			AIC = -2.6034
CUSUMQ = S			SIC = -2.3689

Note: JB = Jarque-Bera test for normality, LM = The Breusch-Godfrey LM test for serial correlation, ARCH = ARCH test for heteroscedasticity, S = Satisfied, ECT is the long run error correction term and F_{PSS} denotes the PSS F-statistic testing the null hypothesis $\rho = \theta_1 = \theta_2 = 0$. The critical values for F_{PSS} test, attained from Pesaran, *et al*., 2001, lower bound and upper bound at the 5% significant level. L_W is the long run coefficient for wholesale price and L_F is the long run coefficient for farm price. '***', '**' and '*' denote the significance at the 1%, 5% and 10% levels, respectively.

Furthermore, all other required data were collected from World Rice Statistics, FAOSTAT, and World Databank. Then, data on historical temperature, rainfall, and solar radiation were obtained from the Data Distribution Centre of the Intergovernmental Panel on Climate Change (IPCC).

To mitigate the estimated variation, this study simulated the additional public storage of 1.30 million is required. With exception for food budget allocation, public budget allocation is needed for warehouse construction as well as quality protection.

The government of Bangladesh can carry out the public food policy activities in order to assist both farmers and consumers during drastic fall in paddy price as well as high price in retail market respectively. To derive concrete decisions with regard to policy variables, Salam *et al.* (2016) estimated the policy efficiency index, which calculates the magnitude of price variation or reduction in price by per unit of additional budget for public food operation from partial equilibrium model. To examine the effects of the policies on the price variations, we set a practical policy criterion where if a price level is 10% higher or lower than a linear approximated trend line, the government should take a special policy. Based on efficiency index, procurement price was decided as suitable policy variable for farmers and subsidized price for consumers. To examine the effects of both policies, we assume that each policy is implemented separately in future outlook.Once the extended support price policy was implemented to examine the policy effect as a special policy on producer welfare,we apply an average support price that is 60% higher thanthe baseline in the year of 2013, 2022, 2028 as well as 2029. Sharp price falls are mitigated and price hikes are not significantly affected. Consequent reduction in variation (CV) from price falling is 1.49 percent. Moreover, the positive change in producer surplus (US$ 1,981 million) in the policy intervened years considerably while the consumers are substantially worse off with the support price policy (US$ –1,785 million). Moreover, the change in net social welfare, which is obtained by subtracting the adaptation policy cost from total surplus, is equivalent to US$–4,351 million.

To examine the effects of the extended subsidized price policies on social welfare in the same fashion,we also apply 75% more reduction compared to baseline of the subsidized price to consumers in 2018, 2019, 2020 as well as 2024. The extended subsidized price policy mitigates price hikes but it does not significantly affect price falls. Consequent reduction in price variation (CV) is 1.38 percent. The result shows consumers are substantially better off with the subsidized price policy: positive change in consumer surplus (US$ 1,501 million) in the policy intervened years while producers are worse off with this food policy (US$ –724 million). Eventually, this policy contributes to the net change in social welfare amounting to US$–5,199 million (USD) after deducting the adaptation policy cost.

Implementing this adaptation policy requires a higher amount of additional public stock (1.50 million tons), which exceeds the level of the current public ending stock. This is one of the major limitations of this policy. These results imply that to mitigate both price hikes and falls simultaneously in the era of climate change, it is a must to establish a dual policy covering support price and subsidized price. Then, we apply a dual policy, which includes price support to the farmers as well as subsidize the consumers. The Once the dual price policy is integrated into the simulation, the projected results show that on average 2.34% variation of both farmers and consumer prices could be reduced. We further noticed a substantial positive change in both surpluses (worth US$5,532 million) and net social welfare (worth US$ –5,547 million) considerably positively higher change in gains compared to that obtained from individual policy implementation. Even though the difference in the magnitude of the change in surplus remains significant, the dual policy dramatically increases the gains for both types of households in aggregate.

Necessity of the food policy operation

Assuming that the scenario of per capita GDP (simulated data scenarios adopted from population and GDP scenarios in SSP2 for the period 2010-2030) is log normally distributed. The previous studies also calculated poverty level using the log normal distribution of income. The parameters (mean and standard deviation) for log normal distribution are computed from national Household Income and Expenditure Survey (HIES) 2010. Then using the estimated parameters and poverty head count numbers (31.5%) in base year 2010 from HIES into inverse of log normal distribution, the poverty line is computed and this is considered as base poverty line for 2010. The base poverty line is weighted with the per capita GDP of SSP2 scenario over the period 2011-2030, the poverty line for entire period is found, the new poverty line as well as density function for per capita GDP of SSP2 scenarios in the era of climate change is estimated to be on average 21% of the population in Bangladesh and they will be vulnerable to expenditure increase associated with the sharp rise in rice price. The bolded dotted vertical line is base year weighted poverty line (Fig. 2). The log normal distribution curve implies the density function of the per capita GDP of SSP2. Again, share of household expenditure on rice is collected from Household Income and Expenditure Survey 2010 in Bangladesh indicating that 39% of total expenditure of the households living in the poverty line is on rice consumption. The vertical dotted line is shifted from baseline with the scenario 1 and the bold dotted vertical line with the scenario 2. Compared with the base year of 2010 in the model, the retail price of rice increase to 25 percent in 2011-2020 and further rise to 43 percent in 2021-2030 which is attributed to climate change, the new poverty line is calculated based on scenario 1: 25% increase of rice expenditure with the rise of rice price and scenario 2: 43% increase of rice expenditure (Fig. 2).

If 25% of rice expenditure increases with the rise of rice price, the new poverty line shifted to right side leading to increase the volume of vulnerable people on poverty line by 4% (25%). Similarly, if 43% of rice expenditure increases with the rise of rice price era of 2017–2030, the poverty will increase to 28% of the total population. This result indicates that the variation of rice price will increase the vulnerability of household in Bangladesh as rice is the main source of foodstuff. The poor and marginalized households are particularly vulnerable to adverse erosion of real purchasing power and thereby enlarging the number of households below the poverty line income in Bangladesh. Even though the social welfare of policy operation is found to be negative, the allocation of food budget for policy operation is unavoidable in the era of climate change (Fig. 2).

■ MA Salam and MAB Siddique

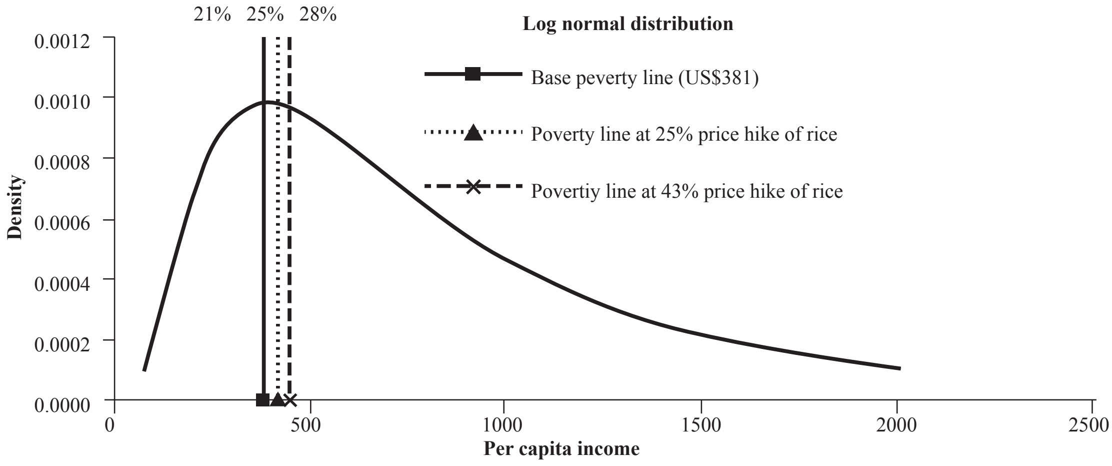


Fig. 2. Impact of variation of rice price on poverty line and food expenditure.

Agricultural Statistics Division

SUMMARY

In T. Aman season, BRRI dhan49 was found near to stable with stability index 1.97 while BR3, BR5, BRRI dhan33, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan56, BRRI dhan57, BRRI dhan70, and BRRI dhan77 appeared to be below average stable. BR4, BR10, BR11, BR22, BR23, BR25, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan66, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan76, BRRI hybrid dhan4, BRRI hybrid dhan6 were found having average stability among T. Aman varieties. Due to lodging, onslaught of bird and rat damage in some locations BRRI dhan62 and BRRI dhan34 were found unstable in T. Aman season.

For long duration varieties Gazipur, Satkhira and Sonagazi were found discriminating locations/ environment because these locations have large PC2 score/longest vector. Cumilla, Rangpur and Sonagazi were the most discriminating location for medium duration varieties. On the other hand, Barishal, Cumilla and Gazipur were the most discriminating locations for short duration varieties. Among the nine locations ideal environment were found in Rajshahi, Kushtia for medium duration varieties and Sonagazi for short duration. Overall, the most promising genotypes BRRI dhan30, BR10 for long duration, BRRI dhan32, BRRI dhan72, BRRI dhan49 for medium duration and BRRI dhan75, BRRI hybrid dhan4, BRRI dhan66 for short duration with high mean yield and stability could be used for commercial cultivation across different locations. Among the genotypes, BRRI dhan30 was ideal for long duration, BRRI dhan32 for medium duration and BRRI dhan75 for short duration.

Seasonal weather forecasting for rice production generated the weather forecast for the specific time of Boro season at *haor* regions as well as made the agro meteorological advisory services based on weather forecasting and this information disseminates through DAE to the farmer's level of that region.

Location wise the highest yielded varieties were found at Barishal (BRRI dhan31, 7.00 t ha^{-1}) and the lowest in Rangpur (BRRI dhan77, 1.97 t ha^{-1}) for T. Aman 2016 season. The yield performances of the same variety at different locations were different. The causes of the yield difference may be due to the soil and the climatic variation in the locations. The maximum temperature has positive effect on yield of BRRI dhan57 and BRRI dhan66 and negative effect of BRRI dhan38. The other climatic factors showed significant positive effect for minimum temperature and negative effect for rainfall, humidity and sunshine.

BRRI dhan50 is suitable in south and eastern areas, BRRI dhan63 is western areas and BRRI dhan66 is suitable in north-western areas of Bangladesh in Boro season. In T. Aman season, BRRI dhan71 is suitable in north-western areas and western areas of Bangladesh are suitable for BRRI dhan72. Productivity will increase, if rice varieties were cultivate according to their suitable areas.

More or less, all seasons in eastern areas are prone to high rainfall and low temperature area and western areas have comparatively low rainfall and high temperature in Bangladesh.

Online application system has been developed by Teletalk Mobile Company Ltd with the help of ICT Cell of Agricultural Statistics division and Administration of BRRI.

STABILITY ANALYSIS OF BRRI VARIETIES

The main objectives of the study were to determine the stability index of BRRI developed rice varieties, maintaining season, year and location-wise database and to identify the bio-physical and socio-economic factors causing instability. Experiments are being conducted in T. Aman with BRRI varieties since T. Aman 2002-17 in 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 season, the number of varieties is 38. The design is RCB with three replications and the effective plot size (harvest area) is 2.6×2.6 m^2 leaving the two border row from each side. Recommended crop management practices are followed. Stability analysis of the experimental data was 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.

Among the T. Aman varieties, BRRI dhan49 was found near to stable with stability index 1.97 while BR3, BR5, BRRI dhan33, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan56, BRRI dhan57, BRRI dhan70, and BRRI dhan77 appeared to be below average stable. BR4, BR10, BR11, BR22, BR23, BR25, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan66, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan76, BRRI hybrid dhan4, BRRI hybrid dhan6 were found having average stable. Due to logging bird and rat damage in some location BRRI dhan62 and BRRI dhan34 were found unstable variety in T. Aman season.

GENOTYPE × ENVIRONMENT INTERACTION OF BRRI VARIETIES

The development of rice varieties is affected by effects of 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 experiment was conducted in multi environment trials for rice growing seasons in Bangladesh. BRRI developed rice varieties (Aman) were used at ten environmental conditions; Barishal (E1), Bhanga (E2), Cumilla (E3), Gazipur (E4), Kushtia (E5), Rajshahi (E6), Rangpur (E7), Satkhira (E8) and Sonagazi (E9). The experimental sites were covered all the ecosystems of Bangladesh. The experiments were carried out in a randomized complete block design (RCBD) with three replications and evaluated for rice grain yield. Each experimental plot was comprised of 3m × 2m. Standard agronomic practices were followed and plant protection measures were taken as required following the recommendation of Adhunik Dhaner Chash, BRRI (2016). AMMI model were used to quantify the effect of different factors (genotype, location) of the experiment. The objectives of this study were to identify BRRI developed 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 and contributed the most part of total variation by the environment (E) for all categories, which explained 50.50, 42.32 and 47.59% of the total variation for long, medium and short duration respectively. Additionally, the relative contribution of genotype sum of squares was found 15.75, 11.79 and 10.15% for long, medium and short duration respectively. Genotype by environment (G × E) contributed the most 35.54% to the total variation for medium duration followed by 30.53% and 22.29% for short and long duration. Greater portion of total variation was explained by environmental main effect indicated 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 adapted rice genotype (s) is essential.

Evaluation of test environments

The genotype and genotype by environment (GGE) biplot explained 67.55, 59.4, and 73.66% of the total variation of the environments for long, medium and short duration respectively. GGE biplot showed three distinct clusters in long duration: one containing Barishal (E1), Kushtia (E5) and Rajshahi (E6), the second containing Gazipur (E4) and Satkhira (E8) and the third one containing Rangpur (E7) and Sonagazi (E9) (Fig. 1a). The closest association was observed between the environments of Barishal (E1) and Kushtia (E5). The location Bhanga (E2) showed negative or no correlation with Cumilla (E3), Rangpur (E7) and Sonagazi (E9). Also Cumilla (E3) was found having negative or no correlation with Barishal (E1), Bhanga (E2) and Gazipur (E4). The ideal environment was found in Rajshahi (E6) for long duration (Fig. 1a). Gazipur

(E4) and Satkhira (E8) had the longest vector and hence was a highly discriminating location (Fig. 1a). But, its angle with the AEA is greater for Gazipur (E4) and environments Satkhira (E8) showed acute angle with the AEA. The location Rajshahi (E6) was highly representative of other locations. Considering the above two qualities together, Rajshahi (E6) was the ideal location for testing genotypes for long duration varieties with its appreciable discriminating ability and representativeness and position nearest the circle point of AEA axis. In medium duration (Fig. 1b), there were three clusters of environments in medium duration, one containing Cumilla (E3) and Rangpur (E7); second cluster containing Kushtia (E5) and Rajshahi (E6) and third cluster containing Gazipur (E4), Satkhira (E8) and Sonagazi (E9). Among these three, E3 and E7 were closely associated (Fig. 1b). Cumilla (E3), Rangpur (E7) and Sonagazi (E9) had the longest vector and hence were highly discriminating. The locations Kushtia (E5) and Rajshahi (E6) were highly representative environments (Fig. 1b). Overall, the location Kushtia (E5) can be considered ideal for evaluating medium duration genotypes. GGE biplot were showed one clusters in short duration (Fig. 1c). Kushtia (E5), Rajshahi (E6) and Satkhira (E8) were considered as the cluster and E1 and E4 had the longest vector, making it more discriminating than the other environments. Considering the ideal environment criteria, Sonagazi (E9) showed a smaller angle with the AEA and hence was a highly representative environment (Fig. 1c) in testing short duration genotypes.

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. Figure 2a–c shows the average-environment coordination (AEC) views of the GGE biplot for grain yield in long, medium, and short duration. Tables 3 and 4 show the yield performances and summary of ideal genotypes with stable and high mean yields in different categories (long, medium and short duration). BRRI dhan30 (G7) recorded the highest average grain yield in long duration (Fig. 2a). BRRI dhan30 (G7), BR10 (G3), BR11 (G4), BR22 (G5) and BRRI dhan31 (G8) were the most stable genotypes with above-average yields. Thus, the BRRI dhan30 (G7) was the most ideal genotype with the highest mean yield and stability among the tested genotypes. The genotype BRRI dhan32 (G22) was the most stable genotype with above-average yield in medium duration (Fig. 2b). BRRI dhan54 (G26) recorded the highest mean yield but genotype BRRI dhan32 (G22) was the ideal genotype with high stability and grain yield. Other stable genotypes with above-average yields were BRRI dhan72 (G28), BRRI dhan73 (G29), BRRI dhan49 (G24). BRRI dhan75 (G37) recorded the highest average grain yield, most stable and ideal genotype in short duration (Fig. 2c). BRRI hybrid dhan4 (G38), BRRI dhan66 (G35) and BRRI dhan71 (G36) were the most stable genotypes and above average yielder.

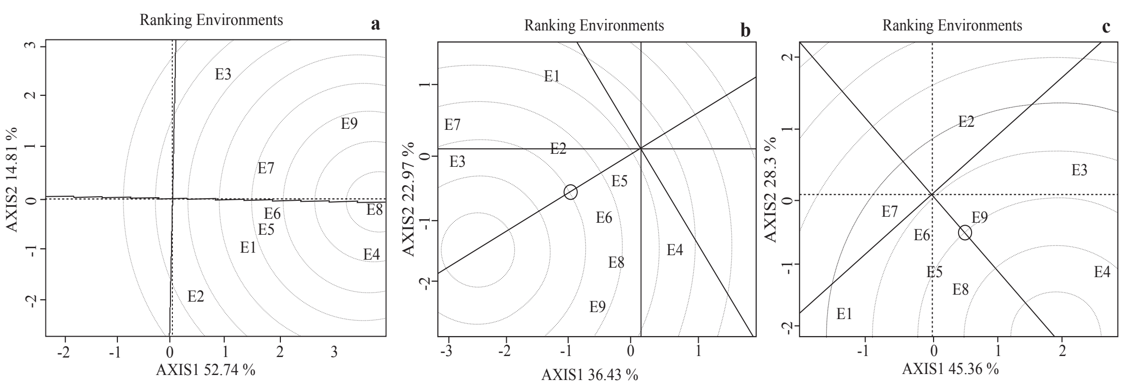


Fig. 1. Association among the test environments based on the average environmental coordinate (AEC), considering stability and adaptability of rice genotypes evaluated across different environments of Bangladesh for grain yield categorized by (**a**) Long duration, (**b**) Medium duration, and (**c**) short duration in T. Aman 2017 growing season.

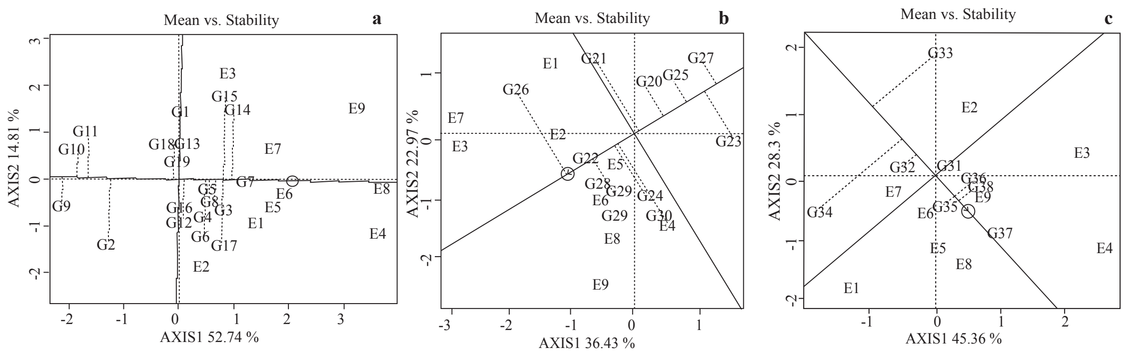


Fig. 2. GGE biplot of mean and stability of rice genotypes for yield and specific genotype × environment interactions of different categories (a) Long duration, (b) Medium duration and (c) short duration in T. Aman 2017 growing season.

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 data set. 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 four sectors containing all the test environments in long duration and accordingly four mega-environments were identified (Fig. 3a): one mega-environment had two locations, Bhanga (E2) and Barishal (E1), the second consisting of four locations, Kushtia (E5), Gazipur (E4), Rajshahi (E6) and Satkhira (E8); the third had two locations, Rangpur (E7) and Sonagazi (E9). Hence, there is no winning genotype in those environments, so it would not likely to be called a mega-environment and the fourth had only one location, Cumilla (E3). BRRI dhan52 (G17) was the winning genotypes in the first mega-environment, BRRI dhan30 (G7) was the winner in the second, and BRRI dhan44 (G14) and BRRI dhan46 (G15) were the winning genotypes in the fourth mega-environment (Fig. 3a). BRRI dhan34 (G9), BRRI dhan37 (G10), BRRI dhan38 (G11) and BR5 (G2) were the low yielder of long duration genotypes. In medium duration, the biplot grouped the test locations into three mega-environments (Fig. 3b). The first mega-environment had four locations, Barishal (E1), Bhanga (E2), Cumilla (E3) and Rangpur (E7). The second one had two locations, Kushtia (E5) and Rajshahi (E6) and the third contained the rest had three locations, Gazipur (E4), Satkhira (E8) and Sonagazi (E9). BRRI dhan54 (G26) was the winning genotype in the first mega-environment while BRRI dhan72 (G28) BRRI dhan32 (G22) was the winner in the second and BRRI hybrid dhan6 (G30) was the winner in the last mega-environment. BRRI dhan70 (G7), BRRI dhan39 (G23) and BRRI dhan53 (G25) were the low yielder of medium duration genotypes. The biplot was divided into three mega-environments in short duration (Fig. 3c). The first mega-environment had five locations, Cumilla (E3), Gazipur (E4), Kushtia (E5), Satkhira (E8), Sonagazi (E9) with BRRI dhan75 (G37) being the winning genotypes. The second mega-environment had three locations, Barishal (E1), Rajshahi (E6), and Rangpur (E7) and BRRI dhan62 (G34) was the winner in this mega-environment. The third mega-environment consisted of one location, Bhanga (E2) with BRRI dhan57 (G33) as the winning genotypes.

MAINTENANCE OF RICE DATABASE

Secondary data on 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 periodically and computerized. Existing databases have been updated and included at BRRI website.

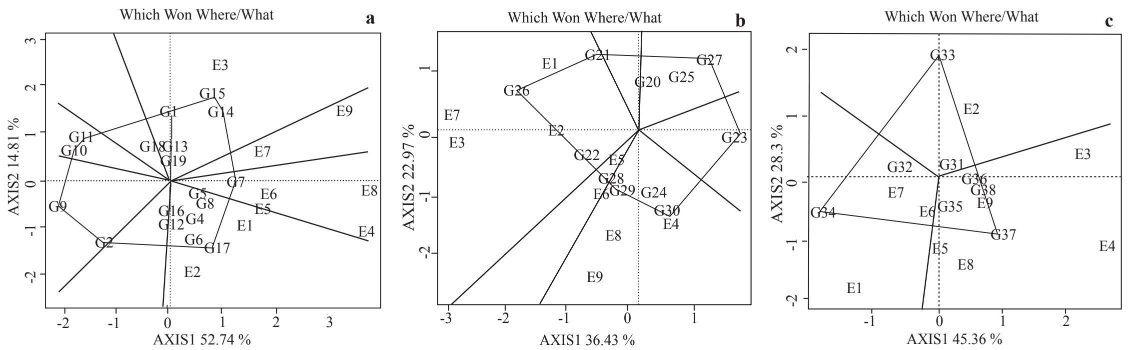


Fig. 3. GGE biplot identification of winning genotypes and their related mega-environments of different categories (**a**) Long duration, (**b**) Medium duration and (**c**) short duration in T.Aman 2017 growing season.

SEASONAL WEATHER FORECASTING FOR RICE PRODUCTION

Weather is one of the most important factors determining success or failure of agricultural production. It effects on every phase of growth and development of plant. Any variability in the weather during the crop season, such as delay in the monsoon, excessive rains, flood, droughts, spells of too-high or too-low temperatures would affect the crop growth and finally the quality and quantity of the yield. So the overall objective of this study are to provide location specific medium range weather forecasts for Boro rice crop production in *haor* regions and Agro-met advisory services (AAS) to the farmers at local level. The weather research and forecasting (WRF) model was used to generate atmospheric simulations based on real data (observations, analyses) or idealized conditions. Two samples of weather forecast and agro meteorological advisory services (Tables 1 and 2) for the *haor* areas have been shown below in the following:

EFFECTS OF CLIMATIC FACTORS ON YIELD OF BRRI VARIETIES

Agricultural sector of this country is already under pressure with the continuously changing climate, land and water resource depletion and faces challenges in providing food security to its increasing population. The main objective of the study is to assess the possible change in yield of BRRI varieties due to different climatic factors using regression model. This study was conducted at all the BRRI regional stations and the headquarters in T. Aman 2016 season. BRRI developed rice varieties were evaluated in this study. The yield data are collect from the experiment titled ‘Stability Analysis of BRRI Varieties’. The experiments were carried out in a randomized complete block design with three replications. Each experimental unit was comprised of 3m × 3m. Standard agronomic practices (BRRI recommended) were followed and

Table 1: **সমন্বিত কৃষি আবহাওয়া ব্যবস্থাজনিত পরামর্শ আবহাওয়ার পূর্বাভাসের সময়: ১৩/০২/২০১৮ হতে ১৮/০২/২০১৮।**

আবহাওয়ার উপাদান সমূহ	১৩/০২/১৮	১৪/০২/১৮	১৫/০২/১৮	১৬/০২/১৮	১৭/০২/১৮	১৮/০২/১৮
মোট বৃষ্টিপাত (মিমি)	০.০০	০.০০	০.০০	০.০০	০.০০	০.০০
সর্বোচ্চ তাপমাত্রা (°সেঃ)	২৯.২১	২৮.৩২	২৭.৬৯	২৭.৮৬	২৭.৬১	২৭.৫৫
সর্বনিম্ন তাপমাত্রা (°সেঃ)	১৪.০৯	১৫.৪১	১৫.৫২	১১.৪৫	১১.৪২	১০.৯৪
সর্বোচ্চ আপেক্ষিক আর্দ্রতা (%)	৭৪.৪১	৬১.২৩	৬৪.১২	৭০.৭৫	৭০.০৮	৭১.৯০
সর্বনিম্ন আপেক্ষিক আর্দ্রতা (%)	৩০.৬৯	৩৪.৫১	২৪.০১	২৫.২৭	২৫.৫৪	২৬.৭৯
বাতাসের সর্বোচ্চ গতিবেগ (কিমি/ঘণ্টা)	১৩.২০	১২.৩১	৮.৮৬	৯.৮৩	১০.৬৫	১০.০৯

আবহাওয়ার পূর্বাভাস ১৩ থেকে ১৮ ফেব্রুয়ারি, ২০১৮ পর্যন্ত

১৩ থেকে ১৮ ফেব্রুয়ারি পর্যন্ত বৃষ্টিপাতের সম্ভাবনা নাই। সম্ভাব্য সর্বোচ্চ তাপমাত্রা ২৭.৫৫ থেকে ২৯.২১°সেঃ এবং সর্বনিম্ন তাপমাত্রা ১০.৯৪ থেকে ১৫.৫২°সেঃ এর মধ্যে থাকার সম্ভাবনা রয়েছে। সকালের সম্ভাব্য আপেক্ষিক আর্দ্রতা ৬০.২৩ থেকে ৭৪.৪১% এবং বিকালে ৩৭.৫৪ থেকে ৫০.৮০% এর মধ্যে থাকার সম্ভাবনা রয়েছে। বাতাসের গতিবেগ ঘন্টায় ০.৪৭ থেকে ১৩.২১ কি:মি: থাকার সম্ভাবনা রয়েছে।

Table 2: **কৃষি পরামর্শ সাপ্তাহিক আবহাওয়ার পূর্বাভাসের উপর ভিত্তি করে বোরো ফসলের সম্ভাব্য সমস্যা ও করণীয়।**

শস্য	শস্য পর্যায়	ক্ষেত্র	সম্ভাব্য সমস্যা ও করণীয়
বোরো ধান	আগাম থেকে সক্রিয় কুশি গজানো পর্যায়	ক্ষতিকর পোকা	**সমস্যা** এ ধরণের আবহাওয়ার পূর্বাভাসে থ্রিপস এবং পাতা মাছির আক্রমণের সম্ভাবনা আছে। **করণীয়** ● পাতা মাছির প্রাদুর্ভাব কমাতে জমি থেকে দাঁড়ানো পানি নিষ্কাশন করতে হবে। ● ১ম ডোজ ইউরিয়া সার ব্যবহারের মাধ্যমে উভয় ধরনের ক্ষতিকর পোকার হাত থেকে রক্ষা পাওয়া যায়। ● যদি পাতার আক্রমণের হার শতকরা ২৫ বা তার বেশি হয় তাহলে ম্যালাটোন ৫৭ ইসি ১মিলি/লিঃ পানিতে মিশিয়ে প্রয়োগ করা যেতে পারে।
		রোগ-বালাই	**সমস্যা** ১। রোপণের ৭-১০ দিনের মধ্যে ব্যাকটেরিয়া জনিত "ক্রিসেক" রোগ দেখা দিতে পারে। **করণীয়** ● আক্রান্ত চারার গোড়ায় পঁচাগন্ধ ও বাদামী পূজের মত DR আছে কিনা পরীক্ষা করে দেখতে হবে। ● জমে থাকা পানি বের করে দিতে হবে। ● আক্রান্ত জমি নিড়িয়ে দিতে হবে ও সুস্থ সবল চারা দ্বারা গোছা প্রতিস্থাপন করতে হবে। **সমস্যা** ২। ধান গাছের কুশির অস্বাভাবিক বৃদ্ধির মাধ্যমে বাকানি রোগ দেখা দিতে পারে। **করণীয়** ● গোছা হতে আক্রান্ত কুশি ভেঙ্গে বা উপড়ে ফেলে দিতে হবে। ● নিয়মানুযায়ী ইউরিয়া সার প্রয়োগ করতে হবে । ● জমিতে পানি ধরে রাখতে হবে।
		মাটি ও শারীরতত্ত্ব	**করণীয়** সারের নির্দেশিত মাত্রা নিশ্চিত করতে হবে : গাছের কুশির পর্যায়ে দ্রুত বৃদ্ধির জন্য দুপুর বেলায় নির্দেশিত ইউরিয়া সার প্রয়োগ করতে হবে।
		সেচ	**করণীয়** জমিতে ১-২ ইঞ্চি পরিমাণ সেচ দিতে হবে।
পরামর্শ	বিরূপ পরিস্থিতিতে প্রতিকারের জন্য নিকটস্থ ব্রি বিজ্ঞানী বা উপজেলা কৃষি অফিসারের সাথে যোগাযোগ করুন।		

plant protection measures were taken as required. Two border rows were used to minimize the border effects. Yields of varieties, climatic factors, location etc were recorded. For this study ANOVA model of combined analysis were used to quantify the effective of different factors (Varieties, location) and Regression Model (RM) were used to identify the most effective factors which influenced rice yield.

Weather data sources and processing

The weather data (daily maximum and minimum temperatures, relative humidity, rainfall and sunshine) from 1st July 2016 to 30th November 2016 were collected from the Bangladesh Meteorological Department (BMD). From the 36 meteorological stations nearest to the BRRI HQ, Gazipur and eight BRRI regional stations as Bhanga, Barishal, Cumilla, Kushtia, Rajshahi, Rangpur, Satkhira and Sonagazi were selected for further processing. Table 3 presents BRRI regional station-wise summary of yield data for T. Aman 2016. We found the highest BRRI dhan31 (7.00 t ha^{-1}) at BRRI RS, Barishal and the lowest BRRI dhan51 (4.69 t/ha) in BRRI RS, Rangpur. According to location, the highest yielding variety was BRRI dhan38 (3.34 t ha^{-1}) in Rajshahi and the lowest was BRRI dhan77 (1.97 t ha^{-1}) in Rangpur. Among all the varieties, the highest average yield (5.46 t ha^{-1}) was found in BRRI RS, Barishal and the lowest (3.43 t ha^{-1}) was found in BRRI RS, Rangpur.

Table 4 presents the ANOVA results of combined analysis for T. Aman 2016. From the ANOVA table

Table 3. Summary of the performance of BRRI varieties in T. Aman 2016.

Region	Highest yield		All variety average yield	Lowest yield	
	Variety	Yield		Variety	Yield
Barishal	BRRI dhan31	7.00	5.46	BRRI dhan57	3.20
Rajshahi	BRRI dhan72	6.51	5.11	BRRI dhan38	3.34
Satkhira	BRRI dhan33	6.14	4.85	BRRI dhan57	2.42
Cumilla	BRRI dhan71	6.17	4.62	BR5	2.86
Kushtia	BRRI dhan51	5.70	4.55	BRRI dhan38	2.75
Bhanga	BRRI dhan71	7.07	4.43	BRRI dhan38	2.04
Gazipur	BRRI dhan73	6.20	4.39	BRRI dhan37	2.18
Sonagazi	BR11	5.81	4.13	BRRI dhan37	2.58
Rangpur	BRRI dhan51	4.69	3.43	BRRI dhan77	1.97

Table 4. AVOVA of combined analysis for T. Aman 2016.

SV	DF	Sum Sq	Mean Sq	F Value	Pr(>F)
Location	8	301.2	37.65	92.547	< 2e-16***
Variety	36	284.4	7.90	19.418	< 2e-16***
Rep:Location	18	11.0	0.61	1.497	0.0841
Variety:Location	288	521.7	1.81	4.453	< 2e-16***
Residuals	648	263.6	0.41		

Note: *** = significant at the 1% level.

it is clear that all the sources of variation (SV) shows significant differences. That means significant yield differences occurred because of location even though the same management practice were followed.

Location wise mean comparisons. It is seen from the mean comparison that the highest average yield was found in Barishal and the lowest average yield was found in Rangpur. Most of the locations showed significant mean yield difference. Though same management practices were followed in case of all the varieties, the yield of the varieties more or less significantly differ in all the locations. The genetic performance of the varieties was the reason. But the yield performances of the same variety at different locations were different. The causes of the yield difference are the soil factor variation and the climatic variation in the stations. Here, we analyse only the effect of the climatic factors on yield of BRRI varieties.

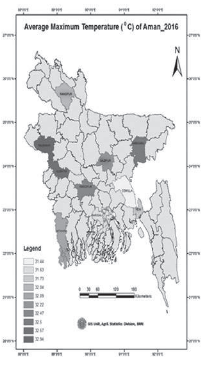


Fig. 4a

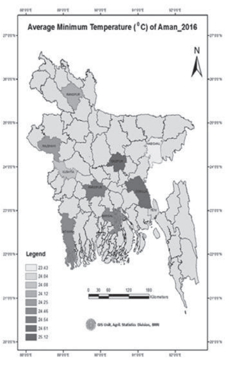


Fig. 4b

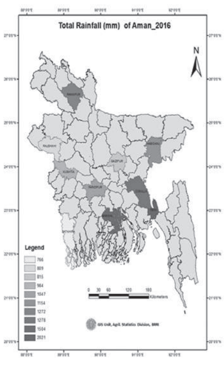


Fig. 4c

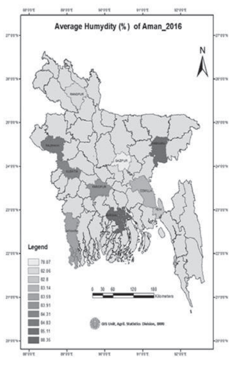


Fig. 4d

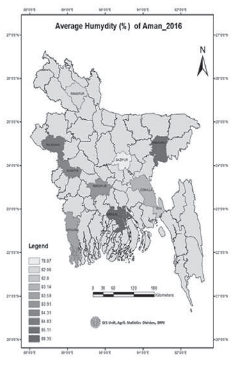


Fig. 4e

The climatic conditions in T. Aman 2016 of the different locations (BRRI HQ and RS) are shown by the following GIS maps (Figure 4a to 4e).

From the climatic maps it is clearly seen that the climatic conditions for average maximum temperature, average minimum temperature, total rainfall, average sunshine and average humidity during T. Aman 2016 are more or less different at the different locations.

From the regression analysis, we found that maximum temperature have positive effect on yield of BRRI dhan57 and BRRI dhan66 and negative effect of BRRI dhan38. All the significant effects were positive for minimum temperature and negative for rainfall, humidity and sunshine except BRRI dhan57 for humidity.

SUITABILITY (EDAPHIC) MAPPING OF BRRI DHAN50, BRRI DHAN63, BRRI DHAN66, BRRI DHAN71 AND BRRI DHAN72

Land is not homogenous all over the Bangladesh. Physical and chemical properties of soil vary spatially. On the other hand, various rice varieties are suitable for some specific physical and chemical properties. As we need high production with limited land, so it would be very helpful if we had variety wise suitability map based on soil properties. BRRI dhan50, BRRI dhan50, BRRI dhan50, BRRI dhan50 and BRRI dhan50 are very prospective varieties. So, these varieties suitability maps are very important. The objective of the study were to construct edaphic suitability maps for newly released BRRI varieties and also find out variety wise suitable area 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 area 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 moderately suitable and 3- for not suitable. Suitable areas for respective rice varieties cultivation in Bangladesh were determined by two steps: step 1, Input vector themes of land type and other soil physical properties were converted into grid themes for analysis in the model builder environment using Arc GIS10, spatial analyst module. Step 2, then each input grid was weighted by the relative influence for suitability assessment. The relative influences were the relative weights in percent assigned to grid themes of soil parameters. These weights were the values of 'Percent Influence Field' in the weighted overlay table of the model builder.

BRRI dhan50, BRRI dhan63 and BRRI dhan66 are Boro season rice varieties. The analytical results indicated that BRRI dhan50 is suitable in south and eastern areas of Bangladesh (Fig. 5a). Western areas of Bangladesh are suitable for BRRI dhan63 (Fig. 5b). BRRI dhan66 is suitable in north-western areas of Bangladesh (Fig. 5c). For BRRI dhan71 is suitable in north-western areas of Bangladesh (Fig. 5d). Western side of Bangladesh is suitable for BRRI dhan72 (Fig. 5e). Productivity will increase, if we cultivate rice varieties according to their suitable area.

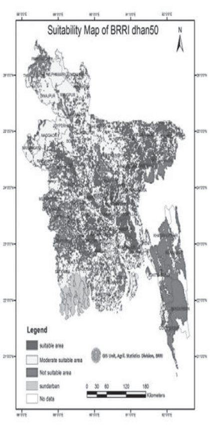


Fig. 5a

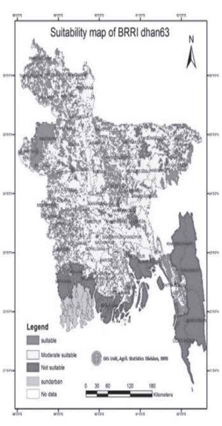


Fig. 5b

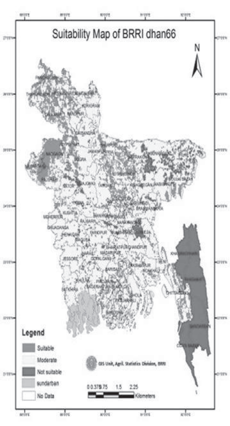


Fig. 5c

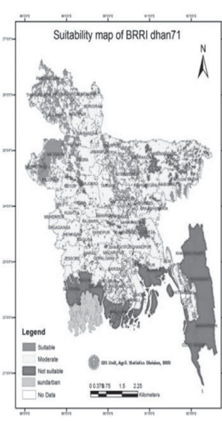


Fig. 5d

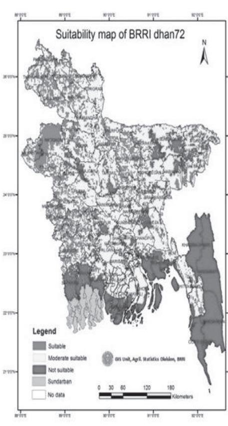


Fig. 5e

PROBABILITY MAPPING OF TEMPERATURE (MAXIMUM and MINIMUM) AND RAINFALL

Bangladesh is an agro-based country. Climatic factors such as temperature, rainfall, atmospheric carbon dioxide and solar radiation etc are closely linked with agricultural production. Thus, climatic factors mapping would be great tool for climatic factors analysis and assist to increase crop production. The objective of the study is to determine the season-wise expected maximum and minimum temperature and rainfall in different region for rice in Bangladesh and season-wise areas of critical maximum and minimum temperature as well as rainfall map of Bangladesh for rice during the period. Forty to fifty years data on daily maximum and minimum temperature and rainfall of 35 weather stations of BMD were collected for the study. Year and season-wise (in case of Aus rice, the length of growing Aus season varies from 15 April to 30 August, Aman 15 June to 30 November and Boro from 15 November to15 May), maximum value of maximum temperature, minimum value of minimum temperature and total rainfall value were determined for the years 2011-15, then average value of those (2011-15) five years were determined of those climatic parameters. Then by using geo-statistical tools of Arc GIS10 software maps were prepared. From the maps scenarios of climatic factors were described. The results indicated that all Aus, Aman and Boro season maximum temperature is high in central western part of Bangladesh and low in south eastern areas (Fig. 6a, 6b and 6c). On the other hand, in all three seasons minimum temperature is high in south eastern areas of Bangladesh but in Aus season it is low in north and eastern areas. In Aman season it is low in western areas and in Boro season it is low in central western areas of Bangladesh (Fig. 7a, 7b and 7c). In Aus season total rainfall is high in south and northern eastern areas. In Aman season south eastern areas and in Boro season north eastern areas of Bangladesh are low rainfall. In all seasons total rainfall is low in western side of Bangladesh (Fig. 8a, 8b and 8c).

ICT ACTIVITIES

Online application system of BRRI

The online application system for recruitment is an ideal portal for the Government. BRRI wants to manage its recruitment related activities through online. So BRRI will introduce this online system to decrease hassles of applicants/students for Job Application. It also reduces time of job application processing for the employer. Online application system will be developed by Teletalk Mobile Company Ltd with the help of ICT Cell, Agricultural Statistics Division and Administration of BRRI already completed agreement between BRRI and Teletalk Bangladesh Limited, a public limited company on 8 March 2017 for Web and SMS based application.

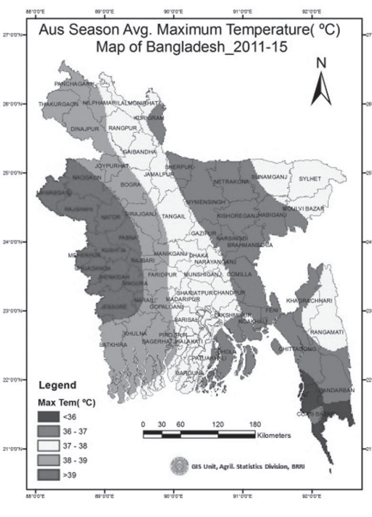


Fig. 6a

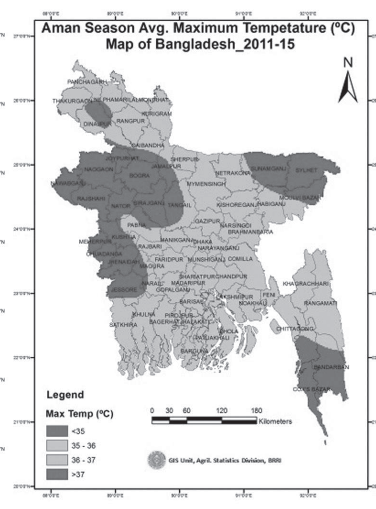


Fig. 6b

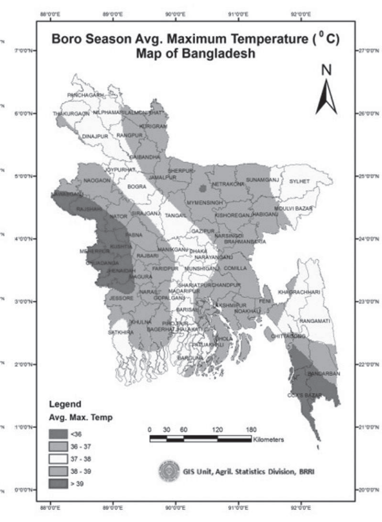


Fig. 6c

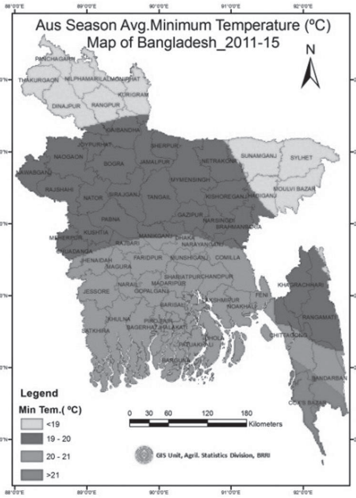


Fig. 7a

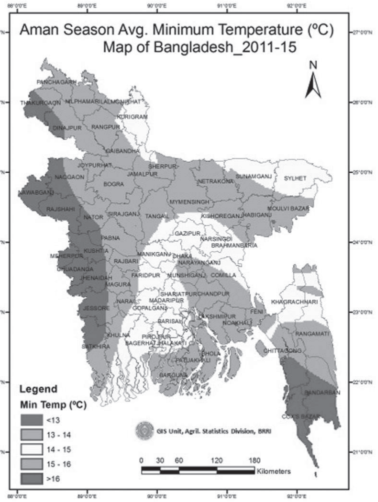


Fig. 7b

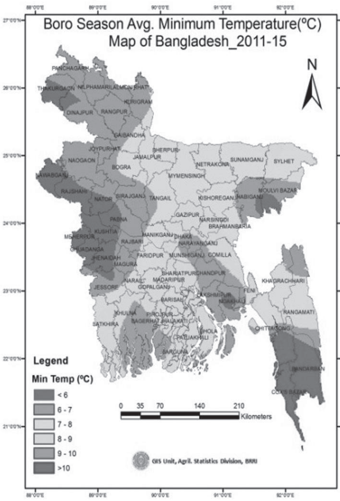


Fig. 7c

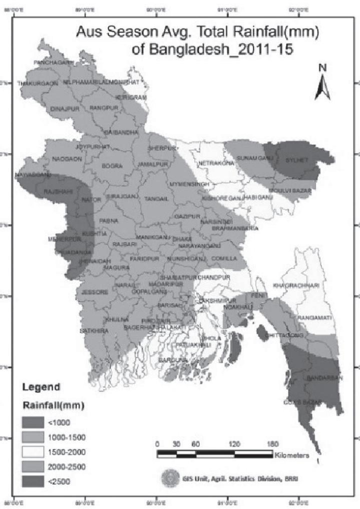


Fig. 8a

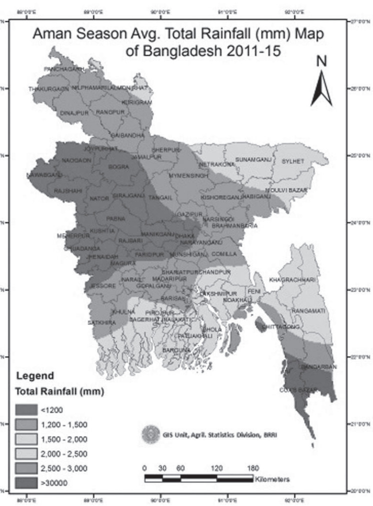


Fig. 8b

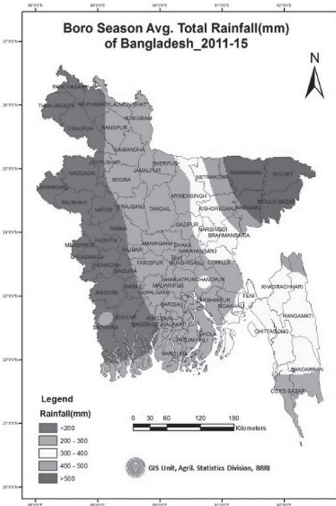


Fig. 8c

e-File (Nothi) management system of BRRI

The implementation of e-Filing system to ensure faster movement of files through the different layers in government offices, increased transparency throughout the organization, and increased accountability in governance. Hence, BRRI has taken initiative to ensure a paperless office management system through e-File (Nothi) system. “e-File Management Software” is used by the administration and all the divisions of BRRI. This software is active in 24/7/365. e-File (Nothi) Management System is already introduced at BRRI with the help of A2i, Prime Minister’s Office (PMO) on 24 September 2017.

Mobile Apps of RKB (Rice Knowledge Bank)

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. Mobile apps Rice Knowledge Bank (RKB) has been hosting at Google Play Store (Table 4). It is available at android-based smart phone. So anybody can download it from Google Play Store of any android-based mobile. Otherwise, this mobile app can shared from other smart phone by ‘SHAREit’ software. RKB is regularly updating all varietal information including all 92 varieties developed by the institute.

Fig. 9. Mobile Apps of RKB (Rice Knowledge Bank) of BRRI.

Achievement

Bangladesh Rice Research Institute (BRRI) awarded National Information and Communication Technology (ICT) Award-2016 at Digital World 2016 for ICT excellence through innovative service delivery regarding specially for mobile app Rice Knowledge Bank (RKB).

e-Tender system of BRRI

The e-Tender system software e-GP is developed under Central Procurement Technical Unit (CPTU), IMED. BRRI introduced e-GP on 1st July of 2016. BRRI is incorporated with it as a first organization among the NARS institute and it is also a first organization under the Ministry of Agriculture (MoA). BRRI has already submitted about 56 (Fifty-six) tenders into e-GP system and the process is continuing.

BRRI web portal management

BRRI web portal https://www.brri.gov.bd has been registered with BTCL. The web portal is developed, managed and updated by ICT Cell of Agricultural Statistics Division and uploaded information with permission of concerned authority. BRRI has made the web portal with both Bengali and English language. It is one of the largest web portal (*www.portal.gov.bd*) in the country and BRRI is incorporated with it as a first organization among the NARS institute.

Facebook group (BRRI networks) of BRRI

BRRI networks is a Facebook group, where only official interactions, various problems and their solutions can be posted. It's a big forum for all the scientists, officers and staffs of BRRI. ICT Cell created this Facebook group to post research related work for noble work of rice and rice related activity of this forum. The Facebook group of *BRRI Network* link is (https://www.facebook.com/groups/1409267722690061/). It is also tagged with the largest web portal of the World, which is named National Web Portal of Bangladesh (http://www.bangladesh.gov.bd/). Thus the *BRRI Network* is continuing with regular updating by posted everybody of this group. At present, *297 (*Two hundred and ninety-seven) individuals have joined this group. It is increasing gradually.

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 12 Mbps to 35 Mbps. At present, bandwidth connectivity is increasing from 35 Mbps to 40 Mbps. It has established new and high configured router where internet speed capacity increased up to 1000 Mbps; the internet speed capacity was

25 Mbps previously. We also established local area network (LAN) connectivity at five regional stations ie Rangpur, Barishal, Sonagazi, Cumilla and Habiganj.

BRKB website management

Bangladesh Rice Knowledge Bank (BRKB) is a treasure of rice knowledge. This is a dynamic source of knowledge that will be updated regularly to keep consistency with the latest innovations and users' feedback. The BRKB contains rice knowledge to address the regional as well as national issues associated with rice production and training. It updates regularly with the latest information of Aus, Aman and Boro rice varieties.

Personal data sheet database

We have created PDS database for all scientists, officers, clerks as per requirement of the Ministry of Agriculture (MoA). It increased 339 (Three hundred and thirty-nine) users into BRRI PDS database. It database is updated regularly with the latest information. It is a routine work.

Web mail and group mail

Webmail is web-based e-mail service that is any e-mail client implemented as a web application running on a web server. ICT cell of Agricultural Statistics Division provides ICT related support services to other divisions such as create web mail, reset password etc. We have created individual e-mail account into BRRI domain for all the scientists and class one officers as per requirement of the Ministry of Agriculture (MoA). The hosting of BRRI Web mail and Group mail has been hosted into BCC (Bangladesh Computer Council) server.

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. Fifty-five 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. ICT cell of Agricultural Statistics Division has taken initiative in accordance with government perspectives but 'BRRI Network' group is first introduced among all the participation of National Agricultural Research System (NARS) and also first among all research institutes. The ICT cell of Agricultural Statistics Division provides e-Filing management system and and e-Tender related support services to other divisions, administration and procurement sections. Furthermore, we provide hardware, network and internet related support services to other divisions.

Farm Management Division

SUMMARY

This experiment was conducted at the West Byde of BRRI HQ farm, Gazipur during T. Aman 2017 and Boro 2017-18 seasons to find out the optimum spacing of different short duration rice varieties. In T. Aman season the treatments were three rice varieties (V1=BRRI dhan71, V2= BRRI dhan75 and V3=BINA dhan17) and five spacings (S1= 15 cm × 15 cm, S2=20 cm × 15 cm, S3= 20 cm × 20 cm, S4=25 cm ×20 cm and S5=25 cm × 25 cm). In Boro season the treatments were four rice varieties (V1=BRRI dhan81, V2= BRRI dhan84, V3= BRRI dhan86 and V4=BRRI dhan28) and the spacings were same as T. Aman season. In each season, the treatments were arranged in a split plot design as variety in the main plots and spacing in the sub plots with three replications. In T. Aman season, irrespective of variety and spacing, the number of tiller per hill increased sharply and reached the maximum at 30 to 45 DAT then gradually decreased. BRRI dhan75 gave the highest grain yield, which was statistically identical with the yield of BRRI dhan71 and BINA dhan17. The spacing (20 cm × 15 cm) produced the highest yield than the others. On the other hand during Boro season the number of tiller per hill increased sharply and reached the maximum at 60 to 80 DAT then gradually decreased and plants grown as (20 cm × 20 cm) spacing produced the highest grain yield and among the varieties BRRI dhan84 gave the highest grain yield during Boro season.

This experiment was initiated on a permanent layout at the BRRI HQ farm, Gazipur in T. Aman 2016. In T. Aman 2017, the experiment was conducted in two approaches. Five treatments in randomized complete block design with three replications were imposed and each treatment was assigned in 4 m × 5 m sized plot. In Approach-1 the treatments were different sources of soil nutrient such as i) BRRI recommended fertilizer dose, ii) Kitchen waste (6 t ha^{-1}), iii) Cowdung bio-slurry (6 t ha^{-1}), iv) Poultry litter (6 t ha^{-1}) and v) control (No nutrient supply). In Approach-2 the treatment combinations were: i) BRRI recommended fertilizer dose, ii) Kitchen waste (3 t ha^{-1}) + ½ BRRI dose, iii) Cowdung bio-slurry (3 t ha^{-1}) + ½ BRRI dose, iv) Poultry litter (3 t ha^{-1}) + ½ BRRI dose and v) control (No nutrient supply). Thirty-day-old seedling of BRRI dhan49 in T. Aman and 45-day-old seedling of BRRI dhan58 in Boro season were transplanted at 20 cm × 20 cm spacing in both the approaches. Grain yield, tiller number, panicle number, plant height and straw yield were significantly affected by the different effect of organic matter in both the approaches during T. Aman and Boro season. Poultry litter related treatments and BRRI recommended dose were performed better in all the parameters except 1000-grain weight. On the other hand control plot (No nutrient supply) gave the lowest result.

Survey and monitoring of labourers' wage rate at different locations around BRRI HQ such as Joydebpur, Chowrasta, Salna, Board Bazar, Konabari, Tongi were conducted throughout the year. The average wage rate day^{-1} varies from Tk 447-491. The wage rate day^{-1} during the peak periods of the year was Tk 490 to 540 in May, Tk 480 to 505 in July-August and Tk 455 to 510 in December-January. The wage rate varied between Tk 395-420, 375-435, 425-490, 390-450, 430-465, 425-490, 385-425 and 435-485 at Habiganj, Rangpur, Rajshahi, Barishal, Sonagazi, Cumilla, Satkhira and Khulna respectively.

This division produced about 23,640 kg rice of which 19,726 kg, and 3914 kg were seeds and mixed rice respectively. This division also produced 8,749 kg breeder seed in collaboration with the GRS division.

BRRI has 746 labourers of which 492 regular, 254 irregular. In BRRI HQ the number of total labourer was 464 of which 325 regular and 139 irregular. The institute has 274 ha of land of which 163 ha was cultivable. Total labour utilization in different divisions was 1,80,568 man days of which 53.03, 43.98 and 2.99% were utilized for research, support service and holidays, respectively. A total of Tk 9,02,84,000 was paid as labour wages of which Tk 4,78,82,000 and Tk 3,97,05,000 and Tk 26,97,000 were paid to the labourers for research work, support service works and leaves, respectively. About 86.07 ha of land were utilized by different divisions in different season of which 11.64 ha in Aus, 36.17 in T. Aman and 38.26 ha in Boro season. This division manages the BRRI flower garden to maintain the aesthetic view of the campus. This division produced visible flower plants summer and winter season.

Effect of spacing on different short duration rice varieties in T. Aman and Boro seasons

This experiment was conducted at the West Byde of BRRI HQ farm, Gazipur during T. Aman 2017 and Boro 2017-18 seasons to find out the optimum spacing of different short duration rice varieties. In T. Aman season, the treatments were three rice varieties (V1=BRRI dhan71, V2= BRRI dhan75 and V3=BINA dhan17) and five spacings (S1= 15 cm × 15 cm, S2=20 cm × 15 cm, S3= 20 cm × 20 cm, S4=25 cm × 20 cm and S5=25 cm × 25 cm). In Boro season, the treatments were four rice varieties (V1=BRRI dhan81, V2= BRRI dhan84, V3= BRRI dhan86 and V4=BRRI dhan28) and the spacings were same as T. Aman season. In each season, the treatments were arranged in a split plot design as variety in the main plots and spacing in the sub plots with three replications. Twenty-five and 40-day-old seedling @ one seedling per hill were transplanted in T. Aman and Boro seasons respectively. Tiller number per hill from transplanting to maturity with 15 and 20 days interval was recorded in T. Aman and Boro season respectively. Yield and yield components data were taken. The collected data were analyzed using Crop Stat Software programme.

PI: K P Halder CI: Md Mamunur Rashid and Setera Begum

Experiment of T. Aman 2017

Tiller number hill^{-1}. Tiller number per hill was recorded from transplanting to maturity with 15 days intervals (Fig. 1). Irrespective of variety and spacing, the number of tiller per hill increased sharply and reached the maximum at 30 to 45 DAT then gradually decreased due to death of some unfertile tillers. Irrespective of spacing, BRRI dhan75 produced the highest number of tiller followed by BINA dhan17 and the lowest in BRRI dhan71. Regardless of variety, wider spacing produced higher number of tiller per hill than closer spacing in all sampling dates.

Plant height. Comparing different varieties, the tallest plant height was recorded in BRRI dhan71 followed by BRRI dhan75 and the lowest in BINA dhan17 but there was no significant difference between BRRI dhan75 and BINA dhan17 (Fig. 2). Comparing different spacing, it was observed that widest spacing (25 cm × 25 cm) produced the tallest plant and it was decreased with decreasing spacing (Fig. 3).

The interaction between variety and spacing was insignificant in all the parameters of yield and yield components (Table 1). Therefore, only the main effect has been described and discussed below.

Effect of variety. The highest number of tiller and panicle m^{-2} was recorded in BRRI dhan75 followed by BINA dhan17 and the lowest in BRRI dhan71 (Table 1). BRRI dhan71 produced the

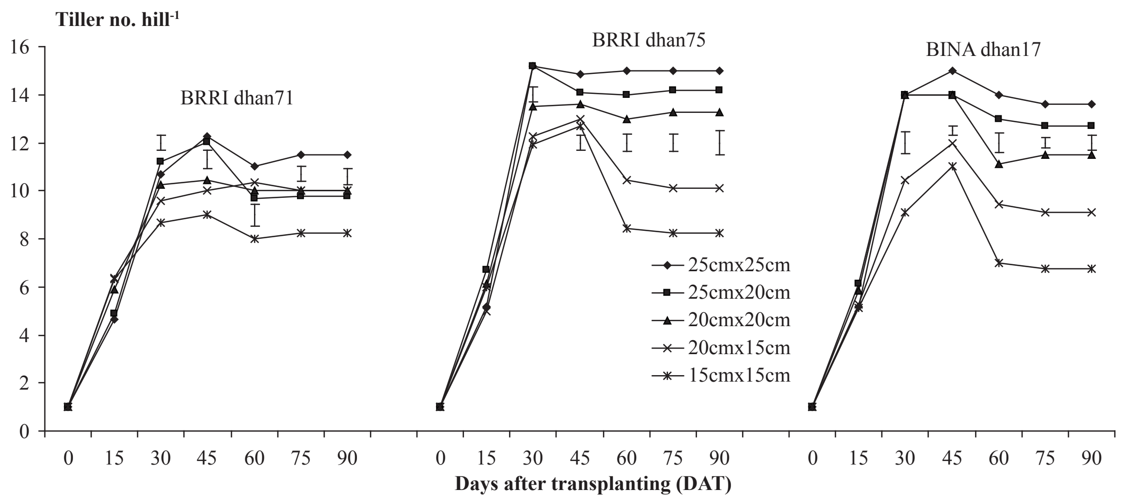


Fig. 1. Tiller number per hill of different short duration T. Aman rice varieties as affected by spacing (Vertical bars represent the LSD (0.05) value).

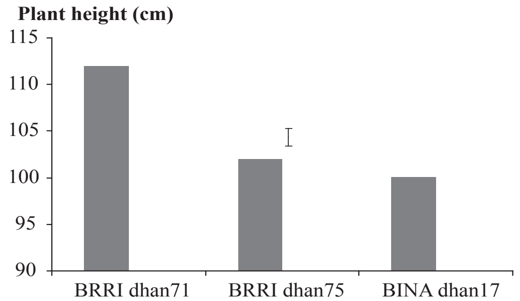


Fig. 2. Plant height at maturity as affected by varieties (Vertical bar represents the LSD (0.05) value).

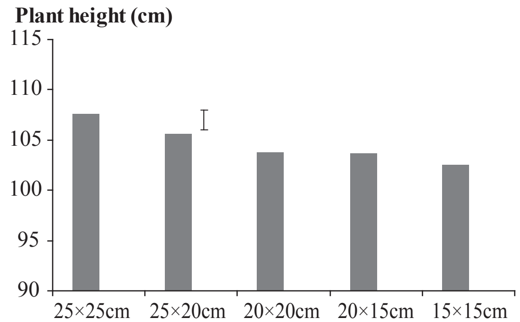


Fig. 3. Plant height at maturity as affected by spacing (Vertical bar represents the LSD (0.05) value).

longest panicle followed by BINA dhan17 and the lowest in BRRI dhan71. Filled grain panicle^{-1} was the highest in BRRI dhan71 and the lowest in BINA dhan17 whereas, the highest percentage of unfilled grain was recorded in BINA dhan17 and the lowest in BRRI dhan75. The 1000 grain weight (TGW) was the highest in BRRI dhan71 and lowest in BRRI dhan75. Variety had no significant effect on grain yield. BRRI dhan75 produced the highest grain yield followed by BRRI dhan71. The lowest yield was recoded in BINA dhan17.

Effect of spacing. All the parameters except panicle length and 1000 grain weight were significantly affected by spacing (Table 2). Closest spacing (15 cm × 15 cm) produced the highest number of tiller and panicle m-^{2}; and percent unfilled grain, which was gradually decreased with increasing spacing. The highest grain yield (5.79 t ha^{-1}) was observed in closer spacing (20 cm × 15 cm) which was statistically identical with the yield of (15 cm × 15 cm) and (20 cm × 20 cm) spacing. The grain yield gradually decreased with increasing spacing. It was the lowest (4.85 t ha^{-1}) in widest (25 cm × 25 cm) spacing which was statistically identical with the yield obtained from (25 cm × 20 cm) and (20 cm × 20 cm).

It may be concluded that BRRI dhan75 gave the highest grain yield which was statistically identical with the yield of BRRI dhan71 and BINA dhan17. The spacing (20 cm × 15 cm) may be considered for obtaining better yield of short duration rice variety in T. Aman season.

Experiment of Boro 2017-18

Tiller number hill^{-1}. Tiller number per hill was recorded from transplanting to maturity with 20 days interval (Fig. 4). Irrespective of variety and spacing, the number of tiller per hill increased sharply and reached the maximum at 60 to 80 DAT then gradually decreased due to death of some unfertile tillers. Irrespective of spacing, BRRI dhan28 produced the highest number of tiller followed by BRRI dhan86, BRRI dhan84 and the lowest in BRRI dhan81. Regardless of variety, wider spacing produced higher number of tiller per hill than closer spacing in all sampling dates.

Plant height. Comparing different varieties, the tallest plant height was recorded in BRRI dhan84 followed by BRRI dhan28 and BRRI dhan81 and the lowest in BRRI dhan86 but there was no significant difference among BRRI dhan81, BRRI dhan28 and BRRI dhan86 (Fig. 5). Comparing different spacings, it was observed that widest spacing (25 cm × 25 cm) gave the tallest plant and it was decreased with decreasing spacing (Fig. 6).

Effect of variety. BRRI dhan84 produced the highest number of tiller m^{-2} followed by BRRI dhan81 and BRRI dhan86 and the lowest in BRRI dhan28. BRRI dhan28 gave the highest number of panicle m^{-2} followed by BRRI dhan84 and the lowest in BRRI dhan81. The highest panicle length was obtained in BRRI dhan84 and the lowest in BRRI dhan81 which was identical with BRRI dhan28. The highest number of filled grain panicle^{-1} was recorded in BRRI dhan81 followed by BRRI dhan84, BRRI dhan86 and the lowest in BRRI dhan28 but the highest percentage of unfilled grain was observed

Table 1. Yield and yield components of rice cultivars as affected by variety T. Aman 2017.

Variety	Tiller no. m^{-2}	Panicle no. m^{-2}	Panicle length (cm)	Filled grain no. $panicle^{-1}$	Unfilled grain (%)	1000 grain wt (gm)	Grain yield (t ha^{-1})
BRRI dhan71	218	215	24.39	94	17.05	23.35	5.48
BRRI dhan75	288	277	20.45	89	13.99	19.92	5.55
BINA dhan17	266	260	22.99	79	20.32	21.54	5.13
LSD at 5%	12.70	12.36	0.77	8.39	4.31	0.72	ns

Table 2. Yield and yield components of rice as affected by spacing T. Aman 2017.

Spacing (cm)	Tiller no. m^{-2}	Panicle no. m^{-2}	Panicle length (cm)	Filled grain no. $panicle^{-1}$	Unfilled grain (%)	1000 grain wt (gm)	Grain yield (tha-1)
15 ×15	312	306	22.48	75	22.74	21.54	5.76
20 ×15	266	257	22.83	87	16.74	21.70	5.79
20 ×20	255	250	22.57	88	16.30	21.27	5.46
25 ×20	232	229	22.43	90	15.90	21.41	5.07
25 ×25	221	212	22.75	96	13.93	22.11	4.85
LSD at 5%	16.40	15.97	ns	10.83	5.57	ns	0.63

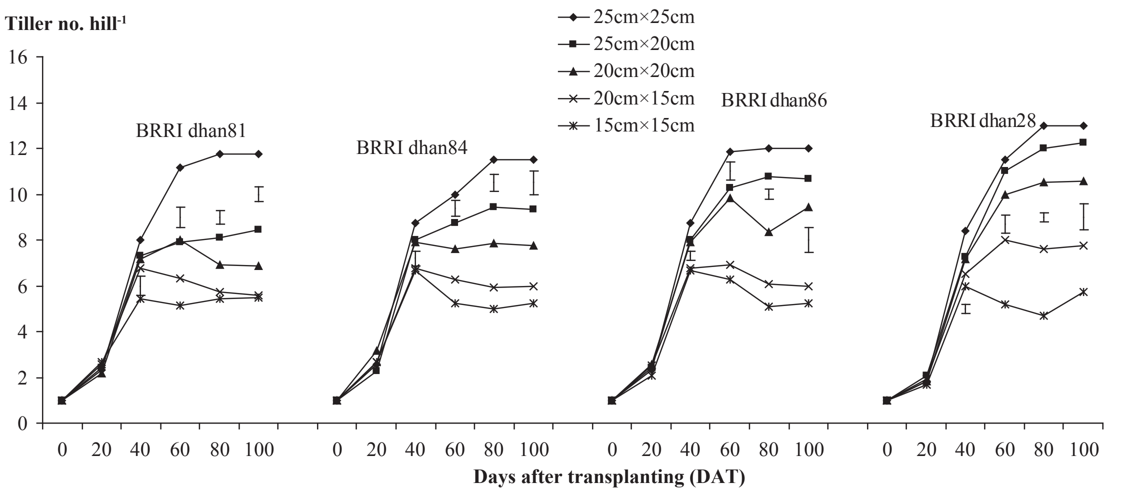


Fig. 4. Tiller number per hill of different short duration Boro rice varieties as affected by spacing (Vertical bars represent the LSD (0.05) value).

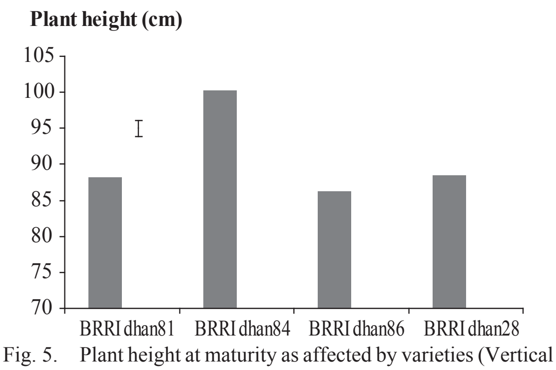


Fig. 5. Plant height at maturity as affected by varieties (Vertical bar represents the LSD (0.05) value).

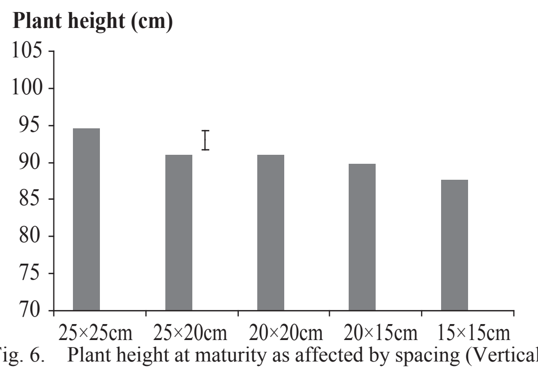


Fig. 6. Plant height at maturity as affected by spacing (Vertical bar represents the LSD(0.05) value).

in BRRI dhan86 which was statistically identical to BRRI dhan84 and the lowest in BRRI dhan28. The highest TGW was recorded in BRRI dhan86 followed by BRRI dhan84 and BRRI dhan28 and; the lowest in BRRI dhan81. BRRI dhan84 produced the highest grain yield. The lowest grain yield was recorded in BRRI dhan28 which was statistically similar to the yield of BRRI dhan81 and BRRI dhan86.

Effect of spacing. The highest number of tiller and panicle was observed in closest spacing (15 cm × 15 cm) which was statistically identical to (20 cm × 20 cm) spacing (Table 4). The tiller and panicle number decreased with increasing spacing. Plants grown as widest (25 cm × 25 cm) spacing produced the longest panicle and the highest number of filled grain panicle^{-1} whereas the highest percentage of unfilled grain was recorded in closest (15 cm × 15 cm) spacing. The highest TGW was observed in (25 cm × 20 cm) spacing, which was insignificant to other spacings except the closest (15 cm × 15 cm) spacing. The plants grown with 20 cm × 20 cm spacing produced the highest grain yield (6.42 t ha^{-1}) and closer or wider than 20 cm × 20 cm spacing decreased yield significanly.

It may be concluded from this study that (20 cm × 20 cm) spacing is the best option for short duration Boro varieties and among the varieties BRRI dhan84 produced the highest grain yield.

Effect of organic matter on soil properties and rice yield

This experiment was initiated on a permanent layout at the BRRI HQ farm, Gazipur in T. Aman 2016. In T. Aman 2017 the experiment was conducted in two approaches. Five treatments in randomized complete block design with three replications were imposed and each treatment was assigned in 4 m × 5 m sized plot. In Approach-1, the treatments were different sources of soil nutrient such as i) BRRI recommended fertilizer dose, ii) Kitchen waste (6 t ha^{-1}), iii) Cowdung bio-slurry (6 t ha^{-1}), iv) Poultry litter (6 t ha^{-1}) and v) control (No nutrient supply). In Approach-2, the treatments combinations were i) BRRI recommended fertilizer dose, ii) Kitchen waste (3 t ha^{-1}) + ½ BRRI dose, iii) Cowdung bio-slurry (3 t ha^{-1}) + ½ BRRI dose, iv) Poultry litter (3 t ha^{-1}) + ½ BRRI dose and v) control (No nutrient supply). 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, 7.0; organic matter, 1.40%; Nitrogen, 0.20%; Phosphorus, 9.80 ppm and Potassium, 0.23 meq/100g soil. Thirty-day-old seedling of BRRI dhan49 in T. Aman and 45-day-old seedling of BRRI dhan58 in Boro season were transplanted at 20 cm × 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 data were taken. Collected data were

Table 3. Yield and yield components of rice cultivars as affected by variety Boro 2017-18.

Variety	Tiller no. m^{-2}	Panicle no. m^{-2}	Panicle length (cm)	Filled grain no. panicle^{-1}	Unfilled grain (%)	1000 grain wt (gm)	Grain yield (tha^{-1})
BRRI dhan81	215	206.	21.75	142.00	12.74	20.48	6.07
BRRI dhan84	236	229.	25.21	141.94	18.51	21.90	6.32
BBRI dhan86	213	210	23.41	125.92	18.70	23.00	5.97
BBRI dhan28	260	248	21.88	111.46	16.20	21.82	5.95
LSD at 5%	18.38	17.73	0.84	9.69	1.79	0.43	0.23

Table 4. Yield and yield components of rice as affected by spacing Boro 2017-18.

Spacing (cm)	Tiller no. m^{-2}	Panicle no. m^{-2}	Panicle length (cm)	Filled grain no. panicle^{-1}	Unfilled grain (%)	1000 grain wt (gm)	Grain yield (t ha^{-1})
15 ×15	278	268	22.69	122.79	18.63	21.20	5.91
20 ×15	246	238	22.65	128.48	17.63	21.94	6.08
20 ×20	230	224	23.06	127.11	16.22	21.97	6.42
25 ×20	211	203	23.00	132.42	15.49	21.99	6.04
25 ×25	191	184	23.92	140.84	14.73	21.89	5.95
LSD at 5%	20.65	19.83	0.95	10.83	2.00	0.48	0.26

statistically analyzed using a standard statistical procedure (R-software 1).

Grain yield, tiller number, panicle number, plant height and straw yield were significantly affected by the different effects of organic matter in both approaches during T. Aman and Boro season. Poultry litter related treatments and BRRI recommended dose performed better in all the parameters **except** TGW. On the other hand control plot (No nutrient supply) gave the lowest result. The details have been discussed below.

PI: Md Mamunur Rashid CI: Md Nayeem Ahmed and K P Halder

Yield and yield components for Approach-1

Plant height. In T. Aman season (BRRI dhan49), different nutrient management have significant effects in rice plant height. The tallest rice plant (101.47 cm) was found in the BRRI recommended fertilizer management, which is statistically similar with 99.90 cm in poultry litter used plot, followed by 93.40 cm in Kitchen waste used plot and 92.05 cm in bio-slurry used plot. The smallest rice plant (89.47 cm) was found in the control plot (Table 5).

Similarly significant difference observed in plant height of BRRI dhan58 for different nutrient management in Boro season. Poultry litter used plot produced the tallest plant (86.87 cm) followed by kitchen waste (79.81 cm) and cow dung (77.95 cm) used plot and BRRI fertilizer management plot produced statistically similar plant height as poultry litter. The shortest plant found in control plot (76.5 cm).

Tiller number. Tiller production varies significantly among the different nutrient management practices in T. Aman and Boro season. BRRI recommended dose and poultry litter plot produced statistically similar tiller number. BRRI recommended fertilizer gave the highest number of tiller (246 tiller m^{-2}) whereas control plot produced the lowest number of tiller (182 tiller m^{-2}) among all the treatments. But kitchen waste, bio-slurry used plot produced statistically similar tiller number per square meter, which significantly differ from BRRI recommended doses and poultry litter plot (Table 5).

Similar results had been observed in tiller production in the Boro season like T. Aman. Poultry litter produced the highest number of tiller (230 tiller m^{-2}) where control plot gave the lowest number of tiller (146 tiller m^{-2}). Bio-slurry and kitchen waste used plot showed statistically similar tiller number per square meter but significantly differ from control, Poultry litter and BRRI recommended fertilizer used plot.

Table 5. Yield and agronomic parameter of different nutrient management practices during T. Aman 2017 and Boro 2017-18 in Approach-1.

Treatment	Plant height (cm)	Tiller m^{-2} (no.)	Panicle m^{-2} (no.)	Grain $panicle^{-1}$ (no.)	1000 grain wt (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
				Aman-2017			
Control	89.47	182	175	111	19.27	3.60	3.57
BRRI dose	101.47	246	238	123	20.07	5.3	5.65
Kitchen waste (6 t ha^{-1})	93.40	196	193	119	20.09	4.18	4.08
Bio-slurry (cow-dung) (6 t ha^{-1})	92.05	195	187	120	19.71	4.10	3.98
Poultry litter (6 t ha^{-1})	99.90	235	227	125	19.48	5.15	5.38
LSD at 5%	2.52	12.45	11.45	6.02	0.84	0.37	0.48
CV %	1.98	7.57	7.64	6.90	2.48	7.10	11.06
				Boro-2017-18			
Control	72.56	146	129	86	21.22	2.10	2.60
BRRI dose	85.8	221	204	140	21.65	5.95	6.20
Kitchen waste (6 t ha^{-1})	79.81	165	153	137	21.20	4.10	4.51
Bio-slurry (cowdung) (6 t ha^{-1})	77.95	160	142	135	21.48	3.80	4.08
Poultry litter (6 t ha^{-1})	86.87	230	211	144	21.70	6.28	6.71
LSD at 5%	2.15	13.02	12.89	7.26	0.81	0.39	0.51
CV %	2.23	5.49	7.25	7.70	2.51	5.12	7.79

Panicle number. Panicle production was significantly affected by all the nutrient management practices during T. Aman season. Here BRRI fertilizer dose and poultry litter used plot produced statistically similar panicle number. The highest number of panicle (238 panicle m^{-2}) was found in BRRI recommended doses followed by 193 panicle m^{-2} in kitchen waste and 187 panicle m^{-2} in bio-slurry used plot. The lowest number of panicle (175 panicle m^{-2}) among all the treatments was observed in control plot. (Table 5).

On the other hand, in Boro season panicle number was significantly affected by different nutrient management practices and similar result like T. Aman was observed here. Among all the treatments poultry litter used plot produced the highest panicle (211 panicle m^{-2}) and control plot gave the lowest panicle (129 panicle m^{-2}). Statistically similar number of panicle was produced in bio-slurry and kitchen waste.

Grain number and grain weight. In T. Aman, BRRI recommended dose, poultry litter, kitchen waste and bio-slurry used plot gave almost similar number of grain per panicle, which was statistically significant from control plot. Poultry litter provides the highest number of grain per panicle (125 grain panicle-1) whereas control plot gave the lowest number of grain (111 grain $panicle^{-1}$). And there was no significant difference among the treatments in case of grain weight (Table 5).

Statistically similar grain per panicle was observed in poultry litter, BRRI dose, kitchen waste and bio-slurry in Boro season. Here also poultry litter used plot produced the highest grain per panicle (144 grain $panicle^{-1}$). On the other hand, control plot also produced the lowest number of grain (86 grain $panicle^{-1}$). No significant difference was found in grain weight among the treatments.

Grain yield. In T. Aman 2017, grain yield was significantly affected by different nutrient management practices. BRRI recommended fertilizer management (5.30 t ha^{-1}) and poultry litter (5.15 t ha^{-1}) gave the highest and statistically similar grain yield followed by kitchen waste (4.18 t ha^{-1}) and bio-slurry (4.10 t ha^{-1}) where kitchen waste and bio-slurry produced statistically similar grain yield. The lowest yield was observed in control plot (3.60 t ha^{-1}) (Table 5).

Grain yield of BRRI dhan58 was greatly affected by different nutrient management practices during Boro 2017-18. In Boro season, poultry litter (6.28 t ha^{-1}) and BRRI recommended fertilizer management (5.95 t ha^{-1}) again produced statistically similar and higher grain yield followed by kitchen waste (4.10 t ha^{-1}) and bio-slurry (3.80 t ha^{-1}) used plot. And the lowest grain yield (2.10 t ha^{-1}) was also observed in control plot like T. Aman.

Straw yield. Significant effects of various nutrient management practices are also noticed in the production of straw as grain in T. Aman 2017. BRRI recommended dose produced the highest straw yield 5.65 t ha^{-1} followed by 4.08 and 3.98 t ha^{-1} in kitchen waste and bio-slurry used plot respectively. Poultry litter produced 5.38 t ha^{-1} straw, which was also statistically similar to BRRI recommended dose. The lowest straw yield 3.57 t ha^{-1} was observed in control plot (Table 5).

Straw yield of BRRI dhan58 was also greatly affected by different nutrient management practices during Boro 2017-18. Poultry litter management produced the highest straw yield of 6.71 t ha^{-1} followed by BRRI recommended dose (6.20 t ha^{-1}), kitchen waste (4.51 t ha^{-1}) and bio-slurry (4.08 t ha^{-1}) used plot whereas poultry litter and BRRI dose show statistically similar straw yield. Control plot gave the lowest (2.42 t ha^{-1}) straw yield among the treatments.

Yield and yield components for Approach-2

Plant height. In T. Aman season (BRRI dhan49), different nutrient management practices have significant effects in rice plant height. The tallest rice plant (103.35 cm) was found in the BRRI recommended fertilizer management, which is statistically similar to poultry litter used plot (102.85 cm), followed by 101.53 cm and 101.60 cm in bio-slurry and kitchen waste used plot respectively. The smallest rice plant (95.23 cm) was found in the control plot (Table 6).

Similarly significant difference was observed in plant height of BRRI dhan58 for different nutrient management practices in Boro season. Poultry litter (86.36 cm) and BRRI fertilizer management plot (85.10 cm) gave statistically similar plant followed by kitchen waste (83.83 cm) and cow dung (82.94 cm) used plot. The shortest plant found in control plot (80.87 cm).

Tiller number. Tiller production varies significantly among the different nutrient management practices in T. Aman. BRRI recommended dose and poultry litter plot produced statistically similar tiller number. BRRI recommended fertilizer produced the highest number of tiller (251 tiller m^{-2}) whereas control plot gave the lowest number of tiller (194 tiller m^{-2}) among all the treatments. But kitchen waste, bio-slurry used plot produced statistically similar tiller number per square meter, which were significantly differ from BRRI recommended doses and poultry litter plot (Table 6).

Similar trend was observed in tiller production in the Boro season like T. Aman. Poultry litter (244 tiller m^{-2}) and BRRI dose (228 tiller m^{-2}) produced the highest and statistically similar number of tiller where control plot gave the lowest number of tiller (159 tiller m^{-2}). Bio-slurry and kitchen waste used plot showed statistically similar tiller number per square meter but significantly differ from control, poultry litter and BRRI fertilizer used plot.

Panicle number. Panicle production was significantly affected by all the nutrient management practices during T. Aman season. Here BRRI fertilizer dose (244 panicle m^{-2}) and poultry litter (238 panicle m^{-2}) used plot gave statistically similar and highest panicle number followed by 216 panicle m^{-2} in bio-slurry and 209 panicle m^{-2} in kitchen waste used plot. The lowest number of panicle (187 panicle m^{-2}) among all the treatments was observed in control plot (Table 6).

On the other hand during Boro season panicle number was significantly affected by different nutrient management practices and similar result like T. Aman was observed here. Among all the treatments poultry litter used plot gave the highest panicle (219 panicle m^{-2}) and control plot gave the lowest panicle (136 panicle m^{-2}). Statistically similar number of panicle produced in bio-slurry and kitchen waste.

Grain number and grain weight. In T. Aman, BRRI recommended dose, poultry litter and kitchen waste used plot gave almost similar number of grain per panicle, which was statistically significant from bio-slurry and control plot. BRRI recommended fertilizer provides the highest number of grain per panicle (115 grain panicle^{-}1) whereas control plot gave the lowest number of grain (98 grain panicle^{-1}). And there was no significant difference among the treatments in case of grain weight (Table 6).

Statistically similar grain per panicle was observed in BRRI fertilizer management, poultry litter, kitchen waste and bio-slurry in Boro season. Here also BRRI fertilizer management produced the highest grain per panicle (145 grain panicle^{-1}). On the other hand, control plot also produced the lowest number of grain (95 grain panicle^{-1}). No significant difference was found in grain weight among the treatments.

Grain yield. In T. Aman 2017, grain yield was significantly affected by different nutrient management practices. BRRI recommended fertilizer management (5.65 t ha^{-1}) and poultry litter (5.34 t ha^{-1}) gave the highest and statistically similar grain yield followed by kitchen waste (4.71 t ha^{-1}) and bio-slurry (4.45 t ha^{-1}) where kitchen waste and bio-slurry produced statistically similar grain yield. The lowest yield was observed in control plot (3.60 t ha^{-1}) (Table 6).

Grain yield of BRRI dhan58 was also affected by different nutrient management practices during Boro 2017-18. In Boro, poultry litter (6.49 t ha^{-1}) and BRRI recommended fertilizer management (6.20 t ha^{-1}) again produced higher and statistically similar grain yield followed by kitchen waste (5.07 t ha^{-1}) and bio-slurry (4.90 t ha^{-1}) used plot. The lowest grain yield was also observed in control plot (2.40 t ha^{-1}).

Straw yield. Significant effects of various nutrient management practices are also noticed in the production of straw as grain in T. Aman 2017. BRRI recommended dose produced the highest straw yield 6.48 t ha^{-1} followed by 5.16 and 5.20 t ha^{-1} in kitchen waste and bio-slurry used plot, respectively. Poultry litter produced 5.18 t ha^{-1} straw, which was also statistically similar to BRRI recommended dose applied plot. The lowest straw yield 4.45 t ha^{-1} was observed in control plot (Table 6).

Straw yield of BRRI dhan58 was also affected by different nutrient management practices in Boro 2017-18. Poultry litter management plot produced the highest straw yield of 6.51 t ha^{-1} followed by BRRI recommended dose (6.17 t ha^{-1}), kitchen waste (4.93 t ha^{-1}) and bio-slurry (4.73 t ha^{-1}) used plot whereas poultry litter and BRRI dose show statistically similar straw yield. Control plot gave the lowest (2.98 t ha^{-1}) straw yield among the treatments.

Table 6. Yield and agronomic parameter of different nutrient management practices during T. Aman 2017 and Boro 2017-18 in Approach-2.

Treatment	Plant height (cm)	Tiller m^{-2} (no.)	Panicle m^{-2} (no.)	Grain $panicle^{-1}$ (no.)	1000 grain wt (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
			Aman-2017				
Control	95.23	194	187	98	20.95	3.60	4.45
BRRI dose	103.35	251	244	115	21.35	5.65	6.48
Kitchen waste (3 t ha^{-1}) + ½ BRRI dose	101.53	219	209	108	21.29	4.71	5.16
Bio-slurry (3 t ha^{-1}) + ½ BRRI dose	101.60	227	216	105	21.14	4.45	5.20
Poultry litter (3 t ha^{-1}) + ½ BRRI dose	102.85	245	238	112	21.29	5.34	6.18
LSD at 5%	1.23	13.15	12.09	6.52	0.78	0.39	0.53
CV %	2.10	4.45	5.70	6.10	3.16	6.40	6.85
			Boro-2017-18				
Control	80.87	159	136	95	21.25	2.40	2.98
BRRI dose	85.10	228	203	145	21.50	6.20	6.17
Kitchen waste (3 t ha^{-1}) + ½ BRRI dose	83.83	207	176	140	21.73	5.07	4.93
Bio-slurry (3 t ha^{-1}) + ½ BRRI dose	82.94	190	162	142	21.85	4.90	4.73
Poultry litter (3 t ha^{-1}) + ½ BRRI dose	86.36	244	219	144	21.61	6.49	6.51
LSD at 5%	1.35	17.11	18.09	5.36	0.76	0.43	0.55
CV %	2.30	6.30	6.45	5.92	2.81	4.95	8.52

Conclusion. Grain yield, tiller number, panicle number, plant height and straw yield were significantly affected by the different effects of organic matter in both the Approaches during T. Aman and Boro season. In every parameter, poultry litter related treatments and BRRI recommended dose performed the best. This study indicates that poultry litter 6 t ha^{-1} or poultry litter (3 t ha^{-1}) + 50% chemical fertilizer is sufficient for rice cultivation and it also indicates that combined nutrient management gave higher rice yield. Further research needed to find out the suitable dose of organic matter or combined fertilizer management.

Monitoring labour wage rate at different locations of Bangladesh

A survey was conducted to find out the labourers' wage rate at different locations around BRRI HQ such as Joydebpur, Chowrasta, Salna, Board Bazar and Konabari etc (Table 7). It was observed that the average wage rate per day was Tk 447-491. The highest wage rate of labourers was in May (Tk 490-540 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 480-505 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 455-510 per day) due to the peak period for harvesting and post-harvest operation of T. Aman rice and transplanting of Boro rice.

In another survey, it was observed that the wage rate varied from place to place and ranged between Tk 395-420, 375-435, 425-490, 390-450, 430-465, 425-490, 385-425 and 435-485 at Habiganj, Rangpur, Rajshahi, Barishal, Sonagazi, Cumilla Satkhira and Khulna, repectively (Table 8).

PI: K P Halder CI: Md Sirajul Islam, Md Mamunur Rashid and Setara Begum

Rice seed production

In different seasons, this division produced 23,640 kg rice of which 19,726 kg seed and 3,914 kg mixed rice. All rice has been stored in the BRRI general store. As a part of the breeder seed programme of GRS Division, this division produced 8,750 kg breeder seed. These seeds were deposited to GRS Division.

PI: Md Mamunur Rashid CI: Md Sirajul Islam, Setara Begum and K P Halder

Table 7. Labourer's wage rate without stuff at different places around BRRI BQ, Gazipur during 2017-2018.

Month	Wage rate (Tk)*	Remark
Apr	410-465	Normal period
May	490-540	Peak period. Harvesting and post-harvest operation of Boro rice and transplanting of Aus rice.
Jun	405-465	Normal period
Jul	485-505	Peak period. Harvesting and post-harvest operation of Aus rice and transplanting of Aman rice.
Aug	480-505	
Sep	445-485	Normal period
Oct	430-480	
Nov	450-485	
Dec	460-510	Peak period. Harvesting and post-harvest operation of Aman rice and transplanting of Boro rice.
Jan	455-505	
Feb	435-480	
Mar	420-465	Normal period
Average	447-491	

* Wage rate of each month is the average rate of different places such as Joydebpur, Chowrasta, Salna, Board Bazar, Konabari etc.

Table 8. Land and labour strength of BRRI, 2017-18.

Name of station	Total land (ha)	Cultivable land		Labour (no.)		Total
		Area (ha)	% of total land	Muster roll		
				Regular	Irregular	
HQ at Gazipur	76.83	44.45	57.9	325	139	464
Cumilla	24.68	16.03	65.0	22	25	47
Habiganj	35.03	25.90	73.9	24	14	38
Sonagazi	45.77	35.90	78.4	26	17	43
Barishal	41.10	10.74	26.1	19	14	33
Rajshahi	13.24	8.92	67.4	21	11	32
Bhanga	11.46	9.55	83.3	13	7	20
Rangpur	6.07	4.05	66.7	26	9	35
Kushtia	0	0	0	10	3	13
Satkhira	20.00	8.10	40.5	6	15	21
Total	274.18	163.64	59.7	492	254	746

Support services

Land and labour management. Including BRRI regional stations, has 746 labourers of which 492 regular and 254 irregular (Table 8). In BRRI HQ, total labour number is 464 of which 325 regular and 139 irregular labourers. BRRI has 274 ha of land of which 163 ha is cultivable. Total labour utilization in different division for research purpose, research related works, support service and leaves was 1,80,568 man days of which 53.03, 43.98 and 2.99% were utilized for research, support service and holiday purpose, respectively. It was observed that total labour wages was Tk 9,02,84,000 of which Tk 4,78,82,000 and Tk 3,97,05,000 and Tk 26,97,000 were paid to the labours for research work, support service works, leaves and holidays, respectively. A total of 86.07 ha of land were utilized by different division in different season of which 11.64 ha in Aus, 36.17 ha in Aman and 38.26 ha in Boro season. This division always manages a visible flower garden to maintain an aesthetic view of the office area, some parts of the campus during summer and winter season.

PI: K P Halder CI: Md Sirajul Islam, Md Mamunur Rashid and Setara Begum

Farm Machinery and Postharvest Technology Division

SUMMARY

A study was aimed to design, fabricate and test the performance of the developed prototype of head feed mini combine harvester which was fabricated in the Janata Engineering Workshop, Chuadanga using locally available materials under Private Public Partnership (PPP). BRRI provided engineering design, drawing, technical and financial support to develop and fabricate the machine. The second prototype of combine harvester was redesigned and fabricated to remove the identified faults in the 1st prototype. The field test of 2nd prototype was conducted to find out the performance, efficiency, operation fault, etc. It was found that harvesting capacity and fuel consumption were 1.23~1.25 bigha/h and 3.84~3.96l/h respectively. There are still some problems in the 2nd version. When layer thickness of the passed straw is more than one inch, some un-threshed panicle remained in the upper layer of rice stalk. The developed combine harvester is appropriate in both dry and muddy fields with plough pan. This machine can also be used in agriculture in a number of ways, to increase productivity, mitigate labour shortage and reduce production cost.

Another study was conducted to incorporate the prilled urea fertilizer deep placement (FDP) technology with the existing rice transplanter (ARP-4UM) to accelerate the adoption of mechanized rice transplanting and FDP technologies to the end users. Walking type 4-rows rice transplanter was selected for FDP technology based on power transmission facility and available space for necessary attachment. The developed rice transplanter cum prilled urea applicator performed well in the lab, research field as well as farmers' field by transmitting power from engine to applicator, receiving and placing the prilled urea to the furrow and covering the placed fertilizer properly.

A separate study was conducted to evaluate the performance of BRRI developed rice transplanter cum prilled urea applicator (RTPUA) in the farmers' fields at Chadgaon, Madan, Netrakona; Bahirbag, Muksudpur, Gopalganj; Tarapur, Kumarkhali, Kushtia and Vararul, Dhirashrom, Gazipur, districts during Boro season 2018. The experiment was laid out in a randomized complete block (RCB) design with three replications. Mechanical transplanting along with deep placement of urea fertilizer (70% of recommended dose) gave significantly higher yield compared to manual transplanting and hand broadcasting of urea except Kumarkhali, Kushtia. RTPUA accounted the highest BCR (1.55, 1.67, 1.79 and 1.49 at Netrakona, Gopalganj, Kushtia and Gazipur, respectively) for 70% of the recommended urea fertilizer application in non-oxidize zone followed by mechanical transplanting plots along with hand broadcasting of urea fertilizer (1.35, 1.38, 1.70 and 1.25).

BRRI developed power weeder was tested in wet land condition in BRRI research field and farmer's field, Jogitola, Gazipur. The performance of the weeder was compared to BRRI weeder, BRRI conical weeder, Double row weeder and hand weeding techniques in wetland condition. The performance of the power weeder was found satisfactory in terms of field capacity (15.16 decimal/h, 14.65 decimal/h at BRRI research field and farmer's field respectively) and degree of weeding (80.38% and 81.43 % at BRRI research field and farmer's field respectively). Farmers can use this weeder in wet land condition.

A de-husking machine was developed to improve the milling performance of rice processing and husking. Brown rice was polished in MNMP polisher. Capacity of the de-husker was 675 kg and the husking efficiency was found 92.3% for BRRI dhan80. The milling recovery was 64% when it was polished in friction type polisher. The average head rice recovery based on input paddy was 55.8%, which was found promising for processing of premiere quality rice. Existing engelberg huller can be replaced with the combination of de-husker and polisher. Besides, this combination gives similar milling recovery of the semi and automatic rice mill.

Solar light trap manufactured, distributed and adaptive field trial was done in farmers' field under special research budget allocation of the Ministry of Agriculture. Aiming to validate and adaptive field trial of BRRI solar light trap to the end users, manufacturer and resource poor farmers that reduces the need for application of insecticides. A total 120 solar light traps were distributed to the farmers' field. Rice insect pests including yellow stem borer (YSB), green leafhopper (GLH), white leafhopper (WLH), leaffolder (LF), caseworm (CW) and rice bug (RB) were the dominant in each of the solar light trap test cases.The highest number of insect

pests was trapped in May than that of April month. In brinjal field, significantly higher number of brinjal fruit and shoot borer (BFSB) were recorded in solar light trap than in pheromone trap. A total of 25 awareness cum demonstration and training programme were conducted along with more than 1,000 potential farmers, manufacturers, NGO personnel. Use of solar light trap both in rice and vegetable crops was found effective in controlling insect pests. It also reduces chemical insecticide application and save environment.

An awareness programme was taken in *haor* areas (Kishorganj, Habiganj and Netrakona) in Boro 2018 season to adopt mat type seedling raising technique and transplanting seedling mechanically in the field. Field demonstration cum training on seedling raising technique and mechanical rice transplanting were conducted at farmers' filed. A total of 18 bighas of farmers' land was transplanted in the demonstration cum training programme. Participant farmers prepared seedling tray in their own hand and these seedlings were used for transplanting.

One week long hands-on in-house training on use of modern agricultural machinery in different farm operations for village mechanic was organized at FMPHT Division of BRRI financed by On Farm water Management Project of the Department of Agriculture Extension (DAE). A total 180 machinery operators from different districts of Bangladesh attended in six batches of training programme. The participants learned to disassemble and assemble a diesel engine, operate rice transplanter, combine harvester, open and closed drum thresher, reaper and reaper binder, power tiller, tractor and winnower. This training included proper operation of machinery, safety measures and assessment of repair and maintenance of BRRI developed machinery and technologies. Basic ideas (how to operate new engine, when it is needed to change air, oil and fuel filter etc) on operation, repair and maintenance of diesel and petrol engines was shown to the participants.

AGRICULTURAL MACHINERY DEVELOPMENT AND TESTING

Head feed mini combine harvester

The head feed combine is different from whole feed type combine where only the panicle is feed into the machine as a result straw remain intact but threshing capacity is lower than the whole feed type. In Bangladesh, straw is used to feed the cattle, as fuel for cooking and household other purposes. So it is necessary to develop a head feed combine harvester.

Development procedure

The work aims to develop a mini combine harvester using locally available materials under Public Private Partnership (PPP) approach between the FMPHT Division, BRRI, Gazipur and Janata Engineering, Chuadanga. The first prototype was developed by using GoB fund, but modified and improved version (second) was done using CRG, NATP-2 project fund. The preliminary test was conducted during the Aman 2017 and Boro 2018 season.

The main design consideration was-

- Feeding only the half portion of the crop (head feeding)
- Incorporate the crawler for moving both dry and wet fields
- Size is small and suitable for fragmented land and small fields
- Strong power (32hp with self-starting) which can pass smoothly and easily
- Compact structure, low height, stripping belt system
- The major thrust was given to develop a combine harvester in a combination of multiple views, viz intake rice straw, local materials, reduction of drudgery, light weight, easy to travel control, flexible turning
- The head feed combine was designed on the basis of locally available low cost materials considering easy fabrication process, simple disassembling and convenient for maintenance.

Design and fabrication

FMPHT division provided design, technical and financial support to Janata Engineering Works to fabricate the combine harvester. The working speed and capacities for different functional elements (cutting part, conveyer, threshing, bagging part, base, and driving power) is very important for the development of a combine but in head feed combine the cutting and feeding part is very much complicated (Fig. 1). The standard parameters were:

- Rotational speed of the paddy conveyer star wheel was higher than the forward speed
- Capacity of feeding table was same as the star wheel feeding
- Optimum plant height ranged from 50 to 80cm
- Cutting speed of 300-350 RPM
- Star wheel peripheral speed was 25~50% greater than the machine forward speed
- Inclination of grain conveyer was 35°

Easy fabrication, low cost, high capacity and a few repairs and maintenance were the major objectives of the prototype development and the following issues were considered:

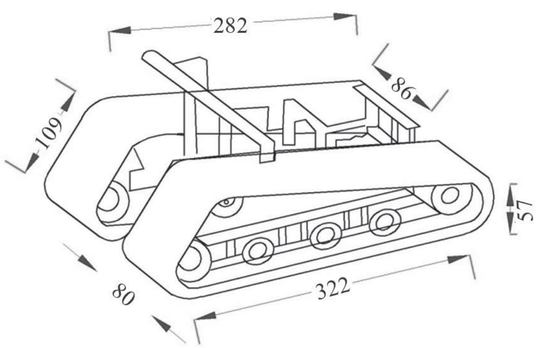
- Use cutter bar from the reaper, which is available found in local markets
- Feeding table made by locally available heavy duty rubber
- Locally available materials for the conveyer, belt pulley, etc.
- Chinese engine, gearbox and crawler
- Grain loss needed to be minimized by improving some of its functional elements (blower and thresher, etc.) and provision of dividers in front of the cutter bar.

The main functional unit of the machine is:

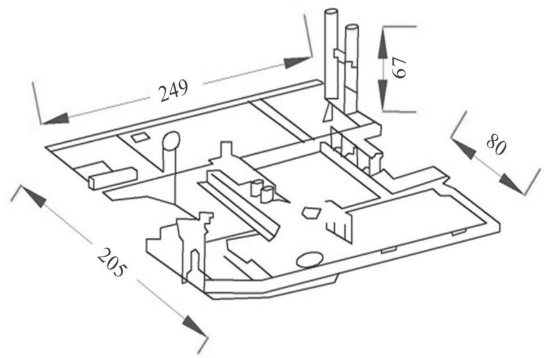
- Travelling mechanism
- Platform/base
- Cutting part with cutting head
- Power system and transmission unit
- Operative section/Driving system
- Hydraulic system with pump assembly for controlling cutting parts up and down
- Electric system
- Bagging system with cleaning mechanism
- Others (Seat assembly, indicator, safety protection)

Test and evaluation

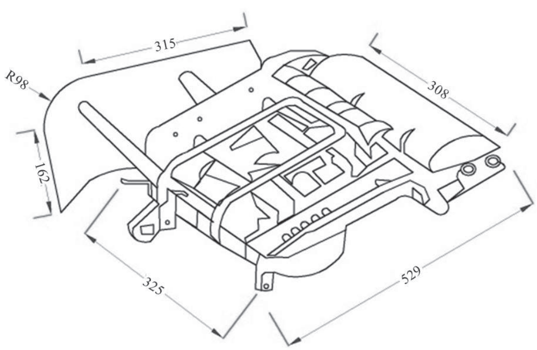
The performance test of developed head feed mini combine harvester was conducted in different



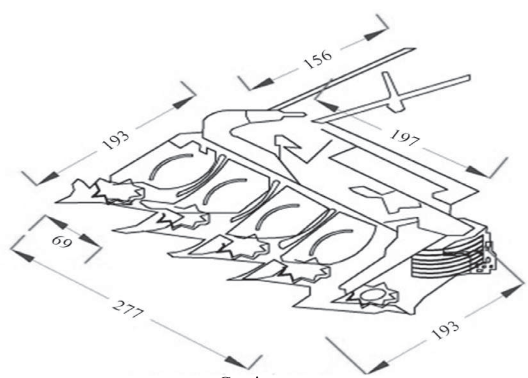
Travelling mechanization



Platform/base of the machine



Threshing part



Cutting part

Note: All dimensions are in cm

Fig. 1. The main functional unit of combine harvester.

field (Dry and wet) conditions in Chuadanga. The identified problem and results were analysed and taking necessary action for further development and improvement. The improved combine harvester was tested on load and no-load conditions. Fine tuning and modification has been done of the developed combine harvester based on laboratory and field test. Modification was a continuous process in the laboratory and field until it becomes user friendly.

Version-1

BRRI has been working to develop the combine harvester since 2016. Series of works have been done continuously to fulfil the goals and farmers' demand. The farmers' feedback was collected in three rice seasons of 1st prototype and that information was used to finalize the second version. The major features, identified faults and necessary measures were mentioned as followed for 2nd version:

First version	Fault	Measure
✓ Wheel: Crawler type ✓ Engine: 20 hp ✓ Gear: Chinese ✓ Power transmission system: locally made ✓ Lifting system: Hydraulic ✓ Starting system: Mechanical ✓ Threshing drum diameter 30 cm	✓ Working speed is low ✓ Gear system didn't work properly ✓ Power transmission problem ✓ Frequent break down in welding parts ✓ Cutting parts lifting is troublesome ✓ Un-threshed paddy due to threshing drum length ✓ Faulty design of cleaning blower ✓ Grain loss in different joint position due to improper welding	✓ New and high quality gear incorporated ✓ Threshing drum diameter increased (42 cm) ✓ Incorporated cyclone separator for paddy shifting ✓ Used lighter materials as per as possible

Version-2

The second version of the mini combine harvester was redesigned to rectify the identified faults of 1st prototype and fabricated at Janata Engineering workshop under PPP. The laboratory test of the second version of the prototype was tested in Aman season 2017. Thoroughly tested and detailed assessment was done in Boro 2018 season. Table 1 presents specification of head feed mini combine harvester.

Performance test

To evaluate the improved combine harvester several field tests were conducted during last two crop seasons (Aman 2017 and Boro 2018) in different fields of Chuadanga district. The following factors were considered to evaluate the performance of both load and no-load conditions. In no-load conditions the laboratory workshop test/road test for verifying the joining/welding/vibration/balancing/speed/clogging/alignment problems. For field performance test the following factors were considered:

- Harvesting area and harvesting time
- Walking speed
- Fuel consumption
- Field capacity

Table 2 shows that the walking speed was 1.37km h^{-1} and 1.25km h^{-1} in dry Aman 2017 and wet Boro 2018 season respectively during the field operation of combine harvester. The working speed in Aman season was higher than that of Boro season, due to muddy field. The average fuel consumption was found 3.84 to 3.96l h^{-1} and field capacity was 0.15 ha h^{-1} (1.25 bigha h^{-1}).

It was observed that the walking speed was 1.37km/h and 1.25km/h in dry Aman 2017 and wet Boro 2018 season respectively during the field operation of combine harvester (Fig. 2). The working speed in Aman season was higher than that of Boro season, due to muddy field. The average fuel consumption was found 3.84 to 3.96l/h and field capacity was 0.15ha/h (1.25 bigha/h).

Table 1. Specification of designed combine harvester.

<table>
<tr><th colspan="2">Particular</th><th>Specification</th></tr>
<tr><td colspan="2">Feeding type</td><td>Half-feeding</td></tr>
<tr><td colspan="2">Dimension (Length*width*height)</td><td>262*120*134 cm</td></tr>
<tr><td colspan="2">Harvesting</td><td>Cutting blade and two blades sliding cutting</td></tr>
<tr><td colspan="2">Convey the paddy</td><td>Chain and star wheel</td></tr>
<tr><td rowspan="4">Threshing type</td><td>Feeding</td><td>Head</td></tr>
<tr><td>Feeding table</td><td>Rotating rubber belt with axial flow spiked</td></tr>
<tr><td>Feeding table
(Length and width)</td><td>140 cm*110 cm</td></tr>
<tr><td>Additional threshing drum type</td><td>Axial flow, spike tooth</td></tr>
<tr><td colspan="2">Convey the threshed grain</td><td>Screw conveyer (Extendible transverse conveyer)</td></tr>
<tr><td colspan="2">Type of concave screen</td><td>Grid type</td></tr>
<tr><td colspan="2">Cleaning</td><td>Cyclone separator with blower</td></tr>
<tr><td colspan="2">Bagging</td><td>Directly bagging</td></tr>
<tr><td rowspan="4">Engine
Output/rpm, kw/rpm
Starting system
Fuel tank capacity, L</td><td>Type</td><td>Air cooling, four stroke, single cylinder, diesel engine</td></tr>
<tr><td>23.87/2200 (Rated HP=32)</td><td></td></tr>
<tr><td>Auto and manual (Both)</td><td></td></tr>
<tr><td>6</td><td></td></tr>
<tr><td rowspan="3">Traveling system
Ground clearance, cm
Transmission</td><td>Crawler specification
(width*pitch*No.of tooth)</td><td>40 cm*9 cm*46</td></tr>
<tr><td>26</td><td></td></tr>
<tr><td>Hydrostatic transmission</td><td></td></tr>
<tr><td rowspan="3">Gear system
(4 nos.)
Oil capacity
Reverse</td><td>Forward</td><td>1st gear, 2nd gear, 3rd gear</td></tr>
<tr><td>Engine 4 liter, Gearbox 8 liter</td><td></td></tr>
<tr><td>single</td><td></td></tr>
<tr><td colspan="2">Power system</td><td>Hydro-static transmission (HST)</td></tr>
<tr><td colspan="2">Grain unloading method</td><td>Manually</td></tr>
<tr><td colspan="2">Overall dimension (L*W*H), cm</td><td>260*135*200</td></tr>
<tr><td colspan="2">Cutting width</td><td>120 cm (4ft)</td></tr>
<tr><td colspan="2">Type of cutter</td><td>Reciprocating type</td></tr>
<tr><td colspan="2">Number of reaped row
(Row to row distance: 20cm)</td><td>6</td></tr>
<tr><td colspan="2">Minimum cutting height, cm</td><td>10</td></tr>
<tr><td colspan="2">Type of cutter</td><td>Reciprocating type (two blades sliding cutting)</td></tr>
<tr><td colspan="2">Minimum ground clearance, cm</td><td>20</td></tr>
<tr><td colspan="2">Suitability</td><td>Dry and wetland</td></tr>
<tr><td colspan="2">Operators needed/manpower</td><td>3</td></tr>
<tr><td colspan="2">Power transmission system</td><td>Chain sprocket/mechanical</td></tr>
</table>

Table 2: **Field test data.**

Place: Sorajganj, Chuadanga, Crop: Rice, Season: Aman 2017.

Test no.	Duration of test (Working h)	Travel speed			Rate of work		Fuel consumption	
		Gear used	Speed		Area covered		l/h	l/ha
			(m/s)	(km/h)	(bigha/h)	(ha/h)		
1	3.0	1st	0.40	1.44	1.29	0.17	3.70	21.41
2	2.5	1st	0.38	1.37	1.23	0.16	3.50	21.32
3	4.0	1st	0.39	1.40	1.26	0.17	3.80	22.55
4	0.5	1st	0.34	1.22	1.10	0.15	4.20	28.59
5	0.30	1st	0.39	1.40	1.26	0.17	4.00	23.74
Average			0.38	1.37	1.23	0.16	3.84	23.52

Place: Sorajganj, Chuadanga, Crop: Rice, Season: Boro 2018.

Test no.	Duration of test (Working h)	Travel speed			Rate of work		Fuel consumption	
		Gear used	Speed		Area covered		l/h	l/ha
			(m/s)	(km/h)	(bigha/h)	(ha/h)		
1	2.0	1st	0.30	1.08	0.97	0.13	4.20	32.41
2	2.0	1st	0.33	1.19	1.06	0.14	3.50	24.55
3	5.0	1st	0.40	1.44	1.29	0.17	3.80	21.99
4	2.5	1st	0.34	1.22	1.10	0.15	4.20	28.59
5	1.30	1st	0.37	1.33	1.19	0.16	4.12	25.78
Average			0.35	1.25	1.12	0.15	3.96	26.66

Fig. 2. Final prototype and field operation of the developed head feed combine harvester

Problem Identification

For the validation of developed combine harvester, a limited scale interview was conducted and opinions were collected from operator, farmers and machinery users regarding the overall performance. In general, they offered satisfactory remarks about the machine performance making special reference to the following problems and comments.

- Sometimes straw clogged in the conveyer belt;
- More time required to harvest in a muddy field;
- Grain breakage was found in main outlet;
- Some un-threshed panicle was observed when rice stalk thickness was more than 1 inch
- The shuttering of grain was observed in the laid down crop during harvesting;
- It was very difficult to move machine for long distance.

Incorporation of prilled urea deep placement mechanism in the mechanical rice transplanter

A research was conducted to incorporate the prilled urea fertilizer deep placement mechanism (FDP) with the walking type rice transplanter (model: ARP-4UM). To accomplish the design and development of the rice transplanter cum prilled urea applicator, the following activities were carried out.

- A belt-pulley arrangement was designed with tension pulley to engage and disengage the engine power from engine shaft to the outer shaft of the applicator gear box
- Designed a simple gear box incorporating worm and worm gear with bevel gear and shaft to transmit the power at 90° directions.
- Chain-sprocket arrangement was incorporated to convey the power from gear box output shaft to the applicator main shaft
- Design and incorporation of fertilizer dispensing mechanism, skid and covering mechanism to the rice transplanter
- Evaluated the performance of the developed transplanter in both research and farmers' field

The following design considerations were made-

- Deep placement of prilled urea fertilizer should be in between two rows and before the rotary picker
- FDP technology should be operated with the existing power of the transplanter
- Depth of fertilizer placement should be in between 100 to 150 mm
- Dispensing pattern of the granule fertilizer should be uniform and continuous
- Power transmission system should be simple with engage and disengage facility
- Locally available materials should be used to minimize the fabrication cost

Engine power available at high RPM (more than 1800 of the walking type rice transplanter) was conveyed to the applicator with the arrangement of a belt-pulley, worm gearing, shaft-bearing, chain-sprocket and bevel gear with engage-disengage facility resulting 22 RPM of the applicator main shaft considering transplanting speed of the transplanter. To convey the engine power, engine pulley was modified to collect engine power from engine to the main gear pulley and single groove main gear pulley was replaced by double grove pulley. This is the first stages of power reduction from 1800 to 810 RPM. Power transmitted to the worm gear at a ratio of 1:35 from gear pulley to reduce the power. Bevel gear of 13 teeth is used in the gear box to change direction of power at 90° intersecting shaft. Gear box (140 mm × 85 mm × 120 mm) made of 3 mm SS sheet. Single start worm gear of 35 teeth is used having 12 mm shaft diameter. Power transmitted from output shaft of the gear box to the applicator main shaft with the ratio of 10:9 by chain-sprocket arrangement. Length of pitch, radius of roller, distance between two plates inside the sprocket are 13, 7 and 6 mm. Tension pulley also added to the power transmission mechanism to engage and disengage during operation. Impellor type mechanism was connected with the main shaft of the applicator to dispense the prilled urea fertilizer to the output channel (Figs. 3 and 4). The developed rice transplanter cum prilled urea applicator (Fig. 5) performed well in the lab, research field as well as farmers' field by transmitting power from engine to applicator, receiving and placing the prilled urea to the furrow and covering the placed fertilizer properly.

Operational procedure

The walking type rice transplanter was modified by incorporating theprilled urea deep placement mechanism in the rice transplanter. During transplanting operation, the following procedure needs to follow for successful placement of the prilled urea.

- Disengage the power of the applicator gear box before starting the engine and transplanting
- Lubricant and grease need to be checked of the applicator gear and chain-sprocket before operation
- Tension of the belt also needs to be checked before operation
- Power of the applicator gear box engaged with the start of transplanting
- At the end of field, during turning, again disengage the power of the applicator gear box for avoiding unnecessary loss of granule
- Time to time re-fill the hopper by prilled urea fertilizer
- Some amount of urea fertilizer need to be carried like seedling mat for re-filing in the field as and when necessary

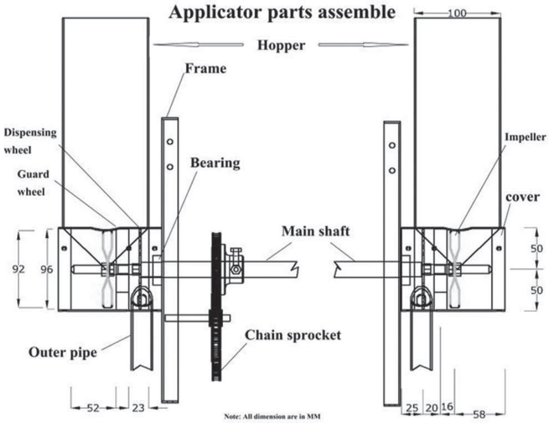


Fig. 3. Assembling mechanism along with all parts of the applicator.

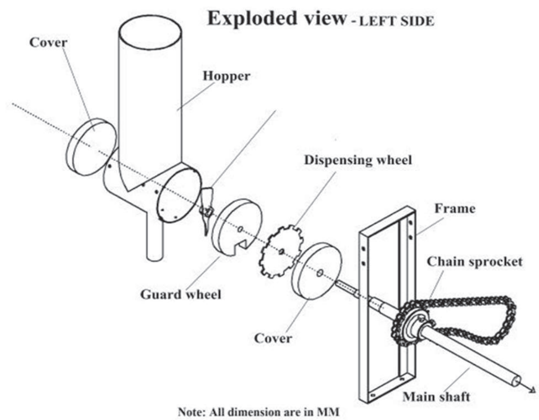


Fig. 4. Full assembling view of the applicator.

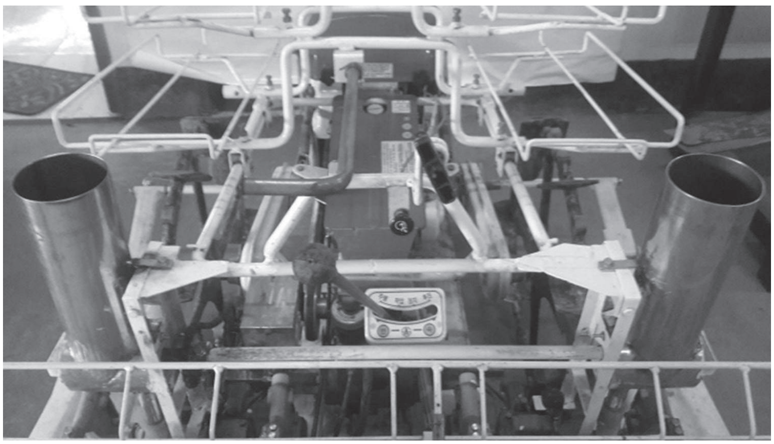


Fig. 5. Impellor type applicator incorporated in the rice transplanter.

Multi-location trials of the BRRI developed rice transplanter cum prilled urea applicator

The performance test of BRRI developed rice transplanter cum prilled urea applicator (RTPUA) was conducted in the farmers' field at Chadgaon, Madan, Netrakona; Bahirbag, Muksudpur, Gopalganj; Tarapur, Kumarkhali, Kushtia and Vararul, Dhirashrom, Gazipur, districts during Boro season 2018. BRRI dhan28 was used to conduct the study except Kushtia, where BRRI dhan58 was used as study material. Soil textures of the study areas were clay, silty loam, clay loam and silty clay loam respectively. The experiment was laid out in a randomized complete block RCB design with three replications. About one meter of buffer spacing was maintained among the sub-plots whereas experimental plot size was 75, 82, 105 and 54 decimal in Netrakona, Gopalganj, Kushtia and Gazipurrespectively. The treatments were- T_1: Mechanical transplanting (MT) along with urea deep placement together (70% urea), T_2: MT + hand broadcasting of urea (UHB) at three equal split, T_3: Hand transplanting (HT) and UHB at three equal split and T_4: Control (-N).

Seedlings were raised both on plastic tray (280×580×25 mm) and farmers' seed bed for mechanical and manual transplanting at the same date. Manual transplanting was done after 15 days of mechanical transplanting. Thirty and 45-day-old seedlings were used in mechanical and hand transplanting plots respectively. Control plots (T_4) were transplanted mechanically using the mat type seedling. Urea fertilizer was placed 6-8 cm depth in non-oxidized zone during mechanical transplanting with the same machine. The pre-determined dose of fertilizer was calibrated before operation of RTPUA. BRRI recommended urea fertilizer dose was considered 260 kg ha^{-1} for BRRI dhan28 and BBRI dhan58 except Madan, Netrakona where urea fertilizer dose was considered 225 kg ha^{-1} for *haor* area (BRRI[1], 2017). At 70% of the recommended dose, the rate of urea fertilizer is 158 and 182 kg ha^{-1} respectively (Table 3).

To maintain the desired rate of fertilizer, fertilizer dispensing rate per rotation of the driving wheel was calculated using the following formula.

$$FDR = \frac{\pi D \times 2L \times RoF}{10^5}$$

Where,

FDR = Fertilizer dispensing (from each channel) rate per rotation of the driving wheel (g/rotation)

D = Wheel diameter of the applicator, cm (about 60 cm)

L = Line to line spacing of the transplanted rice, cm

RoF = Desired rate of fertilizer application, kg ha^{-1}

Recommended dose of urea fertilizer was applied in the hand broadcasted plots whereas 70% of the recommended dose in the treatment T_1. Triple super phosphate (TSP), muriate of potash (MoP), zinc sulphate ($ZnSO_4$) and gypsum fertilizer were applied at sowing. Urea fertilizer was broadcast in three equal applications at seven days after transplanting, vegetative stage and before panicle initiation stage.

Field capacity of the RTPUA

The capacity was found more in Netrakona and less in Kushtia due to soil condition. Field efficiency varied from 53 to 62% irrespective of soil and location. Average of four locations and three replications, actual field capacity of the rice transplanter was found 0.119 hah^{-1}(Table 4).

Crop performance

Plant height. Figure 6 presents plant height at different dates after transplanting varied with the mode of fertilizer application in all locations. At 60 days after transplanting, plant height was observed more for $T_{1,}$ T_2compared T_3, T_4 whereas plant height at harvest time was found higher for $T_{3,}$ which is equal to T_1in Netrakona. In all the locations, T_4 gave lower plant height compared to T_1.

Number of tiller. Figure 7 presents number of tiller per hill at different dates after transplanting varied with the mode of fertilizer application. At different dates after transplanting, mechanical transplanting plots with fertilizer deep placement or without fertilizer deep placement gave higher number of tiller per hill compared to manual transplanting and fertilizer control plots whereas at harvest, there was no significant difference among T_1, T_2 and T_3 treatments in Gopalganj**.** At 30 and 45 days after transplanting, all the treatments varied significantly where T_1 gave higher number of tiller and T_4 gave fewer numbers of tillers in Kushtia. However, at harvest, only T_1 gave significantly higher number of tiller from T_4 whereas T_1, T_2 and T_3 gave similar number of tiller in Gazipur.

Grain yield performance. Grain yield varied with the mode and rate of urea fertilizer application (Table 5). Mechanical transplanting along with deep placement of urea fertilizer (70% of recommended dose) gave significantly higher yield compared to manual transplanting and hand broadcasting of urea except Kumarkhali, Kushtia.

Harvest index. Table 6 presents harvest index of the experimental crop under different treatments. It did not vary with the rate and mode of fertilizer application over the locations and varieties.

Table 3. Percent of fertilizer saving as affected by soil condition and location.

Location	Area (m^2)	Urea dispensed (kg)	Urea dispensed rate (kg/ha)	Theoretical rate of dispensed at 30% saving (kg/ha)	Recommended dose (kg/ha)	% of saving	% of deviation (±)
Netrakona	1180	18.5	156.8	158	225	25.1%	+4.9
Gopalganj	1200	23.2	193.3	182	260	25.7	+4.3
Kushtia	1404	26.1	185.9	182	260	28.5	+1.5
Gazipur	965	18.4	190.7	182	260	26.7	+3.3

Note: Average value of three replications, width of covered per pass of the machine is 1.2 m.

Table 4. Field performance of the RTPUA.

Condition of RTPUA operation		Forward speed of operation (km hr^{-1})	Actual field capacity (ha hr^{-1})	Theoretical field capacity (ha hr^{-1})	Field efficiency (%)
Netrakona					
With UFDP		1.89	0.132	0.227	58.2
Without UFDP		1.93	0.139	0.232	59.9
Gopalganj					
With UFDP		1.76	0.112	0.211	53.1
Without UFDP		1.8	0.122	0.216	61.1
Kushtia					
With UFDP		1.62	0.104	0.194	53.6
Without UFDP		1.63	0.113	0.196	62.8
Gazipur					
With UFDP		1.71	0.117	0.205	57.1
Without UFDP		1.75	0.119	0.210	56.7
Average	With UFDP	1.75	0.12	0.21	55.50
	Without UFDP	1.78	0.12	0.21	60.13

Note: Average value of three replications, width covered per pass of the applicator is 1.2 m. UFDP-Urea fertilizer deep placement

Table 5. Yield performance as affected by mode and rate of urea fertilizer application.

Treatment	Yield of BRRI dhan28 and BRRI dhan58 at different location (t/ha @ 14% m.c)			
	Madan, Netrakona (BBRI dhan28)	Bahirbhag, Gopalganj (BRRI dhan28)	Kumarkhali, Kushtia (BRRI dhan58)	Sadar, Gazipur (BBRI dhan28)
1	5.74 a	8.27 a	7.37 a	5.51 a
2	5.07 b	6.97 b	7.22 a	4.73 ab
3	3.97 c	5.92 b	6.80 a	4.06 b
4	3.65 c	4.39 c	3.07 b	3.27 c
Level of significance	**	**	**	**
% of CV value	3.5	9.26	8.24	8.69
LSD	0.322	1.1825	1.0065	0.783

Note: T_1: Mechanical transplanting (MT) along with urea deep placement together (70% urea), T_2: MT + hand broadcasting of urea (UHB) at three equal splits, T_3: Hand transplanting (HT) and UHB at three equal splits and T_4: Control (-N).

Table 6. Harvest index (%) as affected by mode and rate of urea fertilizer application.

Treatment	Straw yield of BRRI dhan28 and BRRI dhan58 at different locations (t/ha @ 14% m.c)			
	Madan, Netrakona (BBRI dhan28)	Bahirbhag, Gopalganj (BRRI dhan28)	Kumarkhali, Kushtia (BRRI dhan58)	Sadar, Gazipur (BRRI dhan28)
1	57.5	61.1	57.0	52.6
2	53.6	58.5	59.7	52.8
3	52.7	57.7	57.1	57.1
4	57.3	57.0	59.6	60.4
Level of significance	NS	NS	NS	NS
% of CV value	5.56	4.36	3.78	7.02

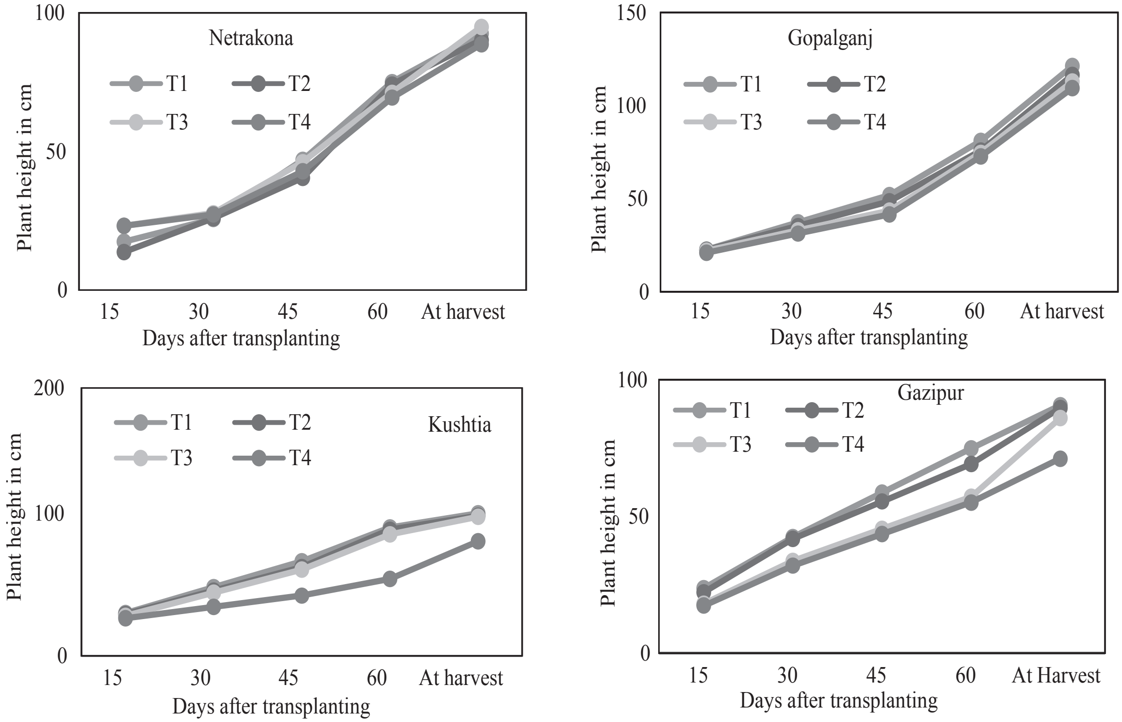


Fig. 6. Plant height in respect to days after tra nsplanting as affected by rate and application methods of urea fertilizer.
Note: T_1: Mechanical transplanting (MT) along with urea deep placement together (70% urea), T_2: MT + hand broadcasting of urea (UHB) at three equal split, T_3: Hand transplanting (HT) and UHB at three equal split and T_4: Control (-N).

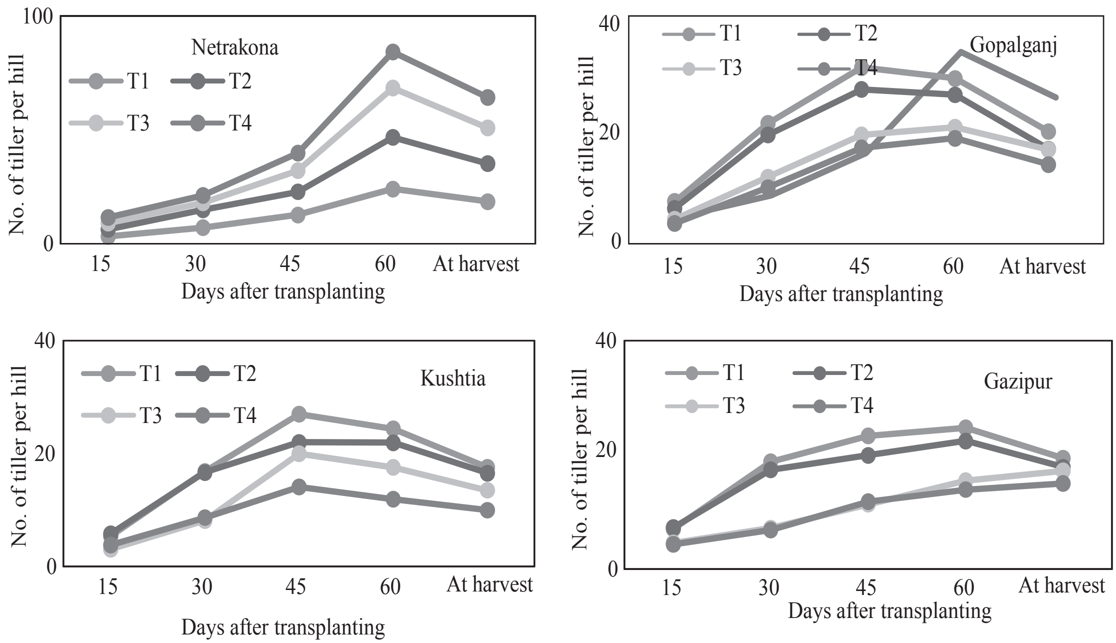


Fig. 7. Plant population in respect to date after transplanting as affected by rate and application methods of urea fertilizer.
Note: T_1: Mechanical transplanting (MT) along with urea deep placement together (70% urea), T_2: MT + hand broadcasting of urea (UHB) at three equal splits, T_3: Hand transplanting (HT) and UHB at three equal splits and T_4: Control (-N).

Economic performance

RTPUA accounted the highest BCR (1.55, 1.67, 1.79 and 1.49 at Netrakona, Gopalganj, Kushtia and Gazipur respectively) for 70% of the recommended urea fertilizer application in non-oxidize zone followed by mechanical transplanting plots along with hand broadcasting of urea fertilizer (1.35, 1.38, 1.70 and 1.25) (Table 7).

Field performance of the weeder

Test and evaluation of BRRI developed power weeder was conducted in BRRI research field at west bide and farmer's field, Jogitola, Gazipur whereas a comparative study of different weeder was also conducted to compare the weeding performance (Fig. 8). Different types of weeder such as BRRI power weeder, BRRI weeder, BRRI conical weeder, BRRI double row weeder were used in this study and data were collected. The performance of the weeders were evaluated in terms of walking speed (m/h), theoretical capacity (dec./h), actual field capacity (dec./h), field efficiency (%), weeding efficiency (%), damage of tiller (%) etc. Table 8 presents the performance of the weeder.

Table 7. Benefit-cost ratio as affected by mode and rate of urea fertilizer application.

Treatment	Input cost (Tk ha^{-1})	Gross return (Tk ha^{-1})	Gross margin (Tk ha^{-1})	BCR
		Netrakona		
T1	78446	121235	42789	1.55
T2	80130	108060	27930	1.35
T3	83160	84740	1580	1.02
T4	81278	77080	-4198	0.95
		Gopalganj		
T1	78940	131925	52985	1.67
T2	80836	111945	31109	1.38
T3	83866	95385	11519	1.14
T4	81278	70815	-10463	0.87
		Kushtia		
T1	78940	141015	62075	1.79
T2	80836	137640	56804	1.70
T3	83866	129720	45854	1.55
T4	81278	58350	-22928	0.72
		Gazipur		
T1	78940	117655	38715	1.49
T2	80836	100930	20094	1.25
T3	83866	85805	1939	1.02
T4	81278	69075	-12203	0.85

Table 8. Field performance of the BRRI developed power weeder.

	Effective field capacity (dec./hr)	Field efficiency (%)	Degree of weeding / weeding efficiency (%)	Plant damage (%)	Walking speed (k/h)
		Operation in BRRI research field, Gazipur			
	16.97	65.84	80.79	2.59	1.74
	13.88	68.67	80.41	3.13	1.36
	14.62	67.39	79.93	2.53	1.47
Avg.	15.16	67.3	80.38	2.75	1.52
		Operation in Jogitola, Gazipur			
	16.75	66.67	81.35	3.12	1.70
	12.57	70.40	82.17	2.94	1.21
	14.62	65.49	80.77	2.98	1.51
Avg.	14.65	67.52	81.43	3.01	1.47

Fig. 8. Operation in BRRI research field and Jogitola, Gazipur.

The BRRI developed power weeder was found suitable to control weeds in the line transplanted field. The weeding efficiency of the power weeder was 80.38, 81.43 % at BRRI research field, Gazipur and farmer's field, Jogitola, Gazipur respectively. The effective field capacity of the developed power weeder was 15.16 decimal/h, 14.65 decimal/h at BRRI research field, Gazipur and farmer's field, Jogitola, Gazipur respectively. Field efficiency of the BRRI developed power weeder was found 67.3% at BRRI research field and 67.52% at farmer's field. Percent of tiller damage was found 2.75, 2.81 at BRRI research field, Gazipur and farmer's field, Jogitola, Gazipur respectively (Table 9). The weeder can uproot and bury the weeds in multi rows at a time with forward operation. Women labourercan alsooperate it easily. Moreover, farmers can use this weeder in their field to get more comfort ability in weeding and mulching.

MILLING AND PROCESSING TECHNOLOGY

Test, evaluation and modification of rubber roll de-husker

Rubber roll de-husker was modified to improve the performance of rice processing. Electric motor (4 kW) was used to operate the de-husker. Two rubber rolls rotated toward opposite direction; one is fixed rubber roll having 230 mm and 154 mm diameter and length respectively. The RPM of the fixed rubber roll is 1043. Another is adjustable rubber roll having the same diameter and length. The RPM of the adjustable rubber roll is 783. A blower with 1028 RPM is used to carry the husk from husking chamber and that runs at 1028 RPM. 50 × 50 mm angle bar and 16 BWG sheet was used to fabricate stairway to facilitate carrying paddy in the hopper. A husk aspirator was connected through a pipe (dia. 200 mm) in the bottom end of the de-husker that operates by 1.5 kW (2840 RPM) motor. A cyclone separator attached in the de-husker for collecting husk. Rubber roll de-husker did not damage the aleuronic layer of paddy. An airstream was blown over the grains and immature grains dropped into the separate hopper for discharge. The paddy and husk discharged separately. BRRI dhan80 (unparboiled) was used in this experiment. The moisture content was 11.3 % (wb.) and each sample size was 20 kg. De-husked paddy was processed in MNMP-15 model friction type polisher to evaluate the milling parameter.

The average de-husking capacity of the husker was 675 kg/h and husking efficiency was about 92.3% (Table 10). Husking efficiency can be increased by closing the adjustable roller, which increases the broken rice (brown). The average brown rice percentage was found 77% and the

Table 9. Weeding performance with different weeding technology at BRRI research field and Jogitola, Gazipur.

Parameter	BRRI research field					Jogitola, Gazipur				
	HW	BW	PW	CW	DW	HW	BW	PW	CW	DW
Effective field capacity (dec./hr)	2.28	5.91	15.16	5.65	9.09	2.35	5.58	14.65	5.47	9.03
Field efficiency (%)	-	81.14	67.3	80.72	81.39	-	80.74	67.52	80.48	80.65
Degree of weeding/weeding efficiency (%)	88.73	70.54	80.38	77.37	74.4	91.02	75.15	81.43	82.14	79.35
Plant damage (%)	1.18	1.29	2.75	1.69	2.35	1.17	1.66	2.81	1.92	2.70
Walking speed (k/h)	-	1.48	1.52	1.42	1.13	-	1.40	1.47	1.38	1.13

Note: Average data of three replications is presented in the Table; HW=Hand weeding; BW=BRRI weeder; PW=BRRI power weeder; CW=BRRI conical weeder; DW=Double row weeder.

rest of it was husk and embryo. Average fixed and adjustable rubber roll RPM was found 1043 and 783 respectively.

Adjustable rubber roll rotatesat 24.92% 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.

Brown rice of BRRIdhan80 from rubber roll de-husker was polished in friction type polisher. The average capacity of the polisher was 678.3 kg/h and the average milling recovery was 64%. The average head rice recovery (based on input paddy) was 55.8% and head rice recovery (based on total milled rice) was 86.94% The broken rice percentage was 8.2% based on input paddy and 13.05% based on total milled rice.

RENEWABLE ENERGY

Validation and adaptive field trial of BRRI developed solar light trap

Engineering design was done with the help of AutoCAD tools and a prototype was fabricated according to design at the BRRI research workshop using locally available materials. The multiplication was done in a local manufacturer workshop with the help of BRRI provided design, guidance and project financial support, thereby manufacturing capability was enhanced of that workshop. The fabricated solar powered light trap was tested in the field and observations were recorded. MS sheet and angle bar, MS pipe, nuts, bolts, solar panel, controller, inverter, battery, bulb, electric cable were used to fabricate the solar powered light trap.

Design consideration

During design, the following criteria were considered:

- Battery backup has to be uniform during operation
- Using local available material
- It has to be simple and easy to adjustment
- The cost must be within the capacity of small and medium farmer
- Light weight for easy movement
- It has to be easy to repair and maintain

Basic system components

Following diagram shows the major components in a typical solar power system (Fig. 9).

Working principle

The solar panel receives sunlight and converts sunlight into DC electricity to charge the battery. This DC electricity is fed to the battery via a solar regulator, which ensures the battery charge properly to protect from damage. DC appliances (DC bulb) can be powered directly from the battery but AC appliances (AC bulb) require an inverter to convert the DC electricity into 220 volt AC power (Fig. 9). DC appliances can be connected to the regulator to take advantage of the low voltage disconnection and protection of the battery. Different geographical locations receive different quantities of average peak sun hours per day. The bulb of solar light trap automatically becomes ON in absence of sunlight and automatically OFF in presence of sunlight. Figures 10 and 11 shows the AutoCAD design and design view of solar light trap.

Pilot scale research

Pilot scale research work was done in rice field, vegetable field, rice-fish ecosystem. The following treatments were considered for pilot scale research: i) the solar light trap, ii) pheromone trap and iii) the farmers practice. Each treatment was practiced in

Table 10. Performance of de-husker for BRRI dhan80.

	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
	670	92	78.0	780	1040	25.00
	679	92	77.0	785	1044	24.80
	676	93	76.0	784	1045	24.97
Av.	675	92.3	77.0	783	1043	24.92

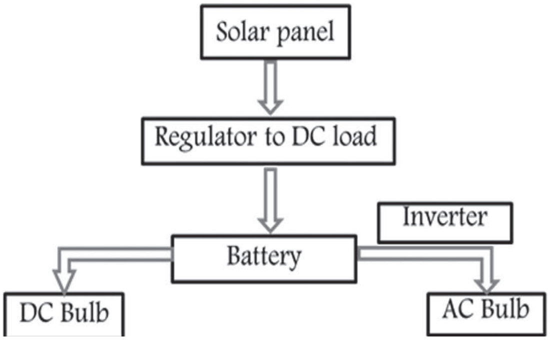


Fig. 9. Flow diagram of solar light trap.

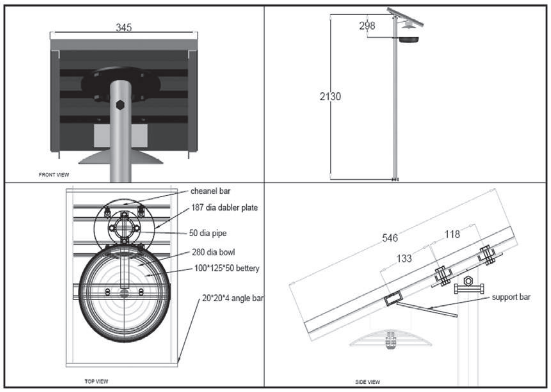


Fig. 10. AutoCAD design of BRRI developed solar light trap.


Fig. 11**.** Design view of the prototype of solar light trap.

each separate plot. The pilot research and field trials were conducted at five locations in Bangladesh including Gazipur, Narsingdi, Bogura, Jashore and Khulna. Selected five solar light traps from each location set for insect pest catches from each light trap were monitored at every day. In all the trials, for monitoring the sex pheromone lures will be used @ 20 traps/ha for rice field. The traps, including sex pheromone and solar light were installed in 10 days after transplanting (DAT) with 20 m × 25 m spacing. Trap height were maintained at 0.5 m above the crop canopy. In all the field trials, insecticide/chemicals were not used. One rice plot in similar area to trap treated plots was remained under farmers practice. Furthermore, the stem borer damage in terms of dead heart (DH) was assessed at 30 and 45 DAT from 100 randomly selected tillers in 1m × 1m micro plot. For white head (WH) damage, the samples were drawn at 15 days after flowering synchronizing with milk filling and dough stage of the crop. The rate of of solar light trap usein the field was 3 solar light trap per ha.

In vegetable crop, brinjal field was used in this study. Brinjal fruit and shoot borer (EFSB) infestation starts when the eggplant crop begins to flower or before that time. Traps were maintained until the last harvest to kill these insects. The trap was installed in a grid of 10 m throughout the field starting 5 m from the border @ 100 traps/ha. A sturdy stick firmly implanted in the soil to support the trap. Then a wire or sturdy thread was used to tie the trap to the stick. The lure inside the trap was always kept at 10-15 cm above the crop canopy. At the same time solar light trap were installed in brinjal field.

The locally available materials such as MS rod, MS sheet and MS flat bar, nuts and bolts were used to fabricate the stand of solar light trap. The solar panel, controller, battery and bulb were collected from local market. It was a 16.8V and 20W solar panel, DC 12V auto controller and Lithium Iron Phosphate battery(DC 12.8V, 7.5A,Life P04type) were used in this trap. Bulb selection is a predominant factor for effective and efficient solar light trap. Around eight types of bulbs were collected from the market for efficacy study of bulb. All the bulbs were observed in BRRI farm for insect pest attraction. Figure 12 shows various types of bulbs.

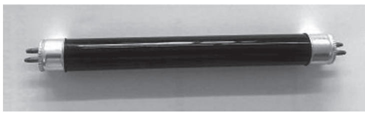
After observing all the bulbs, Bulb no.8 was found most pest attractive which consists of DC 12V, 8W with bluish colourlamp. Bulb no. 9 was fabricated in Supernova Engineering, Mirpur, Dhaka, according the characteristics of bulb no. 8. Table 11 presents the specification of the solar light trap.

As per specification and design, 120 frames of

Bulb 1- 5 watt normal LED bulb (blue colour)

Bulb 2-5 watt normal LED bulb (green colour)

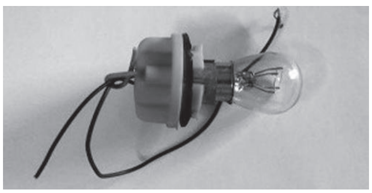
Bulb 3-3 watt normal LED bulb (white colour)



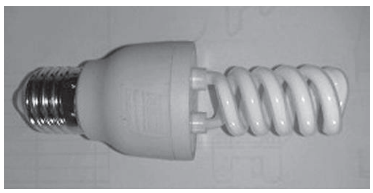
Bulb 4-4 watt black light blue (BLB) bulb (blue colour)

Bulb 5-4 watt germicidal bulb (bluish colour)

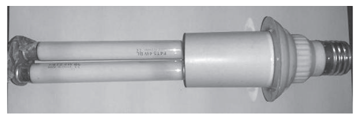
Bulb 6-6 watt normal D.C tube light (white colour)



Bulb 7-3 watt D.C brake light (yellowish colour)



Bulb 8-8 watt pest attracting bulb (bluish colour)



Bulb 9-8 watt D.C black light (BL) (bluish colour)

Fig. 12. Different types of bulb observed in BRRI farm.

solar light trap were fabricated in a local workshop and the light trap were assembled in the FMPHT divisional research workshop and after assembling, the light trap was tested in the FMPHT divisional research area for checking of bulb, duration light hour and load. Test results showed that battery can back up the bulb for light emission with the duration of 5 - 6 hours. After completion of all tests and observations the solar light trap was distributed and installed in the project site of Bogura, Jashore, Narsingdi, Gazipur and Khulna in the farmer's field and also supplied to the some promising farmers and NGOs.

Field demonstration, training and farmers awareness programme is the appropriate tools for dissemination any technology in the farmer's field. BRRI solar light trap was demonstrate at the 25 locations of the project site and about 1000 progressive farmers, mechanics, NGO personnel attended in these demonstration cum training programmes. During training programme BRRI scientist brief the audience about operation, repair and maintenance. Farmer's opinions regarding this trap were also recorded. Almost all the farmers told that it was a magic machine and a lot of insect pests were caught in the light trap and every day they cleaned the trapped insect pests and buried under the soil

Adaptive field trial cum research of solar light trap was conducted in Bogura, Jashore, Narsingdi, Gazipur and Khulna. Insect pests trapped in each light trap were collected and recorded. Significant numbers of insect pests that can cause damage to rice were trapped in each trap in every location. This report shows only two months data of rice insect pests that were caught in light trap (Fig. 13).

Rice insect pests including yellow stem borer (YSB), green leafhopper (GLH), white leafhopper

Table 11. Specification of BRRI developed solar light trap.

Solar panel	16.8V /20W
Auto control	DC12V (No danger of short circuit, electric shock and lightning)
Battery	DC 12.8 V, 7.5 A, Life P04 type (Lithium Iron Phosphate)
Lamp	DC 12V8W
Weight	Approximately 12 kg
Dimension	Main Body: Net length90 inches, bowl dia. 20 inches and 2 inches dia. steel pipe
Type of product	Eco friendly
Type of energy	Solar energy
No of legs	01
Battery charging hours	8 to 10
Set up working area	1 acre per light trap
Set up working hours	6 pm to 12 am
Type of moment	Flexible
Type of colour	Bluish

(WLH), leaffolder (LF), caseworm (CW) and rice bug (RB) were the dominant in each solar light trap (Fig. 14). The highest numbers of insect pests were trapped in May than that of April. YSB was the highest incidence in May and GLH was the second highest (Fig. 14). More than 900 YSB was caught in each light trap. This result indicates that solar light trap would be a promising pest control tool in rice field. We also recorded damaged symptoms both from solar light trap installed plot and farmers' plot (no solar light trap was installed). Significant lower damage was found in solar light trap installed plot than control one (farmers. plot).

Solar light traps also installed in brinjal field for comparing the effectiveness between solar light trap and pheromone trap against brinjal fruit and shoot borer (BFSB). Pheromone trap ware currently using in brinjal crop for controlling BFSB. Figure 15 presents the number of BFSB caught in both solar light trap and pheromone trap. Significantly higher number of BFSB was recorded in solar light trap than in pheromone trap. Two months data were presented here, significantly higher number of BFSB recorded in solar light trap than pheromone trap (Fig. 15). This result indicates that solar light trap is more effective than pheromone trap in brinjal field. Damage of fruits and shoot of brinjal were also recorded.

Fig.13. Insect pests trapped in light trap.

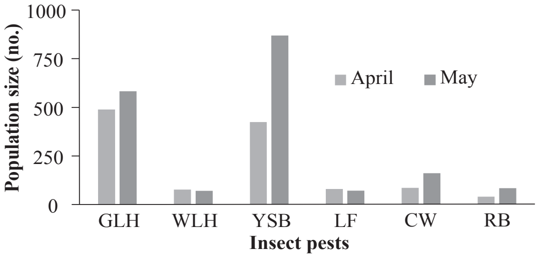


Fig. 14. Rice insect pest trapped in solar light trapin Chowgasa, Jashore, Boro 2017-18. *YSB: Yellow stem borer, GLH: Green leafhopper, WLH: White leafhopper, LF: Leaffolder, CW: Caseworm and RB: Rice bug.*

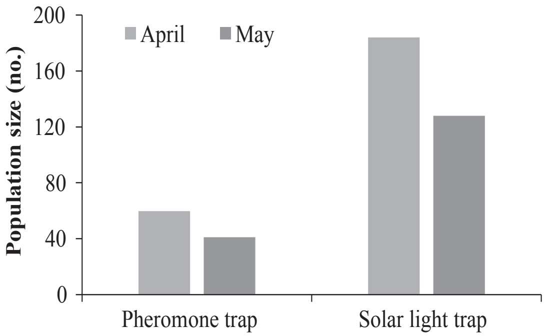


Fig. 15. Brinjal shoot and fruit borer (BSFB) trapped in pheromone and solar light trap Chowgasa, Jashore, Boro 2017-18.

EXTENSION OF AGRICULTURAL MACHINERY

Agriculture mechanization and technology dissemination in three selective haor districts (Kishorganj, Habiganj and Netrakona)

Farmers of Bangladesh still practice hand transplanting method, which is a highly labour intensive farm operation. Manual uprooting of seedling and transplanting needs about 30% of the total labour requirement of rice production. The innovation and breakthroughs of mechanized transplanting technology is an important milestone for rice production mechanization in Japan, China and Korea etc. Mechanical rice transplanter needs soil bearing mat type seeding, raised in trays adaptable for 12-15-day-old seedlings. This seedling raising technique is absolutely new technology to our farmers. An awareness programme was taken in northern haor areas in Boro 2018 season to adopt seedling raising technique and transplanting seedling mechanically in the field. Field demonstration cum training on seedling raising technique and mechanical rice transplanting was conducted at farmer's filed in three hoar districts during Boro 2018 season with the active co-operation of the farmers and DAE personnel. A total of 18 bighasof farmers land was transplanted using threeBRRI developed rice varieties i.eBRRIdhan28, BRRIdhan29 and BRRIdhan58in the demonstration cum training programme. Participant farmers prepared seedling tray in their own hand and these seedlings were used for transplanting. Most of the participants observed this type of machinefor the first time and become very confused about the use of rice transplanter for transplanting the seedling in the field.Participants gotbasic idea (how to prepare seedling tray, operate the transplanter machine, how many adjustable functions were there and in which condition theses functions need to be adjusted) on operation, repair and maintenance.The participants became confident about the use of rice transplanterafter observing the performance of the machine.

Village mechanic training programme

Seven-day-long hands-on in-house training on use of modern agricultural machinery in different farm operationsfor village mechanic were organized atFMPHTDivision of BRRI financby On Farm water Management Project ofthe Department of Agriculture Extension (DAE).A total of 180 machinery operators from different districts of Bangladesh attended in six batches of training programme.Thirty participants attended in each training programme. In orientation programme, the participants eagerly expressed their interests about the importance in timely transplanting, harvesting, threshing, drying and needs of modern machinery in agriculture. In practical session the participants assembled and disassembled a diesel engine, operated rice transplanter, combine harvester, open and closed drum thresher, reaper and reaper binder, power tiller, tractor and winnower. This training included proper operation of machinery, safety measures and assessment of repair and maintenance of BRRI developed machinery and technologies. A basic idea (how to operate new engine, when it needed to change air, oil and fuel filter etc) on operation, repair and maintenance of diesel and petrol engine was shown to the participants. Trained mechanics were able to repair defects of the machine more confidently themselves. After training a set of tool box were given to the participants.

Workshop Machinery and Maintenance Division

SUMMARY

The effects of tillage depths on the productivity of paddy were determined in field experiments in Aman 2017 and Boro 2018 seasons at research farm of BRRI RS, Rajshahi in different tillage depths. There were three tillage depths ie 4-5, 5-6, 6-7 and 7-8 inches. Tillage depths affected dry bulk density of soil, tiller, panicle number and yield of BRRI dhan71 in Aman 2017 and BRRI dhan36 in Boro 2018 season. Dry bulk density of soil decreased slightly with the increase of tillage depth. Tiller and panicle number of plant also increased with the increase of tillage depth. Plant height, dry weight, root length and root dry weight of cultivated paddy was increased with tillage depth in Aman and Boro seasons. These were found highest in 6-7 inches depth of tillage and very little bit change in 7-8 inches depth of tillage. The highest grain yields were found 4.55 t/ha and 3.90 t ha^{-1} in the tillage depth of 6-7 inches and the lowest yields were found 5.85 t ha^{-1} and 5.00 t ha^{-1} in the tillage depth of 3-4 inches of BRRI dhan71 in Aman 2017 and BRRI dhan36 in Boro 2018 season respectively. The highest grain yields of all the seasons were found under the higher tillage depths of 6-7 inches and the lowest yields were obtained in the lower tillage depth of 3-4 inches. Number of tiller, panicle, yield of both varieties were found more or less same in both seasons at 6-7 and 7-8 inches tillage depth. Farmers of Bangladesh practiced usually 4-5 inches depth of tillage. Fuel consumptions were calculated in different plots at different tillage depths during ploughing in Aman 2017 and Boro 2018. Fuel consumptions varied little bit in different plots at different tillage depths in Aman season but those were more or less same in different plots at different tillage depths in Boro season.

Different kinds of farm machinery have been used in the farmers' field such as power tiller, shallow tube well, weeder, pedal thresher, open drum thresher, close drum thresher, sprayer etc. The questionnaire survey was conducted on machinery used in farmers' field at Chandrakona, Sherpur; Hatinakanda, Shymganj, Netrakona and Sheikhpara, Manirampur upazila of Jashore districts. A number of machinery is used in these villages such as power tiller, shallow tube well, engine operated pedal thresher and sprayer. There are no rice transplanter, reaper, combined harvester, open drum thresher and close drum thresher at the farm level of these areas. So, there is a scope to introduce these machinery in the area. The problem is that the operators of the machine is not skilled and they never follow proper machinery maintenance schedule, which increase their operation time and repair cost. So, proper training should be arranged for the machinery operators.

Different kinds of farm machinery have been used in the farmers' field. Some of them were imported and the rest was made by the local workshops. Agricultural machinery workshops were surveyed at different places in Bangladesh. The facilities of machinery of the workshops were foundry, lathe, shaper, drill, milling, grinding, welding, metal cutting and power press. They produced different kinds of agricultural machinery using locally available materials in their workshops. Close drum thresher, open drum thresher, bed planter and maize sheller were the common machinery produced by the local manufacturers, and someone also produced chopper, reaper, winnower and weeder.

There are different kinds of transport/vehicles and farm machinery at BRRI. Repair and maintenance works of these were done by WMM Division. Repair works and changes of spare parts of these vehicles and farm machinery were also done under major and moderate/minor repair and maintenance work. The total cost of major and moderate/minor repair and maintenance was Tk 28,21,264 from July 2017 to June 2018. Among the major repair and maintenance cost was Tk 20,78,214 and moderate/minor repair and maintenance cost was Tk 7,43,050. The major repair and maintenance work was done by direct cash purchase, direct contracting through work order, RFQ (Request for quotation) and OTM (Open tender method). On the other hand, the moderate/minor repair and maintenance work was done only by using the revolving fund.

Pedal thresher was modified to use solar energy to thresh paddy and its performance was evaluated in Boro season. Its revolution per minute (RPM) was 600. Two operators can thresh paddy simultaneously. Capacity of threshing paddy in Pedal thresher using solar energy was found 240 kg/hr.

Determination of tilling efficiency of power tiller at selected areas of Bangladesh

Tillage improves soil conditions by altering the mechanical impedance to root penetration, aggregate size distribution, hydraulic conductivity and water holding capacity, which in turn, affects plant growth and crop productivity. Tillage helps to mix the soil and level the soil surface that reduces the amount of water wasted by uneven pockets of too-deep water or exposed soil. Effective land leveling allows the seedlings to become established more easily. Tillage allows the seeds to be planted at the right depth, and also helps weed control. Interaction of tillage depths affect the soil physical properties such as bulk density, particle density, porosity, field capacity and permanent wilting point. It had significant effect on grain yield. This might be due to exposure of roots to absorb more moisture and nutrients in deep tillage practices, because soil stores more moisture in deep tillage. As a result, grain filling stage does not suffer from water shortage. Crop production could be increased by adopting appropriate tillage operation with different depths, which needs intensive field research.

Experiments were conducted at BRRI RS, Rajshahi in Aman 2017 and Boro 2018 seasons to determine paddy yield as influenced by different tillage depths. There were three different tillage depths such as: 3-4, 4-5, 6-7 and 7-8 inches. Land preparation and the tillage depths were maintained by a power tiller. All sorts of weeds were removed from the field before planting of seedling. Time and fuel were recorded in every ploughing to measure fuel consumption. Seedlings were transplanted at 20 cm apart from rows maintaining 20 cm hill to hill distance and three seedlings per hill. Necessary gap filling was done after eight days of transplanting. Applying irrigation, weeding and other intercultural operations were done often as and when necessary. Paddy was harvested at full maturity. Harvesting, threshing, cleaning and drying of grain were done plot-wise separately. The weights of paddy were also recorded plot-wise.

Dry bulk density of soil was found 1.27 g/cm^3 and it decreased with the increased tillage depth. In Aman 2017 and in Boro 2018 the bulk density differs 1.30 to 1.23 with the change of tillage depth (3-4 to 7-8). It was found minimum 1.22 g/cm^3 at 7-8 tillage depth (Table 1). Fuel requirements were varied little bit in third and forth/final ploughing in each and different plots at different tillage depths where each of the plots (820 m^2) was ploughed separately (Table 2). On the other hand, in Boro season fuel requirements were measured and it varied little bit in third/final ploughing in each and different plots at different tillage depths where each of the plots ploughed separately (Table 3). Fuel requirements decreased chronologically in each and different plots at different tillage depths from first ploughing to final ploughing (Tables 2 and 3). Fuel consumptions were calculated in different plots at different tillage depths during ploughing in Aman 2017 and Boro 2018. Fuel consumptions were varied little bit in different plots at different tillage depths in Aman season but these were more or less same in different plots at different tillage depths in Boro season. Required time was recorded at different tillage depths in different plots during ploughing in Aman 2017 and Boro 2018 seasons (Tables 2 and 3). Time requirements in first and second ploughing in different plots were same in Aman and Boro seasons because total land (2,460 m^2) was ploughed combinedly up to second ploughing. From third ploughing, time consumed in each ploughing in different plots at different tillage depths were recorded and these were more or less same but it decreased chronologically in each plot from first ploughing to final ploughing where the area of each plot was same and it was 820 m^2. Fuel consumption and ploughing time was found slightly higher at 7-8 inches tillage depth over 6-7 inches tillage depth. Fuel requirements were measured and recorded at different tillage depths during ploughing in Aman 2017 and Boro 2018. Table 2 and Table 3 show the values of fuel requirements at different tillage depths in different plots in Aman 2017 and Boro 2018 respectively. Fuel requirements in first

Table 1. Dry bulk density of cultivated soil at different tillage depths.

Tillage depth (inch)	Aman 2017	Boro 2018
	Dry bulk density (g/cm^3)	Dry bulk density (g/cm^3)
3-4	1.27	1.30
4-5	1.24	1.26
6-7	1.22	1.24
7-8	1.22	1.23

Table 2. Fuel consumption and ploughing time of different plots at different tillage depths in Aman 2017.

Item	1st plot (7-8" depth)		2nd plot (6-7" depth)		3rd plot (4-5" depth)		4th plot (3-4" depth)	
	Fuel (ml)	Time (min)	Fuel (ml)	Time (min)	Fuel (ml)	Time (min)	Fuel (ml)	Time (min)
1st ploughing	1465	30	1465	30	1465	30	1465	30
2nd ploughing	990	20.5	992	20.5	992	20.5	992	20.5
3rd ploughing	870	18	800	17	675	16	650	15
Final ploughing	850	17	750	16	650	15	600	15
Total	4175	85.5	4005	83.5	3780	81.5	3705	80.5
Fuel consumption (l/hr)	2.93		2.88		2.78		2.76	

Table 3. Fuel consumption and ploughing time of different plots at different tillage depths in Boro 2018.

Item	1st plot (7-8" depth)		2nd plot (6-7" depth)		3rd plot (4-5" depth)		4th plot (3-4" depth)	
	Fuel (ml)	Time (min)	Fuel (ml)	Time (min)	Fuel (ml)	Time (min)	Fuel (ml)	Time (min)
1st ploughing	1000	22	1000	22	1000	22	1000	22
2nd ploughing	850	18	850	18	850	18	850	18
3rd ploughing	770	17	700	16	600	14	550	13
Final ploughing	810	17	750	16	650	15	600	15
Total	3430	74	3300	72	3100	69	3000	68
Fuel consumption (l/hr)	2.78		2.75		2.70		2.65	

and second ploughing in different plots were same in Aman and Boro seasons, because total land (2,460 m^2) was ploughed combinedly up to second ploughing. After second ploughing, total land was divided into four plots. From third ploughing, fuel and time were also measured and recorded at different depths in Aman season.

Tiller and panicle number of both the varieties increased over tillage depth (Table 4). Grain yield of BRRI dhan71 in Aman 2017 and BRRI dhan36 in Boro 2018 seasons were varied from different tillage depths. Plant height, dry weight, root length and root dry weight of cultivated paddy was increased with tillage depth at Aman season 2017 and Boro season 2018 (Tables 5 and 6). These were found the highest in 6-7 inches depth of tillage and a very little bit change in 7-8 inches depth of tillage. The highest grain yield of BRRI dhan71 in Aman 2017 season was found 4.55 t/ha in the tillage depth up to 6-7 inches and the lowest yield was found 3.90 t/ha in the tillage depth up to 3-4 inches (Table 7). Table 7 also shows the highest grain yield of BRRI dhan36, which was 5.85 t/ha in the tillage depth up to 6-7 inches and the lowest yield was obtained 5.00 t/ha in the tillage depth up to 3-4 inches in Boro 2018 season. The highest yields of all the seasons were found under the higher tillage depths up to 6-7 inches and the lowest yields were obtained in the tillage depth up to 3-4 inches. Yield of both the varieties were found more or less same in both the seasons at 6-7 and 7-8 inches tillage depth.

Deep tillage improved the soil physical environment. It made the soil softer, which was indicated by reduced bulk density, penetration resistance and encouraged root growth and increased the moisture retention capacity of the soil. This might have favoured the roots to proliferate down into the deeper layers of the soil profile to extract more nutrients and moisture that has led to higher growth and yield of the crops. Higher tillage depth favourably influenced the soil-water-plant ecosystem, thereby improved crop yields and quality. Higher tillage depth also reduced weed infestation.

Survey on status and constraint of farm machinery in farmer's field at selected areas

Different kinds of farm machinery have been used in these villages and these machinery are power tiller, shallow tube well, sprayer, modified pedal thresher (like as open drum thresher) operated by 4-6 hp diesel engine (Table 8). Some farmers are the owner of these machinery and some others used these machinery by custom hire service. From this table, we can see that power tiller, shallow tube well, sprayer and modified pedal thresher are

Table 4. Tiller and panicle number of cultivated paddy at Aman 2017 and Boro 2018 season.

Tillage depth (inch)	Aman 2017 (BRRI dhan71)		Boro 2018 (BRRI dhan36)	
	Tiller no./12 hill	Panicle no./12 hill	Tiller no./12 hill	Panicle no./12 hill
3-4	113	109	182	162
4-5	115	111	192	171
6-7	125	117	214	182
7-8	125	118	216	183

Table 5. Plant height, dry weight, root length and root dry weight of cultivated paddy at Aman season 2017 (BRRI dhan71).

Tillage depth (inch)	Average plant height (cm)	Average plant dry weight (g)	Root length (cm)	Average root dry weight (g)
3-4	108.58	61.07	20.50	24.74
4-5	109.81	62.14	20.70	25.58
6-7	114.08	67.02	24.00	27.85
7-8	114.08	67.35	26.40	27.97

Table 6. Plant height, dry weight, root length and root dry weight of cultivated paddy at Boro season 2018 (BRRI dhan36).

Tillage depth (inch)	Average plant height (cm)	Average plant dry weight (g)	Root length (cm)	Average root dry weight (g)
3-4	72.42	44.03	18.66	19.66
4-5	73.83	49.20	20.76	20.77
6-7	78.83	57.07	21.88	23.80
7-8	78.81	57.72	21.61	23.87

Table 7. Yield of paddy with different tillage depths.

Year	Season	Paddy	Tilling depth (inch)	Paddy yield (t/ha)
2017	Aman	BR71	4-5	3.90
			5-6	4.04
			6-7	4.55
			7-8	4.52
2018	Boro	BRRI dhan36	4-5	5.00
			5-6	5.35
			6-7	5.82
			7-8	5.85

Table 8. Agricultural machinery used in the farmers' field.

Machine	Personnel	By custom-hire service	No use
Power tiller	39	299	0
Shallow tube well	138	200	0
Sprayer	246	88	0
Open drum thresher (operated by engine, 4-6 hp)	123	215	0

mostly popular agricultural machinery used in these areas. All the farmers used sickle for harvesting paddy, wheat and other crops. Power tiller is very popular for cultivation of land in these areas. All the farmers of these villages used power tiller. There are nine power tillers in two villages. The owners of power tiller cultivate their own land and rests of the farmers cultivate their land by custom-hire service from the tiller owners. Land was irrigated by custom-hire service or the farmers have to pay 1/5th of the total yield/production in Aman season and 1/4th of the total production in Boro season. Rent/custom-hire service or share of total production and fuel consumption of power tiller, shallow tube well and thresher in these areas are shown in Table 9.

Solar energy use in threshing operation

Pedal thresher was modified to use solar energy in paddy threshing. Solar energy was utilized in modified pedal thresher in threshing of paddy

Table 9. Rent and fuel consumption of different machineries.

Machine	Variable cost			
Power tiller	Rent of tiller (Taka/bigha)	Fuel requirement/ bigha (litre)	Time requirement/ bigha (hr)	Fuel consumption (lit/hr)
	660.00	5-6	2.00-2.50	2.50-3.00
Shallow tube well	Rent of shallow (Taka/hr)	Rent in Aman season (share of total production)	Rent in Boro season (share of total production)	Fuel consumption (lit/hr)
	100.00	1/5	1/4	0.50
Modified pedal thresher (operated by engine, 4-6 hp)	Rent of thresher (Taka/ day)	--	--	Fuel Consumption (lit/hr)
	100.00	--	--	0.50

at BRRI threshing yard, Gazipur. It was run successfully using stored solar energy to thresh paddy and its performance was evaluated in Boro season (Fig. 1). Its revolution per minute (RPM) was 600. Two operators can thresh paddy simultaneously. Capacity of threshing paddy in pedal thresher using solar energy was found 240 kg/ hr. Threshing performance of paddy was good.

Potentiality of engineering workshop for enhancing farm mechanization in selected areas of Bangladesh

Different kinds of farm machinery are used from land preparation to threshing/ winnowing/cleaning crops in the farmers' field. These are open drum thresher, close drum thresher, pedal thresher, weeder, sprayer, seeder, maize sheller, power tiller, pump, combine harvester, rice transplanter, bed planter, potato grader, potato planter, chopper, mango heat treatment etc for enhancing farm mechanization in our country. As a result, cropping intensity has been increasing day by day. Most of the imported machinery were costly, which were used in our agricultural sector but now-a-days, lot of engineering workshops have been developed at different places in our country for manufacturing those agricultural machinery using the locally available materials. So, the farmers are getting these machinery in their locality with low cost. It is necessary to investigate the capacity, limitations and prospects of the engineering workshops at farm level, and quality, production and use level of machinery at different farm operations.

Fig. 1. Major and moderate/minor repair and maintenance cost of different vehicles and farm machinery of BRRI from July 2017 to June 2018.

Agricultural machinery workshops were surveyed at different places in Bangladesh. The facilities of machinery of the workshops are foundry, lathe machine, shaper machine, drill machine, milling machine, grinding machine, welding machine, metal cutting and power press (Table 10). They produce different kinds of agricultural machinery using locally available materials by using these machinery facilities. Table 11 shows the result of the produced machinery by the manufacturers. Close drum thresher, open drum thresher, bed planter and maize sheller are the common machinery produced by the manufacturers, and someone also produced sprayer, chopper, reaper, winnower and weeder. They have no facility of foundry works but they can do any kind of foundry related works from other workshops in their locality if it is necessary.

Various kinds of materials are used to make different parts of the agriculture machinery. Metal sheet, angle bar, rod/sheet, wood and glass are the common materials to make these machineries which

Table 10. Machinery facilities of different engineering workshops.

Workshop / Facility	Foundry (no.)	Lathe machine (no.)	Shaper machine (no.)	Drill machine (no.)	Milling machine (no.)	Grinding machine (no.)	Welding machine (no.)	Metal cutting (no.)	Power press (no.)
Bhai Bhai Engr. Workshop	-	1	-	1	-	1	3	1	1
Kamal Machine Tools	-	1	-	-	-	-	1	-	-
Uttaran Engineering Workshop	-	1	-	2	-	-	2	1	-
Alim Engr. Workshop	1	1	1	1	1	1	2	1	1

Table 11. List of machinery produced by manufacturers.

Machinery / Workshop	Open drum thresher	Close drum thresher	Maize sheller	Chopper	Bed planter	Winnower	Weeder
Bhai Bhai Engr. Workshop	√	√	-	-	-	-	-
Kamal Machine Tools	√	√	-	-	√	-	√
Uttaran Engr. Workshop	√	√	√	-	√	√	√
Alim Engr. Workshop	√	√	√	-	√	√	√

Table 12. Availability of used materials in workshop.

Workshop / Material	Metal sheet	Angle bar	Rod/Shaft	Wood	Glass	Rubber
Bhai Bhai Engr. Workshop	√	√	√	√	√	√
Kamal Machine Tools	√	√	√	√	√	-
Uttaran Engr. Workshop	√	√	√	√	√	-
Alim Engr. Workshop	√	√	√	√	√	-

Table 13. Problem of fabrication/manufacturing and marketing of agriculture machine.

Identity	Bhai Bhai Engr. Workshop	Kamal Machine Tools	Uttaran Engr. Workshop	Alim Engr. Workshop
Lack of capital and credit facility	5	2	2	4
High cost of raw materials	4	1	3	1
High custom duty on finished product	6	6	6	2
Scarcity of skilled labor	2	3	1	3
Load shedding	1	5	5	6
Seasonality of demand	3	4	4	5

are available in the market (Table 12). Manufacturers face some problems to fabricatic/manufacturing and marketing of agricultural machine (Table 13).

There is no way to develop the agriculture sector without mechanization. High rate of imported machinery is a great problem to spread the mechanization. Local workshops/manufacturers can play an important role to reach the agriculture machinery at farm level if they use the locally available material to manufacture the machinery. As a result, the manufacturing cost of the machinery will be low. Then the farmers can buy the machinery from the manufacturers at a cheaper rate. Lack of fund is the main problem to the manufacturer to produce machinery (Table 13). They need subsidy and proper support from the government, which will help them to produce the machinery by improving their workshop.

MAINTENANCE WORK

Repair and maintenance works of transports/ vehicles and different farm machinery

Different kinds of transport/vehicles and farm machinery are at BRRI. WMM Division of BRRI does repair and maintenance works of different kinds of transport/vehicles and farm machinery. There were 39 vehicles (4-wheeler), 110 motor cycles, four tractors with accessories (one scrapper, three harrows, five rotaries, three discs and three scissors), 21 power tillers, 13 hydro-tillers, one reaper, four BRRI field mower, 22 pumps, 13 threshers, two engines, and other farm machinery were repaired and spare parts were changed under major and moderate/minor repair and maintenance work. The repair and maintenance works have been divided into two groups such as:

- Moderate/minor repair and maintenance work
- Major repair and maintenance work

Moderate/minor repair and maintenance work

Moderate/minor repair and maintenance works have been classified into three groups:

- Moderate/minor spare parts change and repaire
- Minor CNG related trouble shooting and electrical works of vehicles
- Transport/vehicles/machinery cleaning and servicing

Moderate/minor spare parts change and repair works of all the vehicles and different farm machinery were done day to day in BRRI except CNG related trouble shootings of these vehicles, because there was no trained manpower in BRRI regarding CNG related trouble shootings. As a result, major/ moderate/minor/or any kind of CNG related trouble shooting of these vehicles was totally done outside BRRI. A total of 39 vehicles (4-wheeler) in 1060 times, 110 motor cycles and other farm machinery in 769 times were repaired and spare parts changed under moderate/minor repair and maintenance work (Table 14). The total cost of moderate/minor repair and maintenance was Tk 7,43,050 from July 2017 to June 2018 (Table 14).

Major repair and maintenance work

There are seven types of major repair and maintenance works:

- Major spare parts change and repaire
- Overhauling
- CNG conversion
- Denting-painting
- Tyre-tube
- Battery
- Major CNG related trouble shooting

Major repair and maintenance works have been done in BRRI workshop and outside BRRI. Some of the major spare parts change, overhauling and repair works have been done in BRRI workshop but major works were done outside BRRI due to fund limitation and some of the major works have been done by direct contracting through BRTC (a Government Workshop), Tejgaon, Dhaka; NAVANA Toyota 3S center, Tejgaon, Dhaka and also in local workshops. On the other hand, most of the CNG related works (CNG conversion, any kinds of CNG related trouble shooting) have been done by direct contracting through Rupantorito Prakritic Gas Co. Ltd., Joar Sahara, Dhaka, a government workshop but denting-painting works have totally been done outside BRRI. At present electrical works have been done in BRRI workshop. Purchasing the battery and tyre–tube or taking the tyre–tube from BRRI store (if available) through requisition were attached to the vehicles/transports in BRRI workshop. The major repair and maintenance cost and times of work of individual vehicles (4-wheeler), motor cycles, tractor/power tiller/hydro-tiller from July 2017 to June 2018 is given in Table 8. A total of 39 vehicles (4-wheeler) in 724 times, tractor in 25 time, power tiller in 175 times, hydro-tiller in 26 times and others were repaired and spare parts changed in BRRI workshop and outside BRRI under major repair and maintenance work. The total cost of major repair and maintenance work was Tk 28,21,264 from July 2017 to June 2018 (Table 14).

Total cost of major and moderate/minor repair and maintenance was Tk 28,21,264 from July 2017 to June 2018 (Table 14). Major repair and maintenance cost was Tk 20,78,214 and moderate/minor repair and maintenance cost was Tk 7,43,050 (Fig. 2). The moderate/minor repair and maintenance work was done only by using the revolving fund. On the other hand, the major repair and maintenance work was done by direct cash purchase, direct contracting through work order, RFQ (Request for quotation) and OTM (Open tender method).

Table 14. Cost and times of repair and maintenance work of different vehicles/transports and farm machinery of BRRI from July 2017 to June 2018.

Type of vehicle	Vehicle/ Machine no.	Time of major work	Time of moderate/ minor work	Total number of work	Cost of major works	Cost of moderate/ minor work	Total cost (Tk)
Bus	0004	7	63	70	140870	62820	203690
-do-	3831	4	116	62	75080	37520	112600
Mini-bus	8430	1	102	103	13186	2150	15336
Micro-bus	0034	0	80	80	0	9043	9043
-do-	0076	0	53	53	0	16220	16220
-do-	3870	0	34	34	0	15650	15650
-do-	0052	0	31	31	0	21500	21500
-do-	0053	1	24	25	8000	22660	30660
-do-	005	3	38	41	233875	38700	272575
-do-	0009	3	22	25	67390	7210	74600
-do-	0010	4	24	28	52116	11067	63183
Jeep	0170	7	15	22	267120	53979	321099
-do-	0188	2	31	33	40500	10520	51020
-do-	0189	3	31	34	63355	20345	83700
-do-	0190	1	26	27	52000	34634	86634
-do-	0086	1	6	7	133900	4300	138200
-do-	0103	3	26	29	51300	42572	93872
-do-	0024	1	10	11	126212	5282	131494
-do-	0025	1	5	6	83635	5645	89280
-do-	0026	1	19	20	8510	14830	23340
Pickup	0091	1	15	16	12500	11150	23650
-do-	0017	0	33	33	0	7030	7030
-do-	0056	2	30	32	14500	48224	62724
-do-	0057	7	25	32	79521	29340	108861
-do-	0058	3	38	41	40853	43840	84693
-do-	0089	1	6	7	24740	5880	30620
-do-	0090	2	13	15	83310	5300	88610
-do-	0109	1	21	22	24800	22717	47517
-do-	0002	2	21	23	31565	23585	55150
-do-	0018	0	0	0	0	0	0
-do-	0011	2	35	37	43737	6445	50182
-do-	0025	1	6	7	83635	5645	89280
-do-	1641	1	5	6	22500	0	22500
-do-	004	1	5	6	12500	6490	18990
-do-	015	1	0	1	90000	0	90000
Truck	0020	1	23	24	24900	2920	27820
-do-	0101	1	16	17	6350	11188	17538
-do-	0001		30	30	0	8935	8935
-do-	0011	2	0	2	22500	0	22500
		60	664	724	1805824	547583	2353407
Motor cycle (110 no.)		0	470	470	0	43247	43247
Tractor (4 nos.)		2	23	25	9640	1880	11520
Power tiller (21 no.)		5	170	175	86750	17980	104730
Hydro tiller (13 no.)		3	23	26	64500	12830	77330
Pump+ mower (26 no.)		2	20	22	37000	5500	42500
Tyres and tubes		0	0	0	0	0	0
Others/Threshers (13 no.)		5	46	51	74500	114030	188530
		17	17	752	769	272390	2821264
		77	1416	1493	2078214	743050	2821264

Adaptive Research Division

SUMMARY

In the reporting period (2017-2018), 31 advanced breeding lines for different seasons were evaluated by conducting 13 advanced line adaptive research trials (ALART) at farmers' field in different agro-ecological regions of Bangladesh. Considering specialty on some important characteristics and farmers' opinion, nine advanced lines for different characteristics in different seasons were recommended for proposed variety trial (PVT). During Aus 2017, one advanced lines for transplanting condition was recommended for PVT. For rainfed low land rice, two advanced lines from Plant Breeding Division and one from Biotechnology Division were found suitable for PVT during T. Aman 2017. During Boro 2018, one line for favourable condition and one for long duration developed by Biotechnology Division were recommended for PVT.

During Aus 2017, Aman 2017 and Boro 2018, Seed Production and Dissemination Programmes (SPDP) were conducted by using different BRRI varieties and other technologies under GOB and different projects (SPIRA, ASRS, TRB and URSP (NATP2). A total of 734 demonstrations were conducted in 151 upazilas of 39 districts, from which about 597 tons of paddy grains were produced and 91 tons (15.3%) were retained as seeds by the farmers for next year cultivation. About 48 thousand farmers gained awareness and knowledge about BRRI varieties through demonstrations, knowledge sharing, field days, field visit and other interactions. Among them about 12 thousand farmers were motivated to adopt BRRI varieties.

Under TRB during Boro 2018 ARD conducted 400 Head to Head trial (Adaptive trial) in different agro-ecological environments using recent BRRI varieties. During Aman 2017 and Boro 2018, seed support programme to farmers and different stakeholders were conducted in different locations of Bangladesh under TRB project to enhance rapid dissemination of newly released BRRI varieties. In T. Aman 2017, 915 kg seeds of 12 varieties (BRRI dhan34, BRRI dhan49, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan77 were distributed to 83 farmers/stakeholders in 25 upazilas of 16 districts. Adaptive Research Division (ARD) conducted 62 farmers' training at different locations under GOB and different projects in which 2,110 trainees (1,936 farmers and 174 SAAOs of DAE) participated. The division also conducted 82 field days at different locations. About 14,000 persons participated in those occasions. A total of 5.4 tons good quality seeds of different BRRI varieties were produced by ARD at BRRI farm those were used for follow up adaptive research trials. Two seed centers for farmers were established at Manda, Naogaon and Monirampur, Jashore. We provided 126 plastic drums at different locations under TRB, ASRS and URSP (NATP2). Around 80 kg seeds can be preserved in each drum.

TECHNOLOGY VALIDATION

Advanced line adaptive research trial (ALART)

T. Aus 2017. Advanced line NERICA10-7-PL2-B from two sources along with BRRI dhan48 as a check were tested at farmers' field in five locations. NERICA10-7-PL2-B gave higher grain yield with around seven days shorter growth duration than the check BRRI dhan48 (Table 1). Besides, the line showed uniform flowering and maturity with almost similar grain size (thousand grain weight is similar). Although plant height of the line is slightly taller than BRRI dhan48, it showed lodging tolerance. Considering grain yield, growth duration and other attributes, NERICA10-7-PL2-B was recommended for proposed variety trial (PVT).

T. Aman 2017, rainfed lowland rice-1 (RLR-1). Five advanced lines: BR8192-10-1-2-3-4, BRRI dhan29-SC3-28-16-15-HR2 (Com), BR8204-5-3-2-5-2, IR11F190 and IR70213-10-CPA-4-2-2-2 along with BRRI dhan39 and BRRI dhan49 as checks were tested at farmers' field in eight locations (Table 2). Most of the farmers showed their interest about BRRI dhan49 due to its higher yield, attractive grain size and phenotypic acceptance. A few farmers also showed their interest about BRRI dhan29-SC3-28-16-15-HR2 (Com) (entry no.2) for its good yield, shorter duration and grain size. Considering all the necessary characteristics and farmers' opinion, BRRI dhan29-SC3-28-16-15-HR2 (Com) (entry no. 2) was recommended for PVT.

■ M A Islam, M R Islam, B Karmakar, M H Kabir, R Barua, M R Biswash, M M Hasan, G S Jahan and M S I Mamin

Table 1. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of advanced line NERICA10-7-PL2-B under ALART grown in different locations of Bangladesh, during T. Aus 2017.

Genotype	Location Grain yield (t/ha)						G. duration (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	Mean	Mean	Mean	Mean
NERICA10-7-PL2-B(S1)	4.25	4.41	4.57	4.64	4.32	4.44	102	23.83	112
BRRI dhan48 (S1)	4.15	4.05	4.07	4.51	4.38	4.23	109	23.25	110
NERICA10-7-PL2-B(S2)	4.22	4.35	4.53	4.56	4.51	4.43	103	24.09	112
BRRI dhan48 (S2)	4.34	4.01	4.12	4.75	4.47	4.34	110	23.43	110
$LSD_{0.05}$			0.42			0.21	0.48	0.37	2.29

L1- Cumilla, L2- Gazipur, L3- Kushtia, L4- Habiganj, L5- Gaibandha.

Table 2. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (RLR-1) grown in different locations of Bangladesh during T. Aman 2017.

Genotype	Location Grain yield (t/ha)									G.duration (day)	TGW (g)	Plant height cm)
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR8192-10-1-2-3-4	4.48	4.43	4.01	5.09	5.11	5.08	4.93	4.25	4.67	0.37	25.89	121
BRRI dhan29-SC3-28-16-15-HR2 (Com)	4.80	5.07	4.08	4.80	5.10	5.45	4.36	5.10	4.85	0.37	21.69	113
BR8204-5-3-2-5-2	5.15	4.84	4.14	4.61	4.47	4.92	5.08	4.72	4.74	0.37	26.36	121
IR11F190	4.76	4.76	3.65	4.80	4.20	4.55	4.43	4.65	4.47	0.37	25.01	124
IR70213-10-CPA-4-2-2-2	4.59	4.51	4.33	4.53	4.20	5.00	4.73	4.62	4.56	0.37	26.50	118
BRRI dhan39 (ck)	4.33	4.26	4.26	4.45	4.57	3.24	4.82	4.40	4.29	0.37	24.23	111
BRRI dhan49 (ck)	4.22	5.10	4.46	5.16	5.02	4.85	4.13	5.15	4.76	0.37	19.76	108
$LSD_{(0.05)}$				0.37					0.17	1.45	0.52	2.5

L1-Feni, L2-Khulna, L3-Chattogram, L4-Mymensing, L5-Sylhet, L6- Rangpur, L7-Barishal, L8-Gazipur.

T. Aman 2017, rainfed lowland rice-2 (RLR-2). Four advanced lines: BR8492-9-5-3-2, BR8210-10-3-1-2, BR8189-10-2-3-1-5 and BR8189-10-2-3-1-6 along with BRRI dhan49 and BR11 as checks were tested at farmers' field in eight locations (Table 3). In respect to grain yield, grain size, growth duration and disease incidence, farmers' interest were mainly concentrated to BRRI dhan49. However, some farmers also showed their interest about BR8492-9-5-3-2 (entry no. 1) for its better yield, shorter growth duration and also grain size like BRRI dhan49. Considering all those characteristics and farmers' opinion, BR8492-9-5-3-2 (entry no. 1) was recommended for PVT.

T. Aman 2017, bacterial blight resistant (BBR). One BBR advanced line BR7959-14-2-1 along with BRRI dhan49 (Std. ck) and BR11 (Sus. ck) were tested at farmers' field in eight locations (Table 4). Compared to check varieties BRRI dhan49 and BR11, farmers did not show interest for the advanced line due to its bold type grain size and disease susceptibility. Considering disease severity, irregular flowering and very large size grain, the line BR7959-14-2-1 was not recommended for PVT.

T. Aman 2017, GSR-salinity. Two salt tolerant advanced lines: HHZ5-SAL12-DT3-Y2 and HHZ8-SAL12-Y2-DT1 along with BRRI dhan73 (Sus. ck) were tested at farmers' field in seven saline prone locations (Table 5). Having similar growth duration both the tested advanced lines gave lower yield than the check variety BRRI dhan73. Grain type of the lines was also very similar to BRRI dhan73. Compared to check variety BRRI dhan73, farmers did not show interest for the advanced lines. So, none of the lines was found suitable for PVT.

T. Aman 2017, GSR-drought. Three drought tolerant advanced lines: HHZ5-DT20-DT3-Y2, HHZ5-SAL10-DT3-Y2 and HHZ23-DT16-DT1-DT1 along with BRRI dhan71 as check were tested at farmers' field in eight drought prone areas (Table 6). In respect to grain yield, growth duration, disease susceptibility and phenotypic acceptance, none of the advanced lines was preferred by the farmers compared to check variety BRRI dhan71. Considering lower grain yield with similar growth duration to BRRI dhan71, more disease susceptibility and farmers' opinion, none of the lines was found suitable for PVT.

Table 3. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (RLR-2) grown in different locations of Bangladesh during T. Aman 2017.

Genotype	Location Grain yield (t/ha)									G.duration (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR8492-9-5-3-2	5.12	4.75	4.16	5.03	5.55	4.89	5.28	4.68	4.93	125	20.78	119
BR8210-10-3-1-2	5.44	4.81	4.20	4.91	5.07	4.49	4.98	4.60	4.81	125	23.28	120
BR8189-10-2-3-1-5	5.13	4.63	4.61	4.95	5.04	5.30	4.99	4.71	4.92	131	26.72	120
BR8189-10-2-3-1-6	5.14	4.57	5.34	4.93	5.09	5.03	4.85	4.83	4.97	132	26.16	121
BRRI dhan49 (ck)	5.19	5.12	4.70	5.16	5.03	4.81	4.39	5.30	4.96	132	19.99	110
BR11 (ck)	5.28	5.04	4.60	5.65	4.63	5.13	5.93	5.22	5.19	138	24.58	114
LSD ($_{0.05}$)				0.33					0.16	1.2	0.46	1.90

L1-Feni, L2-Khulna, L3-Chattogram, L4-Mymensing L5-Sylhet, L6- Rangpur L7-Barishal L8-Gazipur.

Table 4. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (BBR) grown in different locations of Bangladesh during T. Aman 2017.

Genotype	Location Grain yield (t ha^{-1})									G. duration (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR7959-14-2-1	5.11	5.38	4.15	4.34	4.41	4.70	5.45	5.51	4.88	135	31.95	127
BRRI dhan49 (Std. ck)	4.06	5.61	4.20	4.25	4.87	4.45	4.50	5.54	4.69	134	19.70	107
BR11 (Sus ck)	5.12	5.24	4.38	4.83	5.28	4.38	5.60	5.19	5.00	141	24.50	121
LSD ($_{0.05}$)				0.39					0.19	1.2	1.05	1.10

L1-Feni, L2-Khulna, L3-Chattogram L4-Mymensing L5-Sylhet L6- Rangpur L7-Barishal L8-Gazipur.

Table 5. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (GSR-salinity) grown in different locations of Bangladesh during T. Aman 2017.

Genotype	Location Grain yield (t/ha)								G.duration (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	Mean	Mean	Mean	Mean
HHZ5-SAL12-DT3-Y2	4.50	4.66	5.10	4.91	4.12	4.04	4.46	4.54	124	22.5	116
HHZ8-SAL12-Y2-DT1	4.25	4.29	4.34	4.28	3.90	4.10	4.32	4.21	125	23.1	110
BRRI dhan73 (ck)	4.79	4.48	4.52	5.18	4.46	4.98	4.71	4.73	125	22.7	122
LSD (0.05)				0.42				0.16	1.00	0.3	1.00

L1-Noakhali, L2-Khulna L3-Bagerhat L4-Satkhira (Kaliganj) L5-Satkhira (Debhata) L6- Patuakhali (Kalapara) L7-Gazipur.

Table 6. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (GSR-drought) grown in different locations of Bangladesh during T. Aman 2017.

Genotype	Location Grain yield (t ha^{-1})										G. duration (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean	Mean	Mean	Mean
HHZ5-DT20-DT3-Y2	3.92	3.78	4.24	4.58	4.12	4.43	4.47	5.07	4.56	4.35	117	25.10	113
HHZ5-SAL10-DT3-Y2	4.04	3.89	4.78	5.04	4.23	4.59	5.10	4.88	4.41	4.55	120	24.36	112
HHZ23-DT16-DT1-DT1	4.21	4.06	4.86	4.98	4.40	4.27	4.14	3.90	4.83	4.41	115	21.86	112
BRRI dhan71 (ck)	4.30	4.24	5.27	5.86	4.23	4.47	5.53	5.61	4.88	4.93	116	24.35	115
LSD ($_{0.05}$)					0.33					0.16	0.74	0.25	1.58

L1-Rajshahi (Godagari), L2-Rajshahi (Poba), L3-C.nawabganj (Sadar), L4- C.nawabganj (Gomostapur), L5-Naogaon (Sadar), L6-Naogaon (Badalgachi), L7-Dinajpur, L8-Rangpur, L9-Gazipur.

T. Aman 2017, Zinc enriched rice (ZER). Four zinc enriched advanced lines: BR7528-2R-HR16-2-24-1, BR8410-16-4-17-9-1, BR7528-2R-HR16-12-23-P1 and IR84750-213-2-2-3-1 along with BRRI dhan62 and BRRI dhan72 as checks were tested at farmers' field in eight locations (Table 7). In respect to grain yield with shorter growth duration, grain size, disease susceptibility and phenotypic acceptance, some farmers preferred BR7528-2R-HR16-2-24-1 (entry no. 1) compared to check variety BRRI dhan62 and BRRI dhan72. Considering the above characteristics and farmers' opinion, BR7528-2R-HR16-2-24-1 (entry no. 1) was recommended for PVT.

T. Aman 2017, premium quality rice (PQR). Three advanced lines for premium quality rice: BR8535-2-1-2, BR8536-27-2-1-2 and BR8234-1-3-7-1-3-HR21 (Com) along with BRRI dhan34, BINA dhan13 as standard checks and Kalizira as local check were tested at farmers' field in six locations (Table 8). In respect to grain yield with shorter growth duration, grain size and phenotypic acceptance, farmers preferred BR8535-2-1-2 (entry no. 1) and BR8536-27-2-1-2 (entry no. 2) compared to standard check varieties. Considering higher grain yield and earlier growth duration than the check varieties, grain size and farmers' opinion, BR8535-2-1-2 (entry no. 1) and BR8536-27-2-1-2 (entry no. 2) were recommended for PVT.

B. Aman 2017, location specific shallow deep water rice (LSSDWR). Four advanced lines for location specific shallow deep water rice i.e. BR9390-6-2-2B, BR10260-7-19-2B, R10230-15-27-7B (Cutting), BR939-13-2-B (Tall), along with Fulkari as a check and also a local check (Swarnadhighi or Dalldighi or Biroi) were tested in nine locations. All the lines and check varieties were damaged in three locations out of nine, where maximum water depth was 160 to 244 cm at different growth stages. In two locations, only check varieties were survived but all the advanced lines were damaged where maximum water depth

Table 7. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (ZER) grown in different locations of Bangladesh during T. Aman 2017.

Genotype	Location									G.duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR7528-2R-HR16-2-24-1	5.32	5.10	4.36	4.80	4.00	4.04	5.11	4.10	4.60	119	21.15	117
BR8410-16-4-17-9-1	4.42	5.14	4.41	4.40	3.57	4.08	4.55	4.04	4.33	118	25.54	114
BR7528-2R-HR16-12-23-P1	4.57	5.10	4.08	5.00	4.22	4.89	4.64	4.67	4.65	131	22.77	123
IR84750-213-2-2-3-1	4.73	5.13	3.70	5.00	3.32	4.79	4.50	4.21	4.42	125	27.73	109
BRRI dhan62 (ck)	4.01	4.28	3.65	3.50	3.01	3.84	3.94	Damaged	3.75	102	23.91	106
BRRI dhan72 (ck)	5.13	5.13	4.60	4.90	3.87	4.97	5.21	4.91	4.84	127	27.20	118
LSD ($_{0.05}$)					0.28				0.12	1.78	0.56	2.51

L1-Gazipur, L2-Feni, L3-Sylhet, L4-Rangpur, L5-Chattogram, L6- Mymensingh, L7-Khulna, L8-Barishal.

Table 8. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (PQR) grown in different locations of Bangladesh during T. Aman 2017.

Genotype	Location							G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)									
	L1	L2	L3	L4	L5	L6	Mean	Mean	Mean	Mean
BR8535-2-1-2	4.41	3.90	4.30	3.72	4.55	4.43	4.22	124	12.0	112
BR8536-27-2-1-2	4.33	3.41	4.25	4.27	4.24	4.40	4.15	125	12.1	111
BR8234-1-3-7-1-3-HR21 (Com)	4.51	3.58	3.60	3.81	3.96	4.57	4.00	137	15.6	116
BRRI dhan34 (ck.)	3.39	3.22	3.32	3.51	3.41	3.53	3.40	134	11.7	120
Binadhan-13 (Std. ck.)	3.38	2.59	3.10	3.45	3.09	3.71	3.22	140	13.4	128
LSD (0.05)			0.34				0.14	0.4	0.51	1.2

L1-Rajshahi, L2-Rangpur, L3-Dinajpur, L4-Sherpur, L5-Jashore, L6- Gazipur.

was 91 to 138 cm at different growth stages. In the rest four locations, all the advanced lines including the check varieties were survived but yields were not satisfactory (Table 9). Most farmers were not interested to cultivate LSSDWR lines due to its poor yield with long duration compared to their own cultivated varieties. So, none of the advanced lines was recommended for PVT.

Boro 2018, low glycemic index and bacterial blight resistant rice (LGI and BBR rice). Two advanced lines for low glycemic index and bacterial blight resistant rice: BRC266-5-1-1-1 (Low GI) and BR8938-19-4-3-1-1 (BB Res) along with BR16 and BRRI dhan28 as checks were evaluated in eight locations (Table 10). Farmers' interest was mainly concentrated for check variety BRRI dhan28 for its good yield with shorter growth duration, attractive grain size and phenotypic acceptance. Having low glycemic index and bacterial blight resistance, both the lines may be recommended in future for PVT, if the irregularity of flowering and maturity is corrected.

Boro 2018, salinity tolerant rice and green super rice (STR and GSR). Four salt tolerant advanced lines: IR83484-3-B-7-1-1-1 (STR), IR87870-6-1-1-1-1-B (STR), HHZ12-SAL2-Y3-Y2 (GSR) and HHZ5-DT20-DT2-DT1 (GSR) along with BRRI dhan28 (ck) and BRRI dhan67 (R. ck) were evaluated in seven locations (Table 11). Along with check variety BRRI dhan67, farmers showed their interest for HHZ12-SAL2-Y3-Y2 (GSR) (entry no. 3) and HHZ5-DT20-DT2-DT1 (GSR) (entry no. 4) due to its good yield with reasonable growth duration, attractive grain size, phenotypic acceptance and uniformity of its flowering and maturity. So, the advanced lines HHZ12-SAL2-Y3-Y2 (GSR) (entry no. 3) and HHZ5-DT20-DT2-DT1 (GSR) (entry no. 4) were recommended for PVT.

Boro 2018, bacterial blight resistant (BBR), Biotechnology. Developed by Biotechnology Division, three advanced lines for bacterial blight resistant rice: BR(Bio)8333-BC5-1-20, BR(Bio)8333-BC5-2-16 and BR(Bio)8333-BC5-2-22 along with IRBB60 (R. ck), Purbachi (S. ck) and BRRI dhan29 (Std. ck) were evaluated

Table 9. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (LSSDWR) grown in different locations of Bangladesh during B. Aman 2017.

Genotype	Location										G.duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)												
	L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean	Mean	Mean	Mean
BR9390 -6 -2-2B	Damaged	Damaged	Damaged	Damaged	Damaged	0.55	2.36	2.80	3.33	2.26	162	25.44	144
BR10260-7-19- 2B	Damaged	Damaged	Damaged	Damaged	Damaged	0.43	1.55	1.88	3.18	1.76	156	25.18	127
R10230-15-27-7B (Cutting)	Damaged	Damaged	Damaged	Damaged	Damaged	0.43	2.11	1.41	3.11	1.77	158	24.56	152
BR939-13-2-B(Tall)	Damaged	Damaged	Damaged	Damaged	Damaged	0.67	1.92	2.28	3.24	2.03	160	25.40	136
Fulkari (ck)	Damaged	Damaged	Damaged	2.10	0.91	0.97	1.98	2.50	3.11	2.14	157	24.25	201
Local (ck)	Damaged	Damaged	Damaged	2.30	0.86	0.89	2.25	1.84	No local variety	1.63	155	23.80	216

L1-Tangail (Mirzapur1), L2-Tangail (Mirzapur2, L3-Gopalganj (Kashiani), L4- Tangail (Sadar), L5-Tangail (Nagorpur1), L6- Tangail (Nagorpur2), L7-Habiganj (Baniachong1), L8-Habiganj (Baniachong2), L9-Sylhet (Goinghat).

Table 10. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (LGI and BBR) grown in different locations of Bangladesh during Boro 2018.

Genotype	Location									G.duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BRC266-5-1-1-1 (Low GI)	6.82	6.60	4.81	4.75	6.60	6.13	6.33	6.98	6.13	153	22.45	101
BR8938-19-4-3-1-1 (BB Res)	6.36	6.03	6.24	4.71	6.21	7.27	6.19	5.62	6.08	152	23.28	103
BR16 (ck)	6.51	5.66	5.31	5.84	6.14	7.48	5.90	6.69	6.19	163	24.30	92
BRRI dhan28 (ck)	6.09	6.91	5.45	5.06	5.72	6.79	5.82	6.05	5.98	142	22.86	97
LSD $_{(0.05)}$				0.60					0.21	1.07	0.30	0.88

L1-Gazipur, L2-C.nawabganj, L3-Chattogram, L4-Habiganj, L5-Khulna, L6- Feni, L7-Jhalokathi, L8-Rangpur.

Table 11. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (STR and GSR) grown in different locations of Bangladesh during Boro 2018.

Genotype	Location Grain yield (t/ha)								G.duration (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	Mean	Mean	Mean	Mean
IR83484-3-B-7-1-1-1(STR)	6.45	6.42	6.22	6.16	6.18	6.12	6.15	6.24	150	24.41	103
IR87870-6-1-1-1-1-B(STR)	6.36	6.63	6.35	5.88	5.48	5.03	6.26	5.99	149	24.43	97
HHZ12-SAL2-Y3-Y2(GSR)	7.12	6.97	7.24	4.80	5.89	5.66	6.72	6.34	147	22.34	99
HHZ5-DT20-DT2-DT1(GSR)	7.04	6.71	7.13	4.69	6.53	5.91	6.51	6.36	148	22.76	94
BRRIdhan28 (S. ck)	6.61	6.24	6.46	5.97	5.08	5.35	6.30	6.01	140	22.67	97
BRRIdhan67 (R. ck)	6.85	6.65	6.91	5.59	6.14	5.74	7.02	6.41	143	22.09	105
LSD (0.05)				0.49				0.19	0.47	0.22	0.83

L1-Gazipur, L2-Satkhira (Debhata), L3-Satkhira (Ashashuni), L4-Khulna (Batiaghata), L5-Khulna (Paikghacha), L6- Patuakhali (Kalapara), L7-Borguna (Pathorghata).

in eight locations (Table 12). Compared to BRRI dhan29, farmers did not show interest for any advanced lines. Considering all attributes, none of the lines was recommended for PVT.

Boro 2018, favourable Boro-short duration (FB-SD), Biotechnology. Developed by Biotechnology Division, five advanced lines for short duration in favourable condition: BR(Bio)9785-BC2-6-2-2, BR(Bio)9785-BC2-20-1-3, BR(Bio)9787-BC2-63-2-2, BR(Bio)9787-BC2-63-2-4 and BR(Bio)9787-BC2-173-1-3 along with BRRI dhan28 as check were evaluated in eight locations (Table 13). Along with BRRI dhan28, farmers showed interest about entry no. 3 and 4 for their good yield, growth duration, attractive grain size and phenotypic acceptance. Considering all attributes, BR(Bio)9787-BC2-63-2-2 (entry no. 3) was recommended for PVT.

■ M A Islam, M R Islam, B Karmakar, M H Kabir, R Barua, M R Biswash, M M Hasan, G S Jahan and M S I Mamin.

TECHNOLOGY DISSEMINATION

Seed production and dissemination programme (SPDP)

For rapid dissemination and increase availability of newly released BRRI varieties among the farmers, Adaptive Research Division (ARD) conducted seed production and dissemination programme (SPDP) in every season of the year. This is an effective programme for the adoption of BRRI varieties through quality seed production. In the reported period, the SPDPs were conducted in different locations of the country in Aus, Aman and Boro seasons under different funding sources (GOB, SPIRA, ASRS, TRB, URSP (NATP2). In this programme, mainly BRRI varieties were demonstrated in farmers' fields.

SPDP in B. Aus, 2017. SPDPs were conducted in eight upazilas of four districts (Rajbari, Sylhet, Narail and Magura) in B. Aus 2017. BRRI dhan43 and BRRI dhan65 were disseminated in

Table 12. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (BBR-Bio) grown in different locations of Bangladesh during Boro 2018.

Genotype	Location Grain yield (t/ha)									G.duration (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR(Bio)8333-BC5-1-20	7.61	6.80	5.27	5.37	6.78	7.61	7.59	7.67	6.84	162	21.80	99
BR(Bio)8333-BC5-2-16	7.40	5.81	6.19	4.30	6.91	7.74	7.79	7.77	6.74	160	22.83	98
BR(Bio)8333-BC5-2-22	7.51	6.64	5.83	4.22	6.72	7.69	8.11	6.77	6.69	160	23.65	98
IRBB60 (R. ck)	6.26	3.95	5.01	5.24	6.15	6.57	6.72	6.05	5.74	159	24.43	78
Purbachi (S. ck)	6.51	3.19	5.16	4.79	6.38	6.39	5.10	6.64	5.52	151	24.33	91
BRRI dhan29 (Std. ck)	7.92	6.74	6.65	5.80	7.22	7.83	7.83	7.48	7.18	161	22.29	97
LSD ($_{0.05}$)				0.62					0.22	0.57	0.26	1.49

L1-Gazipur, L2-C. nawabgonj, L3-Chattogram, L4-Habiganj, L5-Khulna, L6- Feni, L7-Jhalokathi, L8-Rangpur.

Table 13. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (FB-SD, Bio) grown in different locations of Bangladesh during Boro 2018.

Genotype	Location Grain yield (t/ha)									G. duration (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR(Bio)9785-BC2-6-2-2	6.26	7.26	5.13	5.08	5.81	7.02	5.60	6.33	6.06	144	23.69	95
BR(Bio)9785-BC2-20-1-3	5.87	6.87	4.33	5.21	5.67	7.39	4.95	6.43	5.84	144	24.24	97
BR(Bio)9787-BC2-63-2-2	6.57	6.41	6.18	5.49	6.25	6.35	5.56	6.16	6.13	143	20.61	89
BR(Bio)9787-BC2-63-2-4	6.08	7.42	4.99	5.33	5.60	6.69	5.71	6.34	6.02	145	20.40	90
BR(Bio)9787-BC2-173-1-3	5.75	6.86	5.98	5.20	6.00	5.88	5.60	6.55	5.98	146	21.69	91
BRRI dhan28 (Ck)	6.22	6.83	5.20	4.99	6.12	6.92	5.12	6.12	5.94	142	22.31	97
LSD $_{(0.05)}$					0.62				0.22	0.41	0.30	0.96

L1-Gazipur, L2-C.nawabganj, L3-Chattogram, L4-Habiganj, L5-Khulna, L6- Feni, L7-Jhalokathi, L8-Rangpur.

this programme. Total rice production through demonstrations of BRRI dhan43 and BRRI dhan65 were about 5.5 tons and farmers retained 1382 kg seeds from those varieties for next year cultivation. About 1,185 farmers gained awareness about the varieties through field visits, discussion and knowledge sharing. About 350 farmers were motivated to cultivate those varieties in next year.

SPDP in Jhum, 2017. Demonstration of BRRI dhan43, BRRI dhan48 and BRRI dhan65 were conducted in seven upazilas of three hilly districts (Bandarban, Rangamati and Khagrachari) under SPDP. About 5.5 tons of paddy grains were produced under this programme. And farmers retained 985 kg seeds from those varieties for the next year cultivation. About 1,184 farmers gained awareness about the varieties through field visits, discussion and knowledge sharing. And about 332 farmers were motivated to cultivate those varieties in next year.

SPDP in valley of Hills (T. Aus) 2017. SPDPs were conducted at the vally of hills in seven upazilas of three hilly districts of Bangladesh (Bandarban, Rangamati, Khagrachari) in T. Aus 2017. BRRI developed Aus rice varieties BRRI dhan48 and BRRI dhan55 were used in the demonstration. About 10.8 tons of paddy grains were produced under this programme and farmers retained 2,072 kg seeds from those varieties for the next year cultivation. About 1,496 farmers gained awareness about the varieties through field visits, discussion and knowledge sharing. Furthermore, 352 farmers were motivated to cultivate the variety in the next year.

SPDP, T. Aus 2017. SPDPs were conducted in 14 upazilas of eight districts of Bangladesh (Sherpur, Meherpur, Gaibandah, Rangpur, Naogaon, Moulovibazar, Barguna. Patuakhali) under GoB and three upazilas of three districts (Chuadanga, Chattogram and Sylhet) under TRB project in T. Aus 2017. BRRI developed Aus rice variety BRRI dhan48 was used in the demonstration. About 24.9 tons of paddy grains were produced under this programme and farmers retained 5,311 kg seeds from those varieties for the next year cultivation. About 1,800 farmers gained awareness about the variety through field visits, discussion and knowledge sharing. Furthermore, 792 farmers were motivated to cultivate the variety in next year.

SPDP, T. Aman 2017. SPDPs were conducted in 36 upazilas of 18 districts (Sherpur, Netrokana, Mymensingh, Khulna, Chuadanga, Jhinaidah, Meherpur, Pirojpur, Bhola, Joypurhat, Kurigram, Thakurgaon, Sylhet, Chattogram, Cox's Bazar, Khagrachari, Rangamati and Bandarban) under GoB; 10 upazilas of five districts (Gaibandha, Naogaon, Jashore, Bagerhat and Patuakhali) under SPIRA project; 17 upazilas of 15 districts (Netrokana, Mymensingh, Khulna, Jashore, Chuadanga, Cumilla, Chattogram, Cox'sbazar, Sylhet, Moulivibazar, Rajshahi, Chapai Nawabganj, Naogoan, Dinajpur, Bhola) under TRB project and eight upazilas of four districts (Cumilla, Mymensingh, Barishal and Jhalokathi) in T. Aman 2017. Under URSP, GoB, SPIRA, TRB and URSP (NATP 2), BRRI dhan34, BRRI dhan49, BRRI dhan54, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan76 and BRRI dhan77 were used in the demonstration according to the suitability of the varieties in the respective locations. Total production of those varieties was about 134.8 tons from which about 24.6 tons quality seeds were retained by the farmers for the next year use. About 20,685 farmers gained awareness and knowledge about those varieties. More than 5,151 farmers were motivated to cultivate those varieties.

SPDP, Boro 2017. SPDPs were conducted in 35 upazilas of 18 districts (Kishoreganj, Narayanganj, Manikganj, Tangail, Gopalganj, Netrokana, Sherpur, Mymensingh, Kurigram, Joypurhat, Jashore, Bhola, BrahmanBaria, Khagrachari, Bandarban, Rangamati, Sylhet, Sunamganj) under GoB programme; 16 upazilas of 12 districts (Gaibandha, Dinajpur, Thakurgaon, Panchagarh, Naogaon, C.Nawabganj, Jashore, Jhinaidah, Patuakhali, Chattogram, Cox's Bazar, Moulovibazar) under SPIRA project; 11 upazilas of two districts (Khulna, Bagerhat) under ASRS programme; 16 upazilas of 12 districts (Netrokana, Mymensingh, Dinajpur, Bogura, Naogaon, Khulna, Jashore, Bhola, Cumilla, Cox's Bazar, Bandarban, Sylhet) under TRB project and eight upazilas of four districts (Cumilla, Mymensingh, Kishoreganj and Netrokana) under URSP (NATP 2) project in Boro 2018. Under GoB, SPIRA, ASRS, TRB and URSP (NATP 2), ten modern rice varieties (BRRI dhan47, BRRI dhan50, BRRI dhan58, BRRI dhan60, BRRI dhan63, BRRI dhan67, BRRI dhan68, BRRI dhan69, BRRI dhan74 and BRRI dhan81) were used in those demonstrations in different locations. As a whole, total production by the above demonstrations was 415.4 tons and farmers retained 57.1 tons seeds of those varieties for the next year use. A total of 22,022 farmers gained awareness and knowledge through field visits, discussion and knowledge sharing and 4,977 farmers were motivated to adopt those varieties.

Head to Head trial (Adaptive trial) and seed support programme under TRB

Under TRB in Boro 2018, ARD conducted 400 Head to Head trials (Adaptive trial) in different agro-ecological environments using recent BRRI varieties in collaboration with IRRI, BD officials and other GO, NGO partners. In Aman 2017, seed support programme to farmers and different stakeholders were conducted in different locations of Bangladesh under TRB project to enhance rapid dissemination of newly released BRRI varieties. During T. Aman 2017, 915 kg seeds of 12 varieties (BRRI dhan34, BRRI dhan49, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan77 were distributed to 83 farmers/Stakeholders in 25 upazilas of 16 districts.

FARMERS TRAINING AND PROMOTIONAL ACTIVITIES

Farmers' training. During the reporting period, ARD conducted 62 farmers' training at different locations of the country in which 2,110 trainees (1936 farmers and 194 SAAOs of DAE) participated on modern rice production technologies.

Field day/Farmers' rally. ARD conducted 82 field days at different locations of the country under GOB and different projects (SPIRA, ASRS, TRB and URSP (NATP 2)). Around 14,000 participants including farmers, local leaders and DAE personnel participated in the field days. These programmes also generated much enthusiasm about modern rice production technologies and BRRI varieties that helped rapid dissemination of technologies.

Seed production at BRRI farm

Seeds of recent and promising rice varieties were produced in T. Aman and Boro seasons during the reporting period under the close supervision of Adaptive Research Division. A total of 5.4 tons quality seeds of different BRRI varieties were produced.

Establishment of farmers' seed center under TRB

Two seed centers for farmers were established at Manda, Naogaon and Monirampur, Jashore. We provided 126 plastic drums at different locations under TRB, ASRS and URSP (NATP 2). Around 80 kg seeds can be preserved in each drum. Farmers will preserve good quality seeds of promising rice varieties for rapid dissemination through seed exchange or selling among the farmers.

■ B Karmakar, MA Islam, MR Islam, MH Kabir, R Barua, MR Biswash, MM Hasan, GS Jahan, B Ahmed and MSI Mamin

Training Division

SUMMARY

Training Division conducted 70 training programmes in the reporting year with course duration from one day to one week. Need based course curriculum was developed for these courses. Total number of participants was 2,072. The participants were Sub-Assistant Agriculture Officer of Department of Agriculture Extension (DAE), Non-Government Organizations (NGOs), BRRI Scientists, Imams of mosques and farmers. The highest number of participants was from the DAE. The average knowledge improvement for extension personnel in 1-week Rice Production Training (RPT) was 188%. The results indicate the significance of rice production training for extension personnel. Effectiveness of imparted trainings was determined on the basis of feedback remarks on different aspects. Most of the trainees expressed positive views about the course content and method of training. 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 1,516 responses on different issues were received from the trainees of one week hands-on training on modern rice production practices. The high expectations were found about disease and insect management followed by seed related issues (Table 1).

Table 1. Expectations of the trainees on different subjects in need during 2017-18.

Subject/Issue	Expectation (%)	Rank
Disease	22	1
Insect	18	2
Seed	13	3
Variety	10	4
Soil and fertilizer	10	4
Irrigation	7	5
Agronomy	7	5
Plant Physiology	5	6
Farm Machinery	4	7
Natural stress	2	8
Others	2	8
Total	100	
Response number	1516	

CAPACITY BUILDING AND TECHNOLOGY TRANSFER

Hands-on training on rice production practices

The main objective of the course was to train the field level extension workers of DAE. The course curriculum was designed based on the priority of field problems related to rice production and rice based technologies. Lecture and discussion, field visit, hands-on practical session, review session etc. were the dominant training methods in this course. Duration of the course was one week. A total of 527 SAAOs were trained. Among the participants 441 and 86 were male and female, respectively (Table 2).

Benchmark and final evaluation tool was applied to assess the knowledge improvement of individual participants. The average knowledge gain and improvement of the participants were 48% and 188% respectively (Table 3).

Training on hybrid rice

A training programme on 'Hybrid rice development and seed production' was conducted in 2017-18. Duration of the course was five days. A total of 62 participants were trained through this course in two batches. The participants of these courses were Scientific Officer and Senior Scientific Officer of BRRI, NGO officers and Deputy Director of Seed Certification Agency (SCA). Another five-day-long training programme on 'Hybrid rice and seed production' was conducted for the scientific assistant and senior scientific assistant of BRRI and seed technician of different seed company. Through this training 53 participants were trained in two batches of which 47 and six were male and female respectively. Table 4 presents the particulars of the trainings.

Table 2. Particulars of one week hands-on training on rice production practices, 2017-18.

Batch no.	Duration	No. of participants		
		Total	Male	Female
1	31 March-5 April, 18	25	23	2
2	31 March-5 April, 18	25	21	4
3	7-12 April, 18	24	19	5
4	7-12 April, 18	25	17	8
5	15-20 April, 18	25	21	4
6	15-20 April, 18	25	20	5
7	21-26 April, 18	25	23	2
8	21-26 April, 18	25	21	4
9	28 April-3 May, 18	25	20	5
10	28 April-3 May, 18	25	21	4
11	5-10 May, 18	24	23	1
12	5-10 May, 18	25	24	1
13	12-17 May, 18	25	24	1
14	12-17 May, 18	25	21	4
15	19-24 May, 18	24	18	6
16	19-24 May, 18	25	22	3
17	26-31 May, 18	25	20	5
18	26-31 May, 18	25	23	2
19	2-7 June, 18	25	24	1
20	2-7 June, 18	25	14	11
21	23-28 June, 18	30	22	8
Total		527	441	86

Modern rice production training for Imam

In the year 2017-18 five 3-day training programme on modern rice production was conducted for the Imams of different mosques of Gazipur district. The objective of the course was to train the Imams so that they could participate in dissemination of rice technology by motivating farmers through their lecture in mosque and other occasions. A total of 150 Imams were trained through this course.

Farmers training

Training Division conducted farmers training in *Haor* areas of Bangladesh during the reporting period. A total of 40 batches day-long rice production training programme were conducted with the collaboration of DAE in different upazilas of Kishoreganj, Netrokana, Sunamganj, Habiganj and Sylhet districts. In total 1,200 farmers (1,153 male and 47 female) and 80 SAAO's (76 male and 4 female) were trained through these programmes (Table 5).

Table 3. Knowledge gain, improvement and performance status in hands-on training on rice production practices.

Batch no.	Evaluation score (%)		Gain	Improvement (%)	Performance		
	Benchmark	Final			Distinction	Satisfactory	Participatory
1	26	71	45	170	6	16	3
2	23	70	47	201	5	19	1
3	16	63	51	283	7	15	2
4	25	78	53	215	5	18	2
5	23	66	43	189	2	18	15
6	26	75	49	190	11	12	2
7	27	75	48	176	11	14	0
8	25	69	44	172	6	15	4
9	30	80	49	160	8	12	5
10	25	64	39	155	13	9	3
11	25	68	42	166	9	11	4
12	28	74	46	162	16	7	2
13	27	87	51	222	8	13	4
14	24	70	46	195	7	16	2
15	26	70	44	169	7	17	0
16	25	82	55	224	20	5	0
17	22	63	41	183	5	17	3
18	24	70	46	196	19	5	1
19	21	65	44	204	8	14	3
20	28	70	42	154	7	11	7
21	29	73	45	157	6	21	3
Average	25	72	48	188			

Table 4. Particulars of hybrid rice training course, 2017-18.

Batch no.	Title	Participants (no.)			Designation	Organization
		Total	Male	Female		
1	Hybrid rice development and seed production	62	42	20	SO, SSO, NGO Officer	BRRI, NGO
2	Hybrid rice and seed production	53	47	6	SA,SSA, Seed Technician	BRRI, Seed Company
Total		115	89	26		

Table 5. Rice production training courses for farmers, 2017-18.

District	Training (no.)	Total Trainee (no.)		Participant category (no.)			
				Farmer		SAAO	
		Farmer	SAAO	Male	Female	Male	Female
Kishoreganj	10	300	20	292	8	20	0
Netrakona	6	180	12	178	2	11	1
Sunamganj	16	480	32	444	36	30	2
Sylhet	2	60	4	60	0	4	0
Habiganj	6	180	12	179	1	11	1
Total	40	1200	80	1153	47	76	4

Training information of Training Division

During the reporting period, 70 training programmes have been conducted by the Training Division. Through this training 2,072 participants were trained. Table 6 presents the summaries of the trainings.

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 reveals that all the training programmes on rice production management were very much helpful for the trainees to build up their capacity for modern rice production activities.

Performance of BRRI speakers

Twenty-one batches of 1-week hands-on training on rice production practices 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 as well as 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 speakers' were very good to excellent.

Table 6. Total training conducted by Training Division, 2017-18.

Title	No. of training	Duration	No. of participants			Designation
			M	F	Total	
Hands-on training on modern rice production training (SPIRA)	21	1-week	441	86	527	SAAO
Training on hybrid rice development seed production (Hybrid project)	2	5-day	42	20	62	SO, SSO, NGO officer
Training on hybrid rice and seed production (Hybrid project)	2	5-days	47	6	53	SA, SSA, Seed Technician
Modern rice production training (GOB)	5	3-day	150	0	150	Imam
Farmers training	40	1 day	1153	47	1200	Farmers
			76	4	80	SAAO
Total	70		1,905	167	2,072	

BRRI RS, Barishal

SUMMARY

In T. Aman 2017, from 36 crosses 1,171 seeds were obtained. In F_1, nine out of 11 were selected and confirmed. A total of 1,633 progenies of F_2 population were selected from nine parental materials. For developing the erect and dense panicle, eight materials were selected for further procedure. During Boro 2017-18, 39 F_1 populations were selected from 54 cross combinations; 23 populations were confirmed for F_2 generation; eight progenies were selected for F_3 progeny and seven progenies were selected for F_4 progeny. In observational trial (OT), among 266 entries tested in Boro 2017-18, only 16 were selected for further process. In PYT-1, all the nine advanced lines gave higher yield (7.66-9.57 t ha^{-1}) than the standard checks in Boro 2017-18. For PYT-2, among 14 advanced lines 10 gave more or similar yield than the check varieties. In PYT-3, all the three advanced lines gave more or similar yield than checks. In T. Aman 2017, out of two RYT lines, BR (Bio) 8961-AC26-16 gave higher yield (6.25 t ha^{-1}) than the check. In Boro 2017-18, four RYT were conducted of which BR (Bio) 9777-26-4-3 gave higher yield (8.64 t/ha) in RYT (Bio) FB compared to the check. Only one PVT were conducted during Aman 2017 from where BR (Bio) 9786-BC2-132-1-3 was selected. In Boro 2017-18, PVT lines BRRI dhan29-SC3-28-16-10-8-H R1(Com) and BR(Bio)9876-BC2-59-1-2 were selected.

False smut disease was increased with the increasing of N-level. Lower number of balls on panicle was observed when N2 (1/3rd less than optimum N) and C3 (Azoxystrobin+Propiconazole) was applied at 3rd ST. Out of sixteen chemicals tested against rice blast disease four viz Tebuplus75, Quickout 50WP, Dlink and Mcvo 75 significantly reduced neck blast. Temperature at 28-30°C, humidity at 80-90%, rainfall along with rice variety BRRI dhan52 increased gall midge infestation. Closer spacing, shade (Tree), higher humidity and lower temperature was conducive for leaf folder multiplication. Bacterial leaf blight was the major disease followed by brown spot, blast and sheath blight. Those diseases were higher in local varieties compared to HYV rice. Gall midge was higher in Dasmina, Patuakhali. Leaf folder was higher at Shanker Pasha, Pirojpur.

Sesbania incorporation and 50% N and 100% P-K-S-Zn (STB) gave comparatively higher yield than azolla incorporation treatment in all varieties. Almost all the tested varieties delivered positive responses with the application of zinc (2.5 kg ha^{-1}). For Boro rice, N is the most yield limiting nutrient. In T. Aman 2017, Biofertilizer along with NKS (75%) produced higher yield than the other treatments. But in Boro 2017-18, Bio-organic fertilizer was not effective. In Boro 2017-18, rice transplanted on 25 December and 10 January gave higher yield than the other four times of planting. Higher salinity (5.4 dS m^{-1}) was found in Charduani, Patharghata in March 2018 and decreased onward. Water at the upstream of Boleshor and Burisshor river was found suitable for irrigation throughout the dry season.

Under varietal replacement through Head to Head trial during Boro 2017-18, BRRI dhan74 (6.64 t/ha) and BRRI dhan67 (5.73 t ha^{-1}) gave higher yield having less disease and insect damage followed by BRRI dhan63 (5.65 t ha^{-1}), BRRI dhan28 (5.59 t ha^{-1}) and BRRI dhan62 (5.52 t ha^{-1}). In the ALART of T. Aman 2017, only one line BR8204-53-2-5-2 was superior to other entries for rainfed lowland rice (RLR-1). In the demonstration trial under GOB during T. Aman 2017, BRRI dhan76 and BRRI dhan77 gave 4.87 and 4.92 t ha^{-1} grain yield respectively. In the demonstration under SPIRA, tested varieties showed 73-88% yield advantage over local varieties during T. Aman 2017. Average 5.39 t ha^{-1} yield was recorded in the demonstration of BRRI dhan72 under HP project. Around 12.8 and 27.0 ton breeder seeds of different varieties of Aman and Boro seasons, respectively were produced. Seventeen training, 10 field days, four workshops including fair were conducted.

VARIETY DEVELOPMENT

Hybridization

Development of tidal submergence tolerant rice. Hybridization was done for development of tidal submergence tolerant rice varieties during T. Aman 2017 and 1,171 seeds were obtained from 36 crosses. Out of 11 combinations, nine progenies were selected and confirmed in F_1. A total of 1,633 progenies of F_2 population were selected from nine parental materials. For developing the varieties for erect and dense panicle, eight materials were selected for further procedure. During Boro 2017-18 in F_3 generation a total of 1,633 progenies were grown and of which 143 progenies were selected for further process in F_4.

Introgression of dense and erect panicle and blast resistant gene in Indica rice. During Boro 2017-18, a total of 39 F_1 population were selected from 54 cross combinations and 3,500 seeds were obtained (Table 1). A total of 106 panicles were selected from eight F_2 populations during Boro 2017-18 for further process in F_3 (Table 2).

Observational trial (OT). Under variety replacement programme of TRB, a total of 266 entries were grown along with standard check BRRI dhan28 and BRRI dhan58 in BRRI RS, Barishal during Boro 2017-18. Out of those 266 entries 16 were found promising in terms of yield and selected for further process. The rest entries were recommended for re- trial for the next season.

Preliminary yield trial (PYT). In PYT-1 (Target yield>6 t/ha), all the nine advanced lines (BRBa3-2-1, BRBa 3-2-3, BRBa 3-2-4, BRBa 3-2-5, BRBa 3-3-1, BRBa 3-4-2, BRBa 3-4-7, BRBa 25-3 and BRBa 29-4) gave higher yield (7.66-9.57 t/ha) than the standard checks BRRI dhan58 (7.56 t/ha) and BRRI dhan28 (7.24 t/ha) during Boro 2017-18. Fourteen advanced lines along with checks BRRI dhan28 and BRRI dhan58 were tested for PYT-2 (Yield 5-6 t/ha) during Boro 2017-18. The lines BRBa3-2-6 (7.45 t/ha), BRBa38-2 (7.39 t/ha), BRBa44-2-1 (7.27 t/ha), BRBa3-1-1 (7.26 t/ha), BRBa3-4-5 (7.24 t/ha), BRBa3-1-6 (7.22 t/ha), BRBa3-4-3 (7.17 t/ha), BRBa28-2 (7.06 t/ha), BRBa30-1 (7.05 t/ha) and BRBa3-2-2 (7.04 t/ha) provided yield more or similar to the checks BRRI dhan58 (7.43 t/ha) and BRRI dhan28 (6.25 t/ha). Three advanced lines along with the checks BRRI dhan28 and BRRI dhan58 were tested for PYT-3 (Fine grain) during Boro 2017-18. Advanced lines BRBa48-1 gave 7.7 t/ha yield that was similar to the standard check BRRI dhan58 (7.69 t/ha). On the other hand, BRBa75-1 (7.02 t/ha) and BRBa22-1 (6.5 t/ha) gave more or similar yield to standard check BRRI dhan28 (6.47 t/ha).

Regional yield trial (RYT). One RYT was conducted during T. Aman 2017. Out of two tested lines BR(Bio)8961-AC26-16 gave higher yield (6.25 t/ha) than the check variety BRRI dhan49 (5.93 t/ha) during Transplanted Aman 2017 season (Table 3). In Boro 2017-18, four RYT were conducted of which BR (Bio)9777-26-4-3 gave higher yield (8.64 tha^{-1}) compared to the check variety BRRI dhan58 (7.07 tha^{-1}) in RYT (Bio) FB. On the other hand, in RYT disease resistant (BB) rice BR9650-35-4-3 gave higher yield (8.55 tha^{-1}) than the check variety BRRI dhan58 (6.74 tha^{-1})

Table 1. List of F_1 for introgressing dense and erect panicle gene during Boro 2017-18.

Female	Male	No. of seed sets	Female	Male	No. of seed sets
BR14	MK-632	135	BRRI dhan47	MK-628	66
BR14	MK-634	138	BRRI dhan58	AKT-3	40
BR15	MK-629	209	BRRI dhan58	AKT-1	25
BR19	MK-630	50	BRRI dhan58	MK-633	70
BR2	MK-634	70	BRRI dhan58	AKT-4	25
BR26	AKT-3	59	BRRI dhan58	AKT-3	28
BR8	MK-630	125	BRRI dhan58	Pita-2	37
BR8	MK-632	180	BRRI dhan58	MK-631	37
BR8	Pita-2	240	BRRI dhan58	MK-632	85
BRRI dhan28	AKT-3	76	BRRI dhan62	MK-631	135
BRRI dhan28	Pita-2	28	BRRI dhan62	MK-628	90
BRRI dhan28	YC-140	32	BRRI dhan67	AKT-1	75
BRRI dhan28	MK-628	40	BRRI dhan67	AKT-3	113
BRRI dhan28	AKT-4	100	BRRI dhan67	MK-628	135
BRRI dhan28	MK-634	55	BRRI dhan67	AKT-6	147
BRRI dhan28	MK-629	43	BRRI dhan68	MK-631	275
BRRI dhan29	MK-631	200	BRRI dhan74	MK-632	45
BRRI dhan35	YC-140	45	BRRI dhan74	MK-629	33
BRRI dhan47	RBP-19 (US)	70	BRRI dhan74	MK-631	85
BRRI dhan47	AKT-3	59	Total		3500

Table 2. List of plant selected in F_2 generation during Boro 2017-18.

Parentage	BRBa No.	No. of F_2 plant selected
BRRI dhan62/MK634	BRBa020	21
BRRI dhan72/AKT3	BRBa021	14
BRRI dhan28/MK634	BRBa022	15
BRRI dhan72/MK634	BRBa023	15
BRRI dhan28/MK630	BRBa024	14
BRRI dhan29/MK633	BRBa025	4
BRRI dhan72/MK629	BRBa026	6
BRRI dhan67/MK630	BRBa027	17
Total		106

and BRRI dhan29 (Sus. ck) (6.88 t/ha). But in other RYT, tested lines were not satisfactory compared to the check variety.

Proposed variety trial (PVT). Only one PVT were conducted during T. Aman 2017. Test entriy BR(Bio)9786-BC2-132-1-3 gave (5.1 t/ha) around 0.8 t/ha higher yield than the corresponding check BRRI dhan49 (4.3 t/ha) (Table 4). Two PVT were evaluated during Boro 2017-18. Breeding line BRRI dhan29-SC3-28-16-10-8-HR1(Com) gave almost 0.5 t/ha higher yield than the check BRRI dhan28. In an other PVT, BR (bio) 9876-BC2-59-1-2 also gave higher yield than the check variety BRRI dhan29.

Confined field trial of Golden rice. In Boro 2017-18, confined field trial of Golden rice was conducted including one line, IR112060 GR2-E:2-7-63-2-96 and one check BRRI dhan29. Plant height, tiller number, panicle number, 1000 grain weight (TGW) and grain yield of Golden rice line were 106.85 cm, 14.55, 13.48, 19.55 g and 8.07 t/ha respectively. On the other hand, plant height, tiller number, panicle number, TGW and grain yield of BRRI dhan29 were 106.42 cm, 14.38, 13.35, 20.53 g and 8.64 t/ha. Rice variety BRRI dhan29 gave 0.57 t/ha higher grain yield than Golden rice line (Table 5).

Proposed variety evaluation trial of hybrid rice. Hybrid rice trials were conducted during Aus 2017, T. Aman 2017 and Boro 2017-18 seasons, which were provided by seed certification agency (SCA). In Aman 2017, eight entries were evaluated and two entries H1210 (5.16 t/ha) and H1214 (4.93 t/ha) produced higher yield than the others. In Boro 2017-18, out of 35 entries evaluated, 17 entries produced more than 9 t/ha yield.

PEST MANAGEMENT

Effect of planting time, nitrogen and chemical on false smut incidence. False smut disease was increased with the increasing of N-level. Higher

Table 3. Regional yield trial (RYT) during T. Aman 2017.

Designation	Plant height (cm)	PaCPV (M)	Panicle /hill	Days to 80% maturity	Yield (t/ha)
BR(Bio)8961-AC22-14	122	3 (4)	13	134	5.61
BR(Bio)8961-AC26-16	124	3 (4)	11	136	6.25
BRRI dhan49 (ck)	123	3 (4)	12	135	5.93

Table 4. Proposed variety trial (PVT) during T. Aman 2017 and Boro 2017-18.

Line/ck	GD (day)	Yield (t/ha)
PVT during T. Aman 2017		
BR (Bio) 9786-BC2-132-1-3	127	5.1
BRRI dhan49 (ck)	132	4.3
PVT during Boro 2017-18 (Breeding)		
BRRI dhan29-SC3-28-16-10-8-HR1(Com)	141	6.5
BRRI dhan28 (ck)	141	5.9
PVT during Boro 2017-18 (Biotech)		
BR(bio)9876-BC2-59-1-2	159	7.4
BRRI dhan29 (ck)	164	6.9

Table 5. Confined field trial of Golden rice during Boro 2017-18.

Genotype	Plant height (cm)	# Tiller	# Panicle	1000 gr. wt (g)	Yield (t/ha)
IR112060 GR2-E:2-7-63-2-96	106.85	14.55	13.48	19.55	8.07
BRRI dhan29	106.42	14.38	13.35	20.53	8.64

disease incidence (5.8 ball) was recorded in N3 (1/3rd higher than optimum dose) followed by N1 (Optimum dose, 22 kg/bigha) and N2 (1/3rd less than optimum dose). Higher false smut disease (7.5 ball) was observed at 3rd seeding time (15 July) followed be 2nd seeding (30 June, 3.2 ball) and 4th seeding (30 July, 1.6 ball) while no disease was recorded at 1st ST (15 June). Lower disease incidence (3-ball) in C3 (Azoxistrobin+Propiconazole) followed by C2 (Azoxistrobin, 3.2-ball) and C1 (Nativo, 4.3-ball) while higher disease incidence (7 ball) was recorded in untreated control. Lower number of balls on panicle was observed when N2 (1/3rd less than optimum N) and C3 (Azoxystrobin+Propiconazole) was applied at 3rd ST.

Screening of chemicals against blast disease of rice. Sixteen chemicals viz Success 300 EC, Royal 75 WDG, Mace, Mzole 32.5Sc, Tebuplus 75, Cibazole 32.5, Quickout 50WP, Dlink. Tecobin 75WP, Adistar top, Aiker 20, Bioesoony plus, Suntighter, Mcvo 75, Deconil 500 Sc including one standard check Trooper and one diseased check (untreated control) were tested against rice blast disease. Out of 16 chemicals four viz Tebuplus75, Quickout 50WP, Dlink and Mcvo 75 significantly reduced neck blast over negative (diseased) control (plain water used) and were similar to the standard check, Trooper (Table 6).

Survey of rice diseases in selected areas in Aman and Boro season. In Aman 2017, bacterial leaf blight and blast was recorded as major diseases. Sheath blight, brown spot and false smut were also observed as a prevalent disease. High yielding variety BRRI dhan34, BRRI dhan62 and local variety Sakkhorkhora, Kumragoir, Kalijira, Montasirmota were highly infected by blast disease during the survey period. In Boro 2017-18, blast was recorded as major disease. Sheath blight, brown spot and false smut (later cultivated crop) were also observed as prevalent. High yielding variety BRRI dhan28 and BRRI dhan63 were highly infected by blast disease during the survey period.

Identification of climatic factors responsible for disease and insect outbreak and their management in southern areas of Barishal. Temperature at 28-30°C, humidity at 80-90%, rainfall along with rice variety BRRI dhan52 increased gall midge infestation. Closer spacing, shade, higher humidity and lower temperature was conducive for leaf folder multiplication. Blast disease was less in BRRI dhan67 but high in BRRI dhan61. Standing water and spraying of Trooper reduced blast incidence. Optimum transplanting time and optimum urea dose decreased false smut incidence. Perching, sweeping, light trapping, optimum use of urea and spraying of appropriate insecticide (if necessary) reduced insect infestation. Gall midge was higher in Dasmina, Patuakhali while leaf folder was higher at Shanker Pasha, Pirojpur. Stem borer was found higher in local varieties followed by BR23 and BRRI dhan52. Local varieties, BRRI dhan76 and BRRI dhan77

Table 6. Screening of chemicals against blast disease of rice.

Treatment		Total pan	Inf pan	% inf pan	% reduc
T_1	Success 300 EC	207	18.7	9	86.3
T_2	Royal 75WDG	177	13.3	7.7	88.2
T_3	Mace	190	14.7	7.6	88.3
T_4	Mzole 32.5Sc	203	46.7	22.7	65.3
T_5	Tebuplus 75	193	8	4.1	93.7*
T_6	Cibazole	198	14.7	7.4	88.7
T_7	Quickout 50WP	216	13.3	6.4	90.2*
T_8	Dlink	227	10.7	5.2	92*
T_9	Tecobin 75WP	190	66.7	34.8	46.9
T_{10}	Adistar top	208	17.3	7.8	88
T_{11}	Aiker 20	179	20	11	83.2
T_{12}	Bioesoony plus	167	52	34.5	47.4
T_{13}	Suntighter	159	18.7	11.1	83.1
T_{14}	Mcvo 75	181	12	6.6	90*
T_{15}	Deconil 500 Sc	163	13.3	8.2	87.4
T_{16}	Trooper/Nativo	209	10.7	5.1	92.2*
T_{17}	Untreated control	186	118.7	65.5	0

having long growth duration were infested by rice bug. In case of disease, bacterial leaf blight was the major one followed by brown spot, blast and sheath blight. These diseases were higher in local varieties compared to HYV rice.

CROP-SOIL-WATER MANAGEMENT

Long term missing element trial. Long term missing element trial was conducted at BRRI RS, Barishal during Boro 2017-18. Rice variety BRRI dhan58 was used as test variety. It was observed from the yield data that all the nutrients (N, P, K, S and Zn) were needed to be applied during Boro season to maintain soil nutrient levels as well as for better yield of BRRI dhan58. For Boro rice, N was observed as the most yield limiting nutrient at BRRI RS farm.

Maximizing rice yield through balanced fertilizer application and organic amendment in tidal flooded soil. Four treatments were used namely T_1 =No fertilizer, T_2 =N-P-K-S-Zn @ 107-10-33-14.5-1.2 kg/ha (STB), T_3 =Azolla incorporation + 50% N + 100% P-K-S-Zn (STB) and T_4 =Sesbania incorporation+ 50% N + 100% P-K-S-Zn (STB) in main plot and four varieties BRRI dhan41, BRRI dhan52, BRRI dhan76 and BRRI dhan77 were in sub plot. In case of chemical fertilizer all the BRRI varieties exhibited high yield compared to the other treatments. Sesbania incorporation and 50% N and 100% P-K-S-Zn (STB) gave comparatively higher yield than azolla incorporation treatment in all the varieties (Table 7).

Screening of MV rice for efficient zinc use in tidal flooded soil. Ten varieties namely BR23, BRRI dhan30, BRRI dhan41, BRRI dhan44, BRRI dhan49, BRRI dhan52, BRRI dhan62, BRRI dhan72, BRRI dhan76 and BRRI dhan77 were tested under two treatments viz (i) no zinc application and (ii) Zn @ 2.5 kg/ha during T. Aman 2017. Almost all the varieties produced positive responses with the application of high dose of zinc. Among them, BR23, BRRI dhan49 and BRRI dhan76 reacted more significantly than the others.

Evaluation of bio-organic fertilizer in the soil plant system. For evaluating efficacy of biofertilizer to promote rice plant growth and yield, this experiment was conducted with the help of Soil Science Division. In T. Aman 2017, four treatments namely, T_1= Biofertilizer (2 t ha^{-1}), T_2 = NPKS (100%), T_3 = NKS (75%) + Biofertilizer (2 t ha^{-1}), T_4 =control were treated in BRRI dhan71 variety. BOF+NKS (75%) gave higher yield 3.94 t/ha than the other treatments (Table 8). In Boro 2017-18, four treatments namely T_1= Bio-organic fertilizer @ 2 tha^{-1}, T_2 = NPKS @ 118-18-75-18 kg/ha, T_3 = Bio-organic fertilizer @ 2 tha^{-1} + N (70%) + KS (100%), T_4 =control was treated in BRRI dhan58 variety. NPKS @ 118-18-75-18 kg/ha gave higher yield 6.33 t/ha than the other treatments.

Table 7. Effect of different fertilizer doses on grain yield of four rice varieties.

Variety	Yield (t/ha)					
	No fertilizer	Chemical fert.	Azolla incorp.	Sesbania incorp.	Mean	LSD
BRRI dhan41	2.02	5.98	4.18	4.07	4.06	
BRRI dhan52	1.9	5.74	4.45	4.13	4.05	0.42
BRRI dhan76	2.41	4.51	4.51	4.66	4.02	
BRRI dhan77	2.66	4.05	4.05	3.92	3.67	
Mean	2.25	5.07	4.3	4.2		
LSD		0.59			11.85	
CV		14.19			0.93	

Table 8. Effect of BOF on plant growth and yield of BRRI dhan71.

Treatment	Tiller/m^2	Panicle/m^2	GY (t/ha)
BOF (2 t/ha)	178 a	165	3.40 b
NPKS (100%) kg/ha @ 67-10-41-10	176 a	173	3.61 ab
BOF+ NKS (75%)	182 a	171	3.94 a
Control	150 b	144	1.90 c
CV (%)	6.37	7.62	7.15

Effect of planting date on growth and yield of BRRI released varieties. In T. Aman 2017 season, four planting times and ten rice varieties were used in this experiment. Due to severe rat damage, the experiment was not successful but second planting time gave higher yield. In Boro seasons this study was conducted to determine the cutoff date for planting in different locations and suitable planting date. Six planting times were tested with five varieties namely BRRI dhan58, BRRI dhan63, BRRI dhan69, BRRI dhan74 and BRRI hybrid dhan5 to see the suitable planting date. Rice transplanted in 25 December and 10 January gave higher yield than the other four times of planting.

Yield maximization of Boro rice through integrated crop management approach. This study was conducted to maximize growth and yield of Boro varieties. Two fertilizer treatments (M1=No urea, TSP 90 kg/ha, MoP 150 kg/ha, gypsum 110 kg/ha, $ZnSO_4$ 10 kg/ha as a basal dose and first urea 87 kg/ha at 20 DAT, second urea 87 kg/ha at 35 DAT, third urea 87 kg/ha at 50 DAT as top dress with two seedlings/ hill) and (M2= urea 40 kg/ha, TSP 90 kg/ha, MoP 75 kg/ha, gypsum 110 kg/ha, $ZnSO_4$ 10 kg/ha as a basal dose and first urea 104 kg/ha at 20 DAT, second urea 91 kg/ha and MoP 90 kg/ha at 35 DAT, third urea 78 kg/ha at 50 DAT as top dress with four seedlings/hill) and three varieties (BRRI dhan67, BRRI dhan74 and BRRI hybrid dhan5) were used to conduct the experiment. Higher yield of BRRI dhan67 (4.28 t/ha), BRRI dhan74 (4.69 t/ha) and BRRI hybrid dhan5 (5.48 t/ha) was obtained by second fertilizer treatment (M2) than first fertilizer treatment (M1).

Use of less saline water resources for increasing cropping intensity. This experiment was conducted at Bakerganj, Barishal and Nolcity, Barguna during 2017-18. Boro cultivation was done using fresh tidal water from river and canal through LLP and plastic pipe water distribution system. In Nolcity, 14 bigha land was cultivated by BRRI dhan47, BRRI dhan67 and BRRI dhan74 and at Bakerganj, one acre of land was cultivated by BRRI dhan28 and BRRI dhan74. Rice variety BRRI dhan74 gave 6.9 t/ha yield at Bakerganj and BRRI dhan67 gave 6.6 t ha^{-1} at Nolcity. The water salinity was less than 0.7 ds/m in both the locations.

Assessment of suitable water resources availability for irrigation. The study was under taken to identify suitable water resources for dry season crop production in the Barishal Division. Four major river systems of the area: Tentulia, Buriswar, Biskhali and Boleswar were taken under the study. Water samples were collected from the rivers to measure the electrical conductivity in March to June 2018. The highest salinity in Tentulia river at Panpatti ghat, Golachipa, in Buriswar river at Barobogi, in Biskhali river at Kalmegha and in Boleswar river at Charkhali ferryghat were 0.76, 0.71, 0.480 and 1.08 dS/m respectively (Table 9), which indicated that in upstream side of those river point were suitable for irrigation in dry season.

Planting time for Boro rice cultivation in saline areas (APSIM model). This study was conducted to optimize the water resources and improving the productivity and profitability in coastal region. Six planting times were tested with three varieties namely BRRI dhan28, BRRI dhan67 and BINA dhan-10 to see the effect on yield. Rice transplanted in 15 December and 25 December gave higher yield than the other four times of planting.

SCIO-ECONOMIC AND POLICY

Stability analysis. Stability analysis of BRRI released Boro varieties (37 Boro varieties) were done. The highest yield was observed in BRRI hybrid dhan5 (7.0 t ha^{-1}) followed by BRRI dhan74 (6.8 tha^{-1}). The lowest yield was found in BR17 (2.3 tha^{-1}). In T. Aman season 38 entries were used. BRRI dhan52 gave higher yield (5.55 t/ha) followed by BR22 (5.3 t/ha) while lower yield was obtained from BRRI hybrid dhan6 (2.23 t/ha, rat damaged 60%).

TECHNOLOGY TRANSFER

Variety replacement through Head to Head trial. Twenty trials were conducted at different locations of Barishal region to demonstrate yield advantage of BRRI released HYVs over locally cultivated varieties. In Boro 2017-18 under TRB, BRRI dhan74 (6.64 t/ha) and BRRI dhan67 (5.73 t/ha) gave higher yield having less disease and insect damage followed by BRRI dhan63 (5.65 t/ha), BRRI dhan28 (5.59 t/ha) and BRRI dhan62 (5.52 t/ha). Farmers

Table 9. Salinity in water of different river of Barishal region during dry season 2018.

Location	River	Salinity (dS/m)			
		16-17 March	22-23 April	05-06 May	25-26 June
Panpatti ghat	Tentulia	-	0.510	0.760	-
Taltoli launch ghat		-	-	0.670	0.210
Borobogi	Burishwar	0.520	0.710	-	-
Chotobogi hat		0.350	0.480	-	0.190
Amtoli ferryghat		0.320	0.410	0.500	0.168
Lebukhali ferryghat		0.300	-	0.350	0.147
Kakchira ferryghat		0.240	0.400	0.550	0.182
Kalmegha	Bishkhali	0.340	0.480	0.420	0.195
Patharghata 2 no ward		1.650	1.33	0.480	0.343
Nissanbaria		-	2.10	-	-
M Baliatoli		-	4.11	-	-
Charduani		5.40	5.50	1.000	0.733
Khatachira	Boleshwar	5.30	-	1.600	-
Boromasua		3.20	-	1.100	0.589
Chotomasua		3.08	3.00	0.800	0.354
Charkhali ferryghat		1.08	0.550	0.180	0.234

were motivated to cultivate those varieties because their locally cultivated varieties were less yielder than tested HYVs.

Advanced line adaptive research trial (ALART). Five ALART programmes viz ALART for rainfed lowland rice (RLR-1), ALART for rainfed lowland rice (RLR-2), ALART for zinc enriched rice (ZER), ALART for bacterial blight resistant (BBR) and ALART for green super rice (GSR-salinity) were conducted during T. Aman 2017. Out of five ALART, only line BR8204-53-2-5-2 was superior in yield to other entries in ALART for rainfed lowland rice (RLR-1) during T. Aman 2017 (Table 10). Other lines in different ALART programmes were not satisfactory in terms of growth duration and grain yield.

Demonstration, seed production and scaling up of MV rice in Barishal region. Demonstration trials of BRRI released HYVs of rice were conducted at different locations of Barishal region to replace locally cultivated rice varieties. In the demonstration trial under GOB during T. Aman 2017, BRRI dhan76 and BRRI dhan77 gave 4.87 and 4.92 t/ha grain yield respectively. In the demonstration trials under SPIRA, tested varieties showed 73-88% yield advantage over local varieties during T. Aman 2017. In this season, six demonstration trials of BRRI dhan72 under HP Bangladesh project were conducted and yield of that variety was ranged from 5.16 t/ha to 5.61 t/ha (average 5.39 t/ha). In the demonstration trial of Boro varieties during 2017-18 under SPIRA project, yield of BRRI dhan29, BRRI dhan47, BRRI dhan58, BRRI dhan61, BRRI dhan67, BRRI dhan74 and BRRI hybrid dhan3 were 7.09, 6.26, 7.02, 6.01, 6.74, 7.13 and 8.62 t/ha respectively. Under NATP project, local variety yielded 2.82 t/ha but HYV rice yielded 73-88% more over local varieties.

Table 10. ALART, rainfed lowland rice (RLR-1), T. Aman 2017.

Genotype	GY (t ha^{-1})	GD (day)	Pl. ht. (cm)	Pan/m^2	TGW (g)
BR8192-10-1-2-3-4	4.93	120	107.79	186	27.84
BRRI dhan29-SC3-28-16-15-HR2 (Com)	4.36	122	104.73	190	20.86
BR8204-5-3-2-5-2	5.08	132	126.21	195	27.56
IR11F190	4.43	133	134.15	187	26.09
IR70213-10-CPA-4-2-2-2	4.73	128	124.17	167	31.05
BRRI dhan39 (ck)	4.82	115	105.33	187	24.60
BRRI dhan49 (ck)	4.13	135	111.92	210	19.98
CV (%)	5.85	0.25	1.15	6.95	2.26
LSD (0.05)	0.48	0.57	2.37	23.36	1.02

Breeder seed and TLS production. In T. Aman 2017, around 12.8 ton breeder seed and 5.02 ton TLS of BR23, BRRI dhan34, BRRI dhan41, BRRI dhan44, BRRI dhan49, BRRI dhan52, BRRI dhan62, BRRI dhan71, BRRI dhan72, BRRI dhan76, BRRI dhan77 were produced. On the other hand, around 27 ton breeder seed and 10.9 ton TLS of BRRI dhan26, BRRI dhan28, BRRI dhan29, BRRI dhan47, BRRI dhan50, BRRI dhan67, BRRI dhan74 were produced during Boro 2017-18 (Table 11).

Farmers' field day, training and workshop. A total of 17 training programmes (14 under GoB where 260 male and 160 female; three under SPIRA project where 75 male and 45 female participants attended), 10 field day (five under GoB where 310 male and 190 female; three under SPIRA where 250 male and 350 female; two under NATP project where 180 male and 220 female participants attended and four workshops including krishi mela and unnoyn mela were conducted during the reporting period.

Table 11. Yield data for breeder seed and TLS during T. Aman 2017 and Boro 2017-18.

Variety for Aman 2017	Breeder seed (kg)	TLS (kg)	Variety for Boro 2017-18	Breeder seed (kg)	TLS (kg)
BR23	730	1123	BR3	-	200
BRRI dhan34	2654	1629	BRRI dhan26	7500	2000
BRRI dhan41	750	160	BRRI dhan28	7000	1500
BRRI dhan44	633	130	BRRI dhan29	5500	600
BRRI dhan49	-	119	BRRI dhan47	1000	3000
BRRI dhan52	1875	737	BRRI dhan58	-	1500
BRRI dhan62*	2400	239	BRRI dhan67	3000	2000
BRRI dhan71*	700	-	BRRI dhan74	3000	100
BRRI dhan72*	600	518			
BRRI dhan76	1304	258			
BRRI dhan77	1115	103			
Total	12761	5016		27000	10900

*Produced in Boro 2017-18.

BRRI RS, Bhanga

SUMMARY

Through field RGA 2,605 F_3 progenies were maintained during T. Aman 2017 at BRRI RS, Bhanga in case of 'Breeding for developing high yielding rice varieties for single Boro cropping pattern'. The proposed line BR-SF(Rang)-PL1-B yielded 0.79 t/ha higher than the check variety BR11 with similar growth duration in T. Aman 2017. During Boro 2017-18, the promising proposed lines were BR(Bio)9786-BC_2-59-1-2 in case of long duration and BRRI dhan29-SC3-28-16-10-8-HR1(Com) in case of short duration.

Monibandhobi genotype could not out-yield the standard check variety BRRI dhan46 in RYT, T. Aman 2017. Among RYTs during Boro 2017-18, the promising lines were: IR09A235 in RYT-1 (FBR-1), the lines BR (Bio) 9777-26-4-3 and BR (Bio) 9777-118-6-4 in of RYT-2 (FBR-2), Shampakatari (Shingra-Natore) and BR9207-45-2-2 in RYT (PQR), the lines BR8634-23-1-1-BHA-10, BR8269-60-2-HR-2-1-1-BHA-2, BR8634-23-1-1-BHA-1 and IR101762-1-1-1 in RYT-4 (ZER-1). None was found outstanding line in case of advanced yield trial.

Among short duration Aman varieties, BRRI hybrid dhan4 produced the highest yield (4.12 t/ha) and BRRI dhan54 gave the highest grain yield (5.05 t/ha) in medium duration Aman varieties. Among long duration Aman varieties, BR11 gave the highest grain yield (3.72 t/ha). Among short duration Boro varieties, BRRI hybrid dhan3 yielded the highest (7.29 t/ha), while for long duration Boro varieties BR15 gave the highest grain yield (8.64 t/ha) in case of stability analysis.

In nitrogen and potassium management on growth and yield of short duration T. Aman rice in BRRI dhan71 and BRRI dhan75, the highest grain yield was obtained from N (1/3rd at basal +1/3rd at 15 DAT+ 1/3rd at 30 DAT) + K as basal (BRRI recommended) practice. In nitrogen management on growth and yield of BRRI hybrid dhan5 in Boro season the highest yield was obtained from N @ 124 kg/ha (8.06 t/ha) followed by USG treated plot (8.02 t/ha) and N @ 111 kg/ha (7.98 t/ha).

In identification of potential rice variety in Jute-Relay Aman-Onion cropping pattern under shallow deep water rice ecosystem, the highest REY (Rice equivalent yield) was obtained from BRRI dhan75 (21.47 t/ha), followed by BRRI dhan72 (20.46 t/ha) and BRRI dhan39 (20.45 t/ha).

Under demonstration during T. Aman 2017 in Faridpur district, mean grain yields with growth duration were: 5.28 t/ha with 126 days for BRRI dhan71, 5.54 t/ha with 132 days for BRRI dhan72 and 5.05 t/ha with 123 days for BRRI dhan75; while mean grain yield of BRRI hybrid dhan5 was 9.11 t/ha with growth duration of 144 days in Gopalganj district during Boro 2017-18.

The highest grain yield with growth duration in different locations were obtained as follows: 8.18 t/ha with 150 days in BRRI dhan58 at Goalando, Rajbari; 10.08 t/ha with 148 days in BRRI dhan74 at Bhanga, Faridpur; 8.03 t/ha with 147 days in BRRI dhan63 at Mukshudpur, Gopalganj; 8.65 t/ha with 149 days in BRRI dhan74 at Kalkini, Madaripur and 9.83 t/ha with 147 days in BRRI dhan74 at Shariatpur sadar, Shariatpur.

BRRI RS, Bhanga farm produced about 30.2 tons of seeds of which about 13.00 tons of breeder seed of BRRI dhan28 and BRRI dhan29 and the rest were TLS during Boro 2017-18 season. Three hundred and sixty farmers were trained on modern rice production technologies by BRRI RS, Bhanga during July 2017 to June 2018.

VARIETY DEVELOPMENT

In case of 'Breeding for developing high yielding rice varieties for single Boro cropping pattern' 17,102 plants of F_3 generation were grown during T. Aman 2017 at BRRI RS, Bhanga following field RGA and 2,605 F_3 progenies were maintained by collecting single panicle from each plant (Table 1).

PVT- RLR (T. Aman). The proposed line BR-SF(Rang)-PL1-B yielded 0.79 t/ha higher than the check variety BR11 with similar growth duration in T. Aman 2017. The same line produced almost similar grain yield than the check variety BRRI dhan49 with ten days longer growth duration (Table 2).

PVT- long duration (Biotechnology, Boro). BR(Bio)9786-BC_2-59-1-2 produced higher than the check variety BRRI dhan29 with five days earlier growth duration (Table 3).

PVT- FBR (Boro). The proposed line BRRI dhan29-SC3-28-16-10-8-HR1(Com) out-yielded

Table 1. List of F_3 progenies, breeding for developing high yielding rice varieties for single Boro cropping pattern, T. Aman 2017 at BRRI RS, Bhanga.

BRBh#	Parent	No. of progenie
BRBh06	BRRI dhan58/IR35238-B-1-1-P19	675
BRBh07	BRRI dhan63/BR7812-19-1-6-1-P3	1025
BRBh08	BRRI dhan29/IR35238-B-1-1-P19	455
BRBh09	BRRI dhan29/BR7812-19-1-6-1-P3	450
Total		2605

Table 2. Performance of proposed lines under PVT- RLR during T. Aman 2017 at Barra, Bhanga, Faridpur.

Entry	Growth duration (day)	Yield (t/ha)
BR-RS(Raj)-PL4-B	137	3.94
BR-SF(Rang)-PL1-B	139	5.05
BR11 (ck)	139	4.26
BRRI dhan49 (ck)	129	5.02

DS: 6 Jul 2017, DT: 5 Aug 2017.

Table 3. Performance of proposed line under PVT long duration (Biotechnology) during Boro 2017-18 at Purbo Sadardi, Bhanga, Faridpur.

Entry	Growth duration (day)	Yield (t/ha)
BR(Bio)9786-BC_2-59-1-2	154	10.74
BRRI dhan29 (ck)	159	10.59

DS: 8 Dec 2017, DT: 25 Jan 2018.

the check variety BRRI dhan28 by about 0.63 t/ha with two days earlier growth duration (Table 4).

RYT (Monibandhobi genotype). Monibandhobi genotype yielded significantly lower than the standard check variety BRRI dhan46, but produced identical yield than the local check variety Rajasail with almost similar growth duration (Table 5).

RYT (Boro)-favourable Boro. Among ten advanced breeding lines of RYT-1 (FBR-1), the line IR99090-B-B-62 produced significantly similar yield to the check variety BRRI dhan58 with four

Table 4. Performance of proposed line under PVT (FBR) during Boro 2017-18 at Purbo Sadardi, Bhanga, Faridpur.

Entry	Growth duration (day)	Yield (t/ha)
BRRI dhan29-SC3-28-16-10-8-HR1 (Com)	140	8.89
BRRI dhan28 (ck)	142	8.26

DS: 8 Dec 2017, DT: 25 Jan 2018.

days earlier growth duration (Table 6). The line IR09A235 out-yielded significantly the check variety BRRI dhan28 by about 0.65 t/ha with five days longer growth duration. Among four advanced breeding lines of RYT-2 (FBR-2), the lines BR(Bio)9777-26-4-3 and BR (Bio) 9777-118-6-4 yielded about 0.7 t/ha higher than the check variety BRRI dhan58 with three days longer growth duration (Table 7).

RYT (Premium quality rice). Shampakatari (Shingra-Natore) produced about 0.32 t/ha higher significant grain yield than the check variety BRRI dhan63 with nine days longer growth duration (Table 8). Among three advanced breeding lines BR9207-45-2-2 significantly out-yielded the check variety BRRI dhan50 by about 0.5 t/ha having almost similar growth duration.

RYT (Zinc enriched rice). Among ten advanced breeding lines of RYT-4 (ZER-1), BR8634-23-1-1-BHA-10 produced higher grain yield (6.61 t/ha) than the check BRRI dhan29 (6.48 t/ha) with 16 days earlier growth duration (Table 9). The lines BR8269-60-2-HR-2-1-1-BHA-2, BR8634-23-1-1-BHA-1 and IR101762-1-1-1 yielded higher than the check variety BRRI dhan74 having about 2-3 days longer growth duration. None of the entries out-yielded the check BRRI dhan74 in RYT-5 (ZER-2) (Table 10). In RYT-6 (ZER-3), BRRI dhan62 could not out-yield the check BRRI dhan28 (Table 11).

Table 5. Grain yield and ancillary characters of Monibandhobi genotype with checks under RYT, during T. Aman, 2017 at BRRI RS, Bhanga.

Entry	Plant height (cm)	No. of tiller/hill	No. of panicle/hill	Growth duration	Yield (t/ha)
Monibandhobi	121	13	12	129	1.96
Rajasail (local check)	131	13	12	127	2.24
BRRI dhan46 (Std. check)	121	14	13	129	3.14
CV(%)	1.3	6.0	5.7	0.6	6.0
LSD (0.05)	3.77	1.77	1.51	1.85	0.33

DS: 6 Aug 2017, DT: 27 Aug 2017.

Table 6. Grain yield and ancillary characters of RYT-1, development of rice varieties for favourable Boro environment (FBR-1) in Boro, 2017-18 at BRRI RS, Bhanga.

Entry	Plant height (cm)	No. of tiller/m^2	No. of panicle/m^2	Growth duration (day)	Yield (t/ha)
IR06N220	95.9	268	228	157	4.94
IR99061-B-B-7	87.4	287	245	146	5.09
IR12A288	90.6	282	242	146	5.49
IR09A235	91.2	282	237	145	5.69
IR14N126	86.4	273	232	145	5.32
IR99056-B-B-15	97.3	265	232	144	5.23
IR99090-B-B-62	94.6	305	260	146	6.11
IR99092-B-B-91	101.7	258	227	151	5.98
IR14D111	89.1	292	250	146	5.25
BR8938-30-2-4-2-1	95.5	272	230	151	5.85
BRRI dhan28 (ck)	83.9	243	197	140	5.04
BRRI dhan58 (ck)	88.6	283	248	150	6.07
CV (%)	2.8	6.0	5.4	0.5	4.8
LSD (0.05)	4.38	28.08	21.58	1.13	0.45

Dec 2017, DT: 5 Feb 2018.

Table 7. Grain yield and ancillary characters of RYT-2, development of rice varieties for favourable Boro environment (FBR-2) in Boro 2017-18 at BRRI RS, Bhanga.

Entry	Plant height (cm)	No. of tiller/m^2	No. of panicle/m^2	Growth duration (day)	Yield (t/ha)
BR(Bio)9777-26-4-3	93.7	302	287	157	5.94
BR(Bio)9777-106-7-4	89.8	292	292	154	5.30
BR(Bio)9777-113-12-5	96.3	285	263	160	5.26
BR(Bio)9777-118-6-4	90.5	285	263	157	5.92
BRRI dhan58 (ck)	81.9	257	238	154	5.23
CV (%)	3.3	6.5	8.1	0.8	3.5
LSD (0.05)	5.65	35.20	40.87	2.23	0.36

DS: 8 Dec 2017, DT: 7 Feb 2018.

Table 8. Grain yield and ancillary characters of RYT-3, development of premium quality rice (PQR), in Boro 2017-18 at BRRI RS, Bhanga.

Entry	Plant height (cm)	No. of tiller/m^2	No. of panicle/m^2	Growth duration (day)	Yield (t/ha)
BR8590-5-2-5-2-1	96.1	238	222	156	4.57
BR9207-45-2-2	96.7	328	302	156	5.13
BR8590-5-2-5-2-2	89.8	227	211	153	4.43
Dinazpur Minikat (Rangpur)	83.9	245	227	151	4.27
Shampakatari (Shingra-Natore)	81.5	258	235	155	5.55
BRRI dhan28 (ck)	86.2	330	298	146	4.08
BRRI dhan50 (ck)	76.1	288	263	157	4.62
BRRI dhan63 (ck)	73.9	277	258	146	5.23
CV (%)	3.7	8.4	9.0	0.8	3.4
LSD (0.05)	5.55	40.32	39.89	2.11	0.28

DS: 8 Dec 2017, DT: 7 Feb 2018.

Table 9. Grain yield and ancillary characters of RYT-4, zinc enriched rice (ZER-1), in Boro 2017-18 at BRRI RS, Bhanga.

Entry	Plant height (cm)	No. of tiller/m^2	No. of panicle/m^2	Growth duration (day)	Yield (t/ha)
BR8269-60-2-HR-2-1-1-BHA-2	85.1	248	210	145	6.07
BR8634-23-1-1-BHA-1	98.2	205	182	147	6.04
BR8634-23-1-1-BHA-10	104.3	240	212	142	6.61
BR8634-23-1-1-BHA-2	103.3	262	233	144	5.12
BR8634-23-1-1-BHA-3	99.8	227	198	147	5.32
BR8634-23-1-1-BHA-5	97.1	145	120	146	4.93
BR8634-23-1-1-BHA-6	98.2	218	188	147	5.08
IR101762-1-1-1	100.8	263	238	145	5.94
BR8634-23-1-1-BHA-7	92.9	260	225	148	5.11
BR8634-23-1-1-BHA-8	102.7	255	233	144	5.57
BRRI dhan28 (ck)	87.5	328	302	140	4.92
BRRI dhan29 (ck)	91.7	268	245	158	6.48
BRRI dhan74 (ck)	91.5	232	203	144	5.88
CV (%)	2.5	10.2	11.6	0.9	3.6
LSD (0.05)	4.06	41.69	41.87	2.14	0.34

DS: 11 Dec 2017, DT: 5 Feb 2018.

Table 10. Grain yield and ancillary characters of RYT-5, zinc enriched rice (ZER-2), in Boro 2017-18 at BRRI RS, Bhanga.

Entry	Plant height (cm)	No. of tiller/m^2	No. of panicle/m^2	Growth duration (day)	Yield (t/ha)
BR7528-2R-19-16-RILL-1	95.4	162	147	149	5.13
BR7528-2R-19-16-RILL-15	99.9	188	170	152	5.12
BR7528-2R-19-16-RILL-18	105.7	200	185	146	5.30
BRRI dhan28 (ck)	87.1	345	277	140	4.95
BRRI dhan74 (ck)	87.7	290	258	144	5.68
CV (%)	3.4	6.4	6.4	0.6	1.2
LSD (0.05)	6.06	28.58	25.14	1.68	0.12

DS: 11 Dec 2017, DT: 5 Feb 2018.

Table 11. Grain yield and ancillary characters of RYT-6, zinc enriched rice (ZER-3), in Boro 2016-17 at BRRI RS, Bhanga.

Entry	Plant height (cm)	No. of tiller/m^2	No. of panicle/m^2	Growth duration (day)	Yield (t/ha)
BRRI dhan62	92.7	317	278	138	4.16
BRRI dhan28 (ck)	84.6	315	270	140	4.78
CV (%)	0.6	9.7	8.7	0.3	3.8
LSD (0.05)	1.72	105.61	82.22	1.41	0.58

DS: 11 Dec 2017, DT: 6 Feb 2018.

Advanced yield trial (AYT). Among the two advanced breeding lines, the line BRRI dhan29-SC3-8-HR1 produced almost similar grain yield like the check variety BRRI dhan29 with similar growth duration. Whereas the advanced line BR8643-6-4- could not out-yield the check variety BRRI dhan58 with similar growth duration (Table 12).

SOCIO ECONOMICS

Stability analysis. Among short duration Aman varieties, BRRI hybrid dhan4 yielded the highest (4.12 t/ha) followed by BRRI dhan57 (4.0 t/ha) and BRRI dhan56 (3.99 t/ha). BRRI dhan54 gave the highest grain yield (5.05 t/ha) among medium

Table 12. Grain yield and ancillary characters of advance yield trial (AYT) during Boro 2017-18 in the farmers' fields of greater Faridpur region under BRRI RS, Bhanga.

Entry	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR8643-6-4-4	106.5	152	8.41
BRRI dhan29-SC3-8-HR1	103.4	160	9.01
BRRI dhan29 (ck)	101.3	161	9.07
BRRI dhan58 (ck)	102.9	151	8.77
CV (%)	1.6	0.7	4.1
LSD (0.05)	1.49	1.0	0.33

duration Aman varieties followed by BRRI dhan32 (4.64 t/ha) and BR25 (4.47 t/ha). Among long duration Aman varieties, BR11 gave the highest grain yield (3.72 t/ha) followed by BRRI dhan31 and BRRI dhan40 (3.29 t/ha). Low yield was recorded due to rat damage. Among short duration Boro varieties, BRRI hybrid dhan3 yielded high (7.29 t/ha) followed by BRRI hybrid dhan5 (6.86 t/ha) and BR1 (6.07 t/ha). In Boro season among long duration varieties, BR15 gave the highest grain yield (8.64 t/ha) followed by BR16 (7.46 t/ha) and BRRI dhan29 (7.18 t/ha).

CROP-SOIL-WATER MANAGEMENT

In nitrogen and potassium management on growth and yield of short duration T. Aman rice the highest grain yield was obtained from T_1 (4.65 t/ha) followed by T_2 (4.38 t/ha) and T_3 (4.32 t/ha) treatment in case of BRRI dhan71. There was no significant difference among the treatments in case of sterility percentage and grain yield. In case of BRRI dhan75, the highest yield was obtained from T_1 (4.57 t/ha) followed by T_2 (4.10 t/ha) and 4.06 (4.06 t/ha) treatment. But, there was no significant difference among the treatments in case of grains/panicle and grain yield.

In nitrogen management on growth and yield of BRRI hybrid dhan5 during Boro season, the highest yield was obtained from N @ 124 kg/ha (8.06 t/ha), followed by USG treated plot (8.02 t/ha) and N @ 111 kg/ha (7.98 t/ha). The crop yield was the lowest in control plot (7.66 t/ha) among all the treatments.

FARMING SYSTEMS RESEARCH

In identification of potential rice variety in Jute-Relay Aman-Onion cropping pattern under shallow deep water rice ecosystem, the highest REY (Rice equivalent yield) was obtained from BRRI dhan75 (21.47 t/ha). It was followed by BRRI dhan72 (20.46 t/ha), BRRI dhan39 (20.45 t/ha) and BRRI dhan71 (19.67 t/ha) which were statistically similar but different from BRRI dhan70 (17.52 t/ha) and BRRI dhan34 (16.73 t/ha).

TECHNOLOGY DISSEMINATION

Demonstrations of modern rice varieties during T. Aman 2017 and Boro 2017-18 were done in Faridpur and Gopalganj districts respectively under BRRI RS, Bhanga, Faridpur with the financial assistance of BRRI-SPIRA project. Mean grain yields with growth duration were: 5.28 t/ha with 126 days for BRRI dhan71, 5.54 t/ha with 132 days for BRRI dhan72 and 5.05 t/ha with 123 days for BRRI dhan75. In Boro 2017-18, mean grain yield of BRRI hybrid dhan5 was 9.11 t/ha with growth duration of 144 days. At the maturity of the crop, one field day was arranged with the help of DAE. During field day, the trial farmers shared their experience to neighbouring farmers, which made them interested to these varieties to cultivate those in their own plots and thereby a demand for quality seeds was generated.

Similarly, ten varietal replacement through head to head trials were conducted in five upazilas of five districts namely Goalondo of Rajbari, Bhanga of Faridpur, Muksudpur of Gopalganj, Kalkini of Madaripur, Shariatpur sadar of Shariatpur under BRRI RS, Bhanga with the financial assistance of

BRRI-TRB project. Five BRRI varieties like BRRI dhan28, BRRI dhan 58, BRRI dhan 63, BRRI dhan 67 and BRRI dhan 74 were included in each one bigha trial. The highest grain yield with growth duration in different locations were as follows: 8.18 t/ha with 150 days in BRRI dhan58 at Goalando, Rajbari; 10.08 t/ha with 148 days in BRRI dhan74 at Bhanga, Faridpur; 8.03 t/ha with 147 days in BRRI dhan63 at Mukshudpur, Gopalganj; 8.65 t/ha with 149 days in BRRI dhan74 at Kalkini, Madaripur and 9.83 t/ha with 147 days in BRRI dhan74 at Shariatpur sadar, Shariatpur. The trial farmers stored their seeds according to their choice for growing in the next Boro season.

BRRI RS, Bhanga farm produced about 30.2 tons of seeds of which about 13.0 tons of breeder seed of BRRI dhan28 and BRRI dhan29 and the rest about 19.2 were TLS of short duration Aman varieties e.g. BRRI dhan39, BRRI dhan71, BRRI dhan72, BRRI dhan75 and BRRI hybrid dhan4 as well as Boro varieties of BRRI dhan28, BRRI dhan29, BRRI dhan50, BRRI dhan58, BRRI dhan63, BRRI dhan67, BRRI dhan81 and BRRI hybrid dhan3 and 5 during Boro 2017-18 season.

Three hundred and sixty farmers of greater Faridpur region were trained on modern rice production technologies through 11 training programmes organized by BRRI RS, Bhanga with the cooperation of DAE under the financial assistance of GOB and BRRI-SPIRA project.

BRRI RS, Cumilla

SUMMARY

Altogether 67 crosses were made and 47 crosses were confirmed during T. Aman and Boro at BRRI Regional Station. A total of 909, 451, 320, 214 and 25 plant progenies with desirable plant type and high yield potential were selected from F_2, F_3, F_4, F_5 and F_6 generations, respectively. One hundred thirty-one homozygous lines were bulked under the varietal development programme. Sixty-four genotypes were selected from observational trial (OT) having desirable characters and high yield potential. Thirteen and 15, 25, 10, 10, 10, 15, 10, 16 and 11 genotypes with diverse genetic background having earliness, good grain type, compact panicle, lodging resistance, disease and insect resistance and high yield potential were selected from IRLON, IIRON, MAGIC INDICA 2014 (First generation Module 1), MAGIC INDICA 2014 (First generation Module 2), MAGIC PLUS 2014 (First generation Module 1), MAGIC PLUS 2014 (First generation Module 2), MAGIC GLOBAL 2015 (Second generation Module 1), MAGIC GLOBAL 2015 (Second generation Module 2), MAGIC INDICA 2015 (Second generation Module 1), MAGIC INDICA 2015 (Second generation Module 2), respectively, during T. Aman and Boro season. A total of 110 advanced lines were selected from different yield trials in T. Aus, T. Aman and Boro season during 2017-18.

BR7718-55-1-3 released as BRRI dhan85 for T. Aus season and showed average yield of 4.29 t/ha with 107 days growth duration over nine locations in farmer's field. Moreover, this variety is characterized with long slender grain, 25.7% amylose, high lodging tolerant capacity and capability to withstand in stagnant field from tillering to harvesting. Besides, it gave 71.4% milling outturn, 3.2 L/B ratio, 22.5 gm 1000 wt and 3.6 imbibitions ratio.

In T. Aman 2017, BRRI dhan57, BRRI dhan62 and BRRI dhan75 produced 4.33, 4.27 and 5.21 t/ha grain yield respectively with added NPKZnS fertilizers while in Boro 2017-18, BRRI dhan58, BRRI dhan69 and BRRI dhan75 produced 6.79, 8.53 and 8.64 t/ha grain yield respectively with added NPKZnS fertilizers. Omission of N from complete treatment had significant effect on grain and straw yield of tested varieties both in T. Aman and Boro season.

Combination of bio-organic fertilizer (2 t/ha) with N (70%) + KS (100%) of BRRI recommended dose was found as the best for grain and straw yield on BRRI dhan58. Eighty kg nitrogen ha^{-1} appeared as the best for grain yield and straw yield on BRRI dhan75 in T. Aman season. In Boro season, 120 kg/ha N showed the highest grain yield on BRRI dhan28.

Disease incidence of bacterial blight, sheath blight, blast, false smut and brown spot were 5-80, 5-80, 1-60, 0.1-20 and 10-60 % respectively during T. Aman 2017. Among the major diseases, bacterial blight and sheath blight was found in all the surveyed plots of Cumilla region. Neck blast infection was 44-89% in BRRI dhan28 at farmers practice compared to BRRI practices (8-19%) at Barura location.

About, 48 tons breeder seed of different BRRI varieties of T. Aman and Boro were produced and sent to GRS division, BRRI HQ, Gazipur. Moreover, 8.5 tons of TLS seed of BRRI varieties were produced and sold to the farmers during 2017-18.

VARIETY DEVELOPMENT

T. Aus rice

In proposed variety trial (PVT) of BRRI RS, Cumilla during T. Aus 2017-18, BR7718-55-1-3 was evaluated by national seed board (NSB) in nine locations of Cumilla, Syllhet, Chattogram and hill regions. This line BR7718-55-1-3 was released as BRRI dhan85 for T. Aus season. This variety has 0.20 t/ha higher yield and three days lesser growth duration advantages than BRRI dhan48 (Table 1). Other important features are long slender grain, lodging tolerance and capability to withstand in water stagnant field from tillering to harvesting stage, 25.7% amylose content, 71.4% milling outturn, 3.2 L/B ratio, 22.5 gm 1000 wt and 3.6 imbibitions ratio.

Under TRB project, six entries viz 1, 7, 13, 14, 15 and 16 were selected from observational trial based on yield and growth duration (Table 2). Yield range of selected lines was 4.53-5.68 t/ha. Six and two lines were selected from PYT and RYT#1 respectively.

Table 1. Performance of proposed line in the proposed variety trial (PVT), T. Aus 2017, BRRI RS, Cumilla.

Location	Proposed variety/check			
	BR7718-55-1-3		BRRI dhan48 (ck)	
	Yield (t/ha)	GD (day)	Yield (t/ha)	GD (day)
Bakoi, Laksam, Cumilla	4.67	106	4.60	107
Cumilla (Chandina)	4.78	107	4.45	109
Adarsha Sadar, Cumilla	3.89	109	3.23	111
Jagatpur, Chandpur	3.95	108	3.58	111
Sailpur, B. Baria	4.20	104	4.20	107
Abirnagar, Laxmipur	4.14	106	3.90	109
Bailachori, Matiranga, Khagrachari	4.18	110	4.06	112
Sultanpur, Madhabpur. Sylhet	4.10	108	4.32	110
Chanpurbasti, Chunarughat, Sylhet	4.74	108	4.59	110
Mean	4.29	107	4.10	110

** BR7718-55-1-3 was released as BRRI dhan85 on 27 December 2017.

Table 2. List of selected genotypes along with agronomic characters from observational trial (OT) T. Aus 2017-18, BRRI RS, Cumilla.

Designation	PH (cm)	Panicle/m^2	Tiller/m^2	Yield (t/ha)	GD (day)
BR9829-46-3-2	99	273	320	5.54	120
BR9829-79-5-1	102	293	320	4.40	119
BR9829-62-2-1	104	253	267	4.22	119
BR9829-87-2-3	112	240	280	3.90	121
BR9029-37-2-1-3	108	247	273	3.78	120
BR9029-51-3-5-1	113	334	367	3.94	119
BR9029-51-3-7-1	118	273	300	4.67	122
BR9029-51-3-7-1	103	247	253	4.30	120
BR9029-51-3-8-2	104	280	307	3.87	115
BR8773-2-2-2-2	104	273	300	3.75	114
BR8774-4-1-2-1-1	107	300	327	2.89	114
BR8774-4-1-2-1-3	113	247	273	4.57	119
BR8774-4-1-2-2-3	109	233	247	5.68	119
BR8774-18-3-2-2-4	111	233	240	5.08	118
BR8774-18-3-2-2-5	108	293	320	4.53	120
BR 9011-47-3-5	97	334	360	4.90	118
BR26 (ck)*	105	313	340	5.17	116
BRRI dhan48 (ck)*	101	334	360	4.80	113

DSk: 23 Apr 2017, DT: 22 May 2017 *Data from four replications.

T. Aman rice

Based on desirable traits i.e. high yield, earliness, grain type, panicle type, strong stem, 49 crosses were made and 21 crosses were confirmed. A total of 257 plants were selected from F_2 population. Moreover, 439 plants comprising 196 F_3, 61 F_4, 157 F_5 and 25 F_6 progenies were selected based on aforesaid desirable traits.

TRB project. Seven lines were selected based on yield (4.06-5.06 t/ha) from observational trial. From PYT-BB, BR10388-24-3-3 was selected due to superior yield (4.27 t/ha) than check varieties (2.53-3.98 t/ha). Five lines viz IR94391-131-358-19-B-1-1-1, IR05N412, IR11N313, IR14L158 and IR14L601 were selected based on high yield (3.50 -5.50 t/ha) compared with checks (3.90-4.55 t/ha) from PYT-drought. IR95815-4-1-1-3 was selected from RYT-drought (Table 3). BR9043-11-3-2-2 was selected from RYT-1 (RLR) and two lines namely, BR9123-22-4-2-1 and BR9123-23-2-2-5 were selected from RYT-2 (RLR).

Among the RYT from BRRI HQ, 1, 3, 2, 3, 1 and 1 lines were selected from RYT- 1(PQR), RYT-1 (RLR), RYT (Biotech), RYT (Insect), RYT-ZER and SYT-GSR, respectively for further evaluation.

Table 3. Yield and agronomic performances of breeding materials from regional yield trial (RYT, Drought), T. Aman 17-18, BRRI RS, Cumilla.

Designation	SH (cm)	PH (cm)	Panicle/m^2	Tiller/m^2	GD (day)	Yield (t/ha)
IR67761-53-1-1	45	107	283	314	123	3.00
IR88865-18-1-5-1	35	107	293	327	122	3.58
IR88965-38-2-2-4	40	109	283	313	121	3.57
IR88965-39-1-6-4	36	107	293	321	124	3.99
IR93807-44-2-1-1	29	106	291	324	123	3.41
IR95817-14-1-1-2	36	110	294	327	121	3.55
IR95817-5-1-1-1	37	110	293	326	127	3.26
IR93856-23-1-1-1	39	105	283	312	120	2.93
IR95815-4-1-1-3	36	103	297	328	126	4.72
BRRI dhan 56 (ck)	37	110	308	337	122	4.21
BRRI dhan 66 (ck)	30	112	283	323	125	4.47
BRRI dhan 71 (ck)	28	112	282	318	123	3.32
LSD (5%)	2.20	5.69	30.95	26.91	1.21	0.65

DSk: 11 Jul 2017, D/T:10 Aug 2017.

Different breeding trials of BRRI RS, Cumilla viz OYT-Com, AYT (Water stagnation-1), AYT (Water stagnation-2), AYT (Water stagnation-3), PYT-2 (Com), PYT-3 (Com), PYT-4 (Com), AYT-1 (RLR), AYT-2 (Com), AYT-4 (RLR), AYT-5 (RLR) and AYT-6 (PQR) along with other INGER trials need to be reevaluated during T. Aman 2018-19 due to submerge at seedbed (4-5 days) and main field (7-10 days). Moreover, all these trials faced severe water stagnant situation due to heavy rainfall during harvesting time.

Boro

Under TRB project, BR9943-4-2-3-2 and BR9943-7-2-3-1 were selected from observational trial for their high yield (8.23-9.13 t/ha). Considering the yield performance (7.23 t/ha) BR 9208-8-1-1-1 was selected from AYT-FB. BR 9945-75-1-1, BR 8904-28-2-3-2-2-2 and BR 8905-17-2-3-3-1-1 were selected from PYT-FB for higher yield (6.28-7.78 t/ha). Considering the yield (6.40-6.45 t/ha) and growth duration (147 days), BR9647-7-1-1 and BR9647-8-1-2 were selected. Two entries, BR 9650-108-2-1 and BR 9650-108-2-3 were selected for high yield capacity (7.34-8.03 t/ha).

BRRI HQ. In RYT-FBR, IR99061-B-B-7 and IR14N126 were selected on the basis of high yield (6.28-6.48 t/ha) and growth duration (145-146 days). All entries were selected from RYT-Biotech for high yield (7.60-8.50 t/ha) and growth duration (149-155 days) as compared to BRRI dhan58 (6.26 t/ha and 154 days). HHZ15-DT7-SAL4-SAL1 (8.95 t/ha and 154 days) was selected from PVS-GSR. In RYT-PQR, DINAZPUR MINIKET and SHAMPAKATARI were selected for yield (6.30-6.80 t/ha). Considering yield performance (7.60 t/ha), BR8634-23-1-1-BHA-10 was selected from RYT-1 (ZER). None of the entries were selected from RYT-2 (ZER), RYT-3 (ZER), YMT, RYT-Insect and RYT-BB due to low yield performance and longer growth duration as compared to the checks.

BRRI RS, Cumilla breeding programme. Considering the noticeable traits namely, high yield, earliness, grain type, panicle type, strong stem, 18 crosses were made and 26 crosses were confirmed. A total of 652 plants were selected from F_2 population. Moreover, 571 plants comprising 255 F_3, 259 F_4 and 57 F_5 25 progenies were selected based on desirable traits. From the observational trial-Com, 150 lines were tested along with 10 check varieties viz, BRRI dhan28, BRRI dhan29, BRRI dhan48, BRRI dhan50, BRRI dhan57, BRRI dhan58, BRRI dhan60, BRRI dhan62, BRRI dhan63, BRRI dhan69 and BRRI dhan75. Forty-two lines were selected having good phenotypic acceptability and yield potential and earliness. Promising entries were BRC428-15-1-2 (9.08 t/ha), BRC365-23-2-2-2-2 (8.97 t/ha), BRC365-19-3-1-2-2 (8.95 t/ha), BRC430-19-1-1 (8.95), BRC428-3-1-2 (8.89 t/ha), BRC427-9-1-3 (8.71 t/ha) and BRC426-13-1-1 (8.50 t/ha) with the growth duration of 147-153 days. From PYT-Com-SD, all entries were selected for high yield (6.19-7.66 t/ha) and early growth duration (141-146 days) as compared with checks (6.15- 6.72 t/ha and 145-149 days) (Table 4). In PYT-Com-MD, 16 entries were selected from 26 entries on basis of high yield (6.38-8.01 t/ha). From PYT-Com-LD, BRC325-11-1-1-1, BRC335-1-3-2-1-1, BRC335-1-3-2-2-1 and BRC335-4-1-1-2-1 were selected for high yield (7.27-8.14 t/ha). Six entries were selected from PYT-IIRON. On the basis of high yield, four and 20 entries were selected from SYT-1 (IIRON) and SYT-2 (MST) respectively. SYT-3 (Super yielder) trial is needed to be further evaluated for considerable damage by heavy rain along with water stagnant situation. Five entries namely, BRC297-15-1-1-1, BRC302-1-4-4-4, BRC302-2-1-2-1, BRC269-15-1-1-3 and BRC302-18-1-2-1 were selected from AYT-Com on basis of high yield (6.29-6.66 t/ha) as compared with checks (4.72-6.46 t/ha) (Table 5). Three entries were selected from AYT-1 (IIRON).

PEST MANAGEMENT

Survey and monitoring of rice diseases in selected areas

Disease survey was conducted in three upazilas of Cumilla district during T. Aman, 2017 and Boro 2017-18 to assess the present status of different rice diseases under various climatic environments. Disease incidence and disease severity data of major rice diseases were recorded. Different rice diseases such as neck blast, bacterial blight, sheath blight, brown spot were found in different rice varieties in the surveyed areas. On average, disease incidence of bacterial blight, sheath blight, blast, false smut and brown spot were 5-80, 5-80, 1-60, 0.1-20 and 10-60% respectively during T. Aman 2017. Among the major diseases, bacterial blight and sheath blight disease was found in all the surveyed plots in the region. Neck blast disease was observed high in aromatic rice BRRI dhan34 in one location of sadar Dakkhin only. In Boro 2017-18, the disease incidence of neck blast, bacterial blight, sheath blight and brown spot were 1-70, 5-70, 10-60 and 10-100% respectively. This year blast disease was found not so devastating compared to that of the last three years because of increasing awareness of the campaign blast disease management and prevention by BRRI scientists along with DAE personnel.

Integrated management of blast disease for enhancing rice production in relation to climate change in Cumilla region

A total of seven field demonstrations on rice blast disease management following BRRI and farmer practices were conducted in the selected blast prone areas of three upazilas in Cumilla district. Five kg of MoP fertilizer per bigha was applied at the last top dress of urea followed by keeping water in the field along with two times application of fungicide Trooper (Tricyclazole) @ 500 g/ha at late booting stage in the morning and flowering stage in the evening as preventive measures. The practices those farmers locally adopted were treated as farmers practice (FP). Neck blast disease obtained severe 44-

Table 4. Yield and agronomic performances of breeding materials from preliminary yield trial (PYT)- Com-short duration, Boro 17-18, BRRI RS, Cumilla.

SN	Designation	PH (cm)	GD (day)	Yield (t/ha)
1	BRC366-1-1-2-2	91	146	6.44
2	BRC333-2-2-1-1-2	98	145	6.19
3	BRC333-2-2-1-2-1	92	145	7.66
4	BRC333-2-2-1-3-2	97	144	7.12
5	BRC333-2-2-1-3-3	93	144	6.21
6	BRC344-1-1-1-1-1	109	141	6.81
7	BRC344-3-1-2-1-2	121	142	6.82
8	BRC344-4-1-1-1-3	97	143	6.15
9	BRC345-5-2-2-1-1	110	145	7.31
10	BRC345-5-2-2-1-2	114	144	6.44
11	BRRI dhan28 (ck)	93	145	6.15
12	BRRI dhan58 (ck)	90	149	6.72
13	BRRI dhan63 (ck)	84	147	6.14

Sk: 26 Nov 2017, D/T: 9 Jan 2018.

Table 5. Yield and agronomic performances of breeding materials from advanced yield trial (AYT)- Com, Boro 2017-18, BRRI RS, Cumilla.

Designation	PH (cm)	GD (day)	Yield (t/ha)
BRC297-15-1-1-1	103	144	6.29
BRC302-1-4-4-4	108	146	6.47
BRC302-2-1-2-1	126	149	6.63
BRC269-15-1-1-3	105	148	6.47
BRC298-18-2-3	104	151	5.45
BRC319-6-1-1	118	151	4.91
BRC319-9-1-3	135	160	4.81
BRC302-2-1-2-2	116	149	5.62
BRC302-18-1-2-1	108	143	6.31
BRRI dhan28 (ck)	109	144	4.72
BRRI dhan58 (ck)	95	151	6.46
BRRI dhan69 (ck)	93	153	5.60
BRRI dhan63 (ck)	87	149	5.44

DSk: 28 Nov 2017, D/T:11 Jan 2018.

89% in BRRI dhan28 at farmers practice compared to BRRI practices (8-19%) at Barura location because, farmers did not use additional potash fertilizer as top dress and sprayed non-registered blast fungicides as well as inappropriate time of fungicide spray. Rice yield was saved up to 68% by preventive management of neck blast disease of rice in Barura location.

CROP-SOIL-WATER MANAGEMENT

Long-term effects of some macro and micronutrients on yield and nutrition of upland rice

Trial was conducted at BRRI RS, Cumilla (Grey Terrace Soil, AEZ 15) during T. Aman 2017 for determining N, P, K, Zn and S requirement of some BRRI released rice varieties viz BRRI dhan57 and BRRI dhan62 and BRRI dhan75. 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), T_6= NPKZnS (STB) were imposed in the subplots and rice verities in the main plots following split-plot design with three replications. Fertilizer doses were NPKZnS @ 110-15-42-9-1.5 kg/ha in T. Aman and 145-31-77-13-1.5 kg/ha in Boro. Twenty-eight and forty-day-old seedlings were used in T. Aman and Boro season respectively. Standard management practices were followed for growing the crops. The nutrient requirement of the rice genotypes were calculated assuming that 18 kg N, 3 kg P, 20 kg K, 1.5 kg S and 0.15 kg Zn are required per ton grain yield and recovery of applied fertilizer nutrient by rice plant is 30% N, 20% P, 50% K, 12% S and 6% Zn. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis.

In T. Aman 2017, BRRI dhan57, BRRI dhan62 and BRRI dhan75 produced 4.33, 4.27 and 5.21 t/ha grain yield respectively with added NPKZnS fertilizers (Table 6). Omission of N from complete treatment had a significant effect on grain and straw yield of tested varieties (Tables 6 and 7). In case of BRRI dhan57, grain yield was drastically reduced due to omission of potassium (Tables 6 and 8).

In Boro 2017-18, BRRI dhan58, BRRI dhan69 and BRRI dhan75 produced 6.79, 8.53 and 8.64 t/ha grain yield respectively with added NPKZnS fertilizers (Table 9). Omission of N from complete treatment had significant effect on grain and straw yield of tested varieties (Tables 9, 10 and 11).

Effect of N rates on the yield of BRRI dhan75

The trial was undertaken to determine the N response behaviour of BRRI dhan75 in T. Aman at BRRI, RS Cumilla for Cumilla region. Thirty-one-day-old

Table 6. Effect of N, P, K, Zn and S and their omission on grain yield of BRRI released T. Aman varieties, 2017, BRRI RS, Cumilla.

Treatment	Grain yield (t/ha)		
	BRRI dhan57	BRRI dhan62	BRRI dhan75
PKSZn (-N)	1.98	2.42	2.86
NKSZn (-P)	4.17	4.19	5.17
NPSZn (-K)	3.36	3.90	5.07
NPKZn(-S)	3.62	4.22	5.47
NPKS(-Zn)	3.83	4.32	4.86
NPKZnS	4.33	4.27	5.21
LSD (0.05)		0.55	
CV (%)		8.33	

2017; DT: 5 Aug 2017.

Table 7. Effect of N, P, K, Zn and S and their omission on straw BRRI released varieties, T Aman 2016-17, BRRI RS, Cumilla.

Treatment	Straw yield (t/ha)		
	BRRI dhan57	BRRI dhan62	BRRI dhan75
PKSZn (-N)	3.52	4.01	4.62
NKSZn (-P)	5.02	5.01	7.21
NPSZn (-K)	4.07	5.10	6.89
NPKZn(-S)	4.45	5.72	7.59
NPKS(-Zn)	5.70	6.68	7.33
NPKZnS	5.91	5.98	7.17
LSD (0.05)		0.68	
CV (%)		10.65	

Table 8. Requirement of fertilizer N, P, K, Zn and S for observed yield of BRRI varieties by missing elements technique, BRRI RS farm, Cumilla, T. Aman 2017.

Varietiy	Nutrient requirement (kg/ha)					Average grain yield (t/ha)
	N	P	K	S	Zn	
BRRI dhan57	105	2.4	39	9	1.2	3.55b
BRRI dhan62	83	1.2	15	1	0.0	3.95a
BRRI dhan75	105	0.6	7	0	1.0	4.96a
Applied nutrients	110	15	42	9	1.5	

Table 9. Effect of N, P, K, Zn and S and their omission on grain yield of BRRI released varieties, Boro 2017-18, BRRI RS, Cumilla.

Treatment	Grain yield (t/ha)		
	BRRI dhan58	BRRI dhan69	BRRI dhan75
PKSZn (-N)	2.52	3.15	3.88
NKSZn (-P)	5.70	7.56	7.57
NPSZn (-K)	5.67	6.85	7.65
NPKZn(-S)	6.23	6.87	9.14
NPKS(-Zn)	6.39	6.93	8.59
NPKZnS	6.79	8.53	8.64
LSD (0.05)		0.53	
CV (%)		9.59	

DS: 25 Nov 2017; DT: 5 Jan 2018.

Table 10. Effect of N, P, K, Zn and S and their omission on straw BRRI released varieties, Boro 2017-18, BRRI.

Treatment	Straw yield (t/ha)		
	BRRI dhan58	BRRI dhan69	BRRI dhan75
PKSZn (-N)	3.06	4.12	4.69
NKSZn (-P)	6.79	8.57	8.71
NPSZn (-K)	6.59	7.49	8.37
NPKZn(-S)	6.36	7.79	8.76
NPKS(-Zn)	6.55	8.07	8.65
NPKZnS	7.10	8.24	8.27
LSD (0.05)		1.03	
CV (%)		9.81	

Table 11. Requirement of fertilizer N, P, K, Zn and S for observed yield of BRRI varieties by missing elements technique, Boro 2017-18, BRRI.

Variety	Nutrient requirement (kg/ha)					Average grain yield (t/ha)
	N	P	K	S	Zn	
BRRI dhan58	192	16	45	07	1.0	5.55c
BRRI dhan69	242	15	76	21	04	6.65b
BRRI dhan75	214	16	67	0	0.2	7.58a
Applied nutrients	145	31	77	13	1.5	

seedlings in T. Aman season were transplanted at 20 × 20 cm spacing. Six N doses (0, 40, 60, 80, 100 and 120 kg/ha) were used following RCB design with three replications. Nitrogen was applied in three splits i.e. 34% at basal, 33% at 25 DAT and rest 33% at seven days before PI stage. A blanked dose of P, K, S and Zn were applied as soil test based (STB) at the time of final land preparation. Standard management practices were followed for growing the crops. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis. Among the nitrogen doses, N_{80} produced the highest grain yield (Table 12). On the other hand, N_{120} produced the highest straw yield (Table 12).

Effect of N rates on the yield of BRRI dhan28

This investigation was undertaken to determine the N response behavior BRRI dhan28 at BRRI RS, Cumilla (AEZ-15, land type-MHL) during Boro 2017-18. Forty day-old seedlings were transplanted at 20 × 20-cm spacing. Six N doses (0, 40, 80, 120, 160 and 200 kg/ha) were used following RCB design with three replications. Nitrogen was applied in three splits i.e. 34% at basal, 33% at 25 DAT and the rest 33% at seven days before PI stage. A blanked dose of P, K, S and Zn were applied as soil test based (STB) at the time of final land preparation. Standard management practices were followed for growing the crops. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis. There were differences in the grain and straw yield of BRRI dhan28 for different treatments. Among the nitrogen doses, N_{120} produced the highest grain yield (Table 13). On the other hand, N_{160} produced the highest straw yield (Table 13).

Evaluation of bio-organic fertilizer in the soil plant system in BRRI RS, Cumilla

The trial was conducted at BRRI RS farm, Cumilla, (Grey Terrace Soil, AEZ 15) during Boro 2017-18 seasons for determining performances of bio-organic fertilizer on BRRI dhan58. Six fertilizer treatments viz. T_1 = Biofertilizer (2 t/ha), T_2 = NPKS (100%), T_3 = N (70%) +KS (100%) + Biofertilizer (2 t/ha), T_4 = N (70%) +PKS (100%), T_5 = NPKZnS (100%), and T_6 = Control were imposed in a randomized complete block design with three replications. Among the treatments, T_3 = N (70%) +KS (100%) + Bio fertilizer (2 t/ha) was the best for grain yield and straw yield on BRRI dhan58 (Table 14).

Table 12. Effects of N rates on the grain and straw yield (t/ha) of newly released BRRI dhan75 at BRRI, 2017.

N rate (kg/ha)	Grain yield (t/ha)	Straw yield (t/ha)
N_0	3.76b	4.94b
N_{40}	4.27ab	4.93b
N_{60}	4.16ab	6.05ab
N_{80}	4.55a	6.94a
N_{100}	4.03ab	7.13a
N_{120}	4.21ab	7.39a
$LSD_{0.05}$	0.55	1.03
% CV	4.66	8.07

DS: 8 Jul 2017; DT: 9 Aug 2017.

Table 13. Effects of N rates on the grain and straw yield (t/ha) of newly released BRRI dhan75 at BRRI, 2016-17.

N rate (kg/ha)	Grain yield (t/ha)	Straw yield (t/ha)
N_0	2.57c	3.71b
N_{40}	4.87b	5.59ab
N_{80}	5.72ab	6.50a
N_{120}	5.90a	6.27a
N_{160}	5.09ab	6.56a
N_{200}	5.27ab	6.51a
% CV	6.74	12.69

DS: 5 Dec 2017; DT:15 Jan 2018.

Table 14. Effects of treatments on the grain and straw yield (t/ha) of BRRI dhan58 Boro variety at BRRI, 2017-18.

N rate (kg/ha)	Grain yield (t/ha)	Straw yield (t/ha)
T1 = Bio fertilizer (2 t/ha)	6.58ab	7.73ab
T2 = NPKS (100%)	8.31ab	8.62ab
T3 = N (70%) +KS (100%) + Bio fertilizer (2 t/ha)	8.67a	8.95a
T4 = N (70%) +PKS (100%)	7.51ab	7.93ab
T5 = NPKZnS (100%)	7.82ab	8.43ab
T6 = Control	3.29c	3.46c
% CV	11.22	17.85

SOCIO-ECONOMICS AND POLICY

In Aman, among the 38 varieties, BR25 (4.86 t/ha) gave the highest yield followed by BRRI BRRI dhan32 (4.82 t/ha), BRRI dhan54 (4.65 t/ha), BRRI dhan73 (4.53 t/ha) and BRRI dhan75 (4.44 t/ha). Growth duration of these varieties ranged from 119-136 days. In Boro, among the 37 varieties considering the yield performance, the top five varieties were BRRI hybrid dhan5 (9.11 t/ha), BRRI hybrid dhan3

(8.59 t/ha), BRRI dhan58 (7.81 t/ha), BRRI dhan68 (7.80 t/ha) and BR3 (7.14 t/ha). Growth duration of these varieties ranged from 147-161 days.

TECHNOLOGY TRANSFER

Varietal replacement through head to head (HTH) trial during Boro 2017-18

Five newly released rice varieties were selected for HTH trial in 10 locations of Cumilla, Chandpur and B. Baria district having 33 decimal of land each to evaluate the adaptability of modern rice varieties at farmers' field. Ten field trials were conducted for the adaptability and replacement of newly released rice varieties with mega rice varieties like BRRI dhan28. Among the used rice varieties in this study, yield of BRRI dhan58 (upto 7.2 t/ha) and BRRI dhan74 (upto 8 t/ha) yielded highest compared to other rice varieties viz BRRI dhan28, BRRI dhan63 and BRRI dhan67. Farmers' preferred top yielder varieties viz BRRI dhan58 and BRRI dhan74 than the other varieties.

Block demonstration of newly released rice varieties during Aman and Boro 2017-18

Three block demonstrations were conducted using new rice varieties viz BRRI dhan70 and BRRI dhan75 during T. Aman 2017 and four block demonstrations established using new rice varieties BRRI dhan60, BRRI dhan63, BRRI dhan67, BRRI dhan74 and BRRI dhan75 during Boro 2017-18 were conducted in the farmers' field levels to investigate the performance and dissemination of newly released promising rice varieties at farmers' level. In T. Aman 2017, the yield of BRRI dhan70 and BRRI dhan75 was 5 and 5.3 t/ha respectively. In all the blocks, the highest yield was obtained from BRRI dhan75 ranged from 7.75 to 8.39 t/ha followed by BRRI dhan74 (6.94-7.63 t/ha) during Boro 2017-18 season. Demo farmers as well as neighbour farmers were also interested to cultivate BRRI dhan70 and BRRI dhan75 in Aman and BRRI dhan74 and BRRI dhan75 in Boro season.

Field demonstration of BRRI rice varieties

A total of 16 field demonstrations of BRRI dhan28, BRRI dhan58, BRRI dhan60, BRRI dhan63, BRRI dhan67, BRRI dhan74 and BRRI dhan75 were conducted in Cumilla, Chandpur and B. Baria districts during Boro 2017-18. Irrespective of location, BRRI dhan75 yielded the highest with the range of 7.50 to 8.29 t/ha followed by BRRI dhan74 (6.42-7.5 t/ha).

Training on integrated blast disease management and modern rice cultivation

Three training programmes about integrated management of blast disease for enhancing rice production in relation to climate change were conducted during Boro 2017-18 season three in upazilas (Muradnagar, Barura and Burichong) of Cumilla district funded by GOB. A total of 75 farmers as well as 15 SAAOs (extension personnel) participated and were able to understand about the devastating rice disease blast and its management practices through the training.

Ten GOB-funded and three BRRI-SPIRA project funded trainings were conducted on modern rice cultivation and dissemination of newly released rice varieties in Cumilla, Chandpur and B. Baria districts in 2017. A total of 420 farmers were trained who gained required knowledge about newly released rice varieties from these trainings.

Field days

One field day was conducted at Barura upazila in Cumilla district on the rice blast disease management and building up farmer's awareness on this devastating disease in presence of extension personnel funded by GOB project during Boro 2017-18. About 100 farmers participated on the field day. Farmers had much interested to participate and learn about the blast disease management. The rice farmers became well aware of the severity of the disease incidence and significantly reduced its effects and ultimately the yield was considerably increased by following BRRI practices compared to farmers' practices.

Seven field days were conducted on newly released BRRI varieties under block demonstration in Cumilla, Chandpur and B. Baria districts during Aman 2017 and Boro 2017-18 funded by BRRI-SPIRA project. About 700 farmers as well as extension personnel attended the field days. Most of the farmers expressed their interest to cultivate new rice varieties in their areas.

Seed production

In T. Aman 2017 and Boro 2017-18, a total of 48.24 tons of breeder seeds of different BRRI varieties were produced and sent to GRS Division, BRRI Gazipur. Moreover, 8.5 tons of TLS seed of BRRI varieties were produced and sold to the farmers.

BRRI RS, Habiganj

SUMMARY

BR9011-19-1-2 produced significantly higher yield with two days longer growth duration than the check BRRI dhan48 in T. Aus 2017.

The genotype BR8548-8-22-5-15 (4.34 t ha^{-1}) gave significantly higher yield than the check BRRI dhan39 with similar growth duration in T. Aman 2017.

The ZER line BR8269-60-2-HR2-1-1-BHA-2 produced significantly higher grain yield with check variety BRRI dhan74 in Boro 2017-18.

The PQR entries BR9207-45-2-2 and BR859-5-3-3-4-2 produced significantly higher grain yield than all the check varieties but four days earlier than the check BRRI dhan50 and six days later than BRRI dhan63 in Boro 2017-18.

Three genotypes BR859-5-2-5-2-2, Dinazpur Minikat (Rangpur) and Shampakatari (Shingra-Natore) gave significantly higher yield than the check variety BRRI dhan50 in Boro 2017-18.

The GSR entry HHZ12-Y4-Y1-DT1 gave the highest grain yield than the check BRRI dhan69 with six days shorter duration in 2017-18.

FBR line IR09A235 produced about 1.70 t ha^{-1} higher yield than the check BRRI dhan58 with two days earlier in 2017-18.

FBR entries IR12A288, IR99090-B-B-62 and BR8938-30-2-4-2-1 also produced about 0.96, 0.93 1.10 t ha^{-1} higher yield respectively, than the check BRRI dhan58 with similar duration in 2017-18.

FBR entry BR(Bio)9777-26-4-3 gave the highest grain yield than the check BRRI dhan58 with similar duration. BR(Bio)9777-118-6-4 also produced significantly higher yield than BRRI dhan58 with two days longer duration in 2017-18.

Among the Abed's entries Kainalhati-2 produced the highest yield (6.62 t ha^{-1}) with 149 days growth duration followed by Kainalhati -4 (6.12 t ha^{-1}) with 140 days growth duration in Boro 2017-18.

Among Nepali varieties none of the genotype produced higher yield than the check BRRI dhan28. The highest number of panicle (24/hill) and yield (6.0 t ha^{-1}) was found in Khumal-7 with 159 days growth duration. The highest spikelet degeneration was observed in the genotype Khumal-5 in Boro 2017-18.

Higher adoption of BRRI dhan48 was observed in Sylhet region (43.6%)>BRRI dhan28 (17.2%)> and BR26 (8.3%) in 2017.

Among the districts of Sylhet region, higher adoption of BRRI dhan48 was observed in Habiganj (60.3%)>Moulvibazar (46.6%)> and Sylhet (32.1%) in 2017.

In case of BRRI dhan28, higher adoption was observed in Moulvibazar (26.3%)>Habiganj (20.7%)> and Sunamganj (15.6%) in 2017.

In case of BR26, higher adoption was observed in Sunamganj (14.1%)>Sylhet (8.2%)> and Moulvibazar (7.5%) in 2017-18.

Higher adoption of BRRI dhan49 was observed in Sylhet region (22.1%)>BR11 (18.0%)> BR22 (8.8%)> and BRRI dhan52 (3.9%) in 2017.

Among the districts of Sylhet region, higher adoption of BRRI dhan49 was observed in Habiganj (32.8%)>Moulvibazar (25.9%)>Sylhet (17.1%)> and Sunamganj (16.0%) in 2017.

In case of BR11, higher adoption was observed in Moulvibazar (27.6%)>Sylhet (16.6%)>Sunamganj (15.5%)> and Habiganj (11.6%) in 2017.

In case of BR22, higher adoption was observed in Habiganj (22.1%)>Sunamganj (8.8%)>Moulvibazar (5.8%)> and Sylhet (3.6%) in 2017.

From a long term missing element trial of Boro-Fallow-Fallow cropping pattern, it was found that besides NP, K is the most yield limiting nutrient element in BRRI Habiganj farm.

In terms of growth duration and yield, BRRI dhan62 is not suitable for cultivation in Boro season in comparison with BRRI dhan28 in low land *haor* areas.

The best time for Boro rice transplanting in Habiganj farm for achieving higher yield was 1-15 January.

VARIETY DEVELOPMENT

RYT, T. Aus 2017

Fourteen genotypes along with two standard check BR26 and BRRI dhan48 were evaluated at BRRI farm Habiganj. BR9011-19-1-2 produced significantly higher yield with two days longer growth duration than the check BRRI dhan48. Also, BR9011-67-4-1 and BR9011-46-2-2 produced similar grain yield with the check variety BRRI dhan48 (Table 1).

Table 1. Yield and ancillary characters of RYT genotypes, T. Aus 2017, BRRI RS, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR9011-46-2-2	102.1	110	5.56
BR9011-67-4-1	103.6	109	5.61
BR9011-19-1-2	103.9	112	5.89
BRRI dhan48 (ck)	95.9	110	5.51
$LSD_{(0.05)}$	3.27	1.32	0.25

DS: 19 Apr 2017, DT: 16 May 2017, Spacing: 20 cm × 15 cm.

PVT, T. Aus 2017

NERICA10-7-PL2-B along with check variety BRRI dhan48 was evaluated in Durgapur, Chunarughat, Habiganj. NERICA10-7-PL2 produced significantly higher grain yield (5.60 t ha^{-1}) with four days earlier growth duration than the check variety BRRI dhan48.

PVT, B. Aus 2017

Tested entry, BR6848-3B-12 along with the check BRRI dhan43 was evaluated in Tetuia, Chunarughat as well as BRRI Habiganj farm under wet direct seeding condition. BR6848-3B-12 produced higher yield (5.12 t ha^{-1}) over the check variety. BRRI dhan43 with similar growth duration.

RYT (BB), T. Aman 2017

Nine genotypes along with three check varieties, BRRI dhan39 (Sus. ck), BRRI dhan49 (Sus. ck) and IRBB60 (Res. ck) were evaluated. None of the genotype produced higher yield than the check BRRI dhan49. The genotype BR8548-8-22-5-15 gave significantly higher yield (4.34 t ha^{-1}) than the check BRRI dhan39 with similar growth duration.

RYT (Biotechnology), T. Aman 2017

Four genotypes along with check BRRI dhan49 were evaluated. None of the genotype produced higher grain yield than the check BRRI dhan49.

PVT (RLR), T. Aman 2017

Two genotypes, BR-RS(Raj)-PL4-B and BR-SF(Rang)-PL1-B along with two check varieties BR11 and BRRI dhan49 were evaluated in Jagothpur, Habiganj. The proposed genotypes BR-RS(Raj)-PL4-B and BR-SF(Rang)-PL1-B gave about 0.90 t ha^{-1} higher grain yield with four days longer growth duration than the check BRRI dhan49 but gave similar yield with three days earlier than the check BR11.

PVT for higher yield (Biotechnology), T. Aman 2017

The genotype BR (Bio) 9786-BC2-132-1-3 along with the check variety BRRI dhan49 was evaluated in Jagothpur, Habiganj. The proposed genotype BR (Bio) 9786-BC2-132-1-3 produced about 1.0 t ha^{-1} higher grain yield with seven days shorter growth duration than the check variety BRRI dhan49.

RYT (ZER), Boro 2017-18

ZER-1. Ten genotypes along with three checks BRRI dhan28, BRRI dhan29 and BRRI dhan74 were evaluated. The genotype BR8269-60-2-HR2-1-1-BHA-2 produced significantly higher grain yield with the check BRRI dhan74. Another genotype BR8634-23-1-1-BHA-10 gave similar grain yield with the check variety BRRI dhan74 (Table 2).

ZER-2. Four genotypes along with two checks BRRI dhan28 and BRRI dhan74 were evaluated. None of the genotype performed better yield than the check BRRI dhan28 and BRRI dhan74. Most of the hills were dying after transplanting due to cold injury.

ZER-3. Two genotypes along with the check BRRI dhan28 were evaluated. BRRI dhan62 was unable to germinate. BRRI dhan57 produced lower yield than the check variety BRRI dhan28.

RYT (PQR), Boro 2017-18

Six genotypes along with three checks BRRI dhan28, BRRI dhan50 and BRRI dhan63 were evaluated. The genotype BR9207-45-2-2 and BR859-5-3-3-4-2 produced significantly higher grain yield than all the check varieties but four days earlier than BRRI dhan50 and six days later than BRRI dhan63. Three genotypes BR859-5-2-5-2-2, Dinazpur Minikat (Rangpur) and Shampakatari (Shingra-Natore) gave significantly higher yield than the check variety BRRI dhan50 (Table 3).

Table 2. Yield and ancillary character of ZER-1 materials, Boro 2017-18, BRRI, Habiganj.

Designation	Plant ht (cm)	Growth duration (day)	Yield (t ha^{-1})
BR8269-60-2-HR2-1-1-BHA-2	97.4	150	6.97
BR8634-23-1-1-BHA-10	100.6	150	6.84
BRRI dhan74 (ck)	96.8	149	6.71
$LSD_{(0.05)}$	1.70	0.97	0.21

DS: 24 Nov 2017, DT: 6 January 2018, Spacing: 20 cm × 20 cm.

Table 3. Yield and ancillary character of PQR lines, Boro 2017-18, BRRI RS, Habiganj.

Designation	Plant ht (cm)	Growth duration (day)	Yield (t ha^{-1})
BR9207-45-2-2	105.4	154	6.68
BR859-5-2-5-2-2	98.5	153	6.01
BR859-5-3-3-4-2	92.6	154	6.61
Dinazpur Minikat (Rangpur)	86.8	146	6.15
Shampakatari (Shingra-Natore)	91.9	148	6.20
BRRI dhan50 (ck)	83.5	158	5.66
BRRI dhan63 (ck)	82.2	148	6.23
$LSD_{(0.05)}$	2.66	1.14	0.29

DS: 27 Nov 2017, DT: 08 January 2018, Spacing: 20 cm × 20 cm.

RYT (BB resistant), Boro 2017-18

Four genotypes along with the three check varieties BRRI dhan58, BRRI dhan29 and IRBB60 were evaluated. None of the genotype produced higher yield than the check BRRI dhan58 and BRRI dhan29 but all tested genotypes gave higher yield than the check IRBB60.

RYT (Insect resistant), Boro 2017-18

Six genotypes along with three check; T27A, BRRI dhan28 and BR3 were evaluated. Three genotypes BR8340-5-6-1, BR8340-5-8-4 and BR8339-6-2-5-2 produced significantly higher yield than all the check varieties (Table 4).

RYT (GSR), Boro 2017-18

Three genotypes along with three check BRRI dhan28, BRRI dhan58 and BRRI dhan69 were evaluated. The genotype HHZ12-Y4-Y1-DT1 gave the highest grain yield than the check variety BRRI dhan69 with six days shorter duration (Table 5).

RYT (FB), Boro 2017-18

Ten genotypes along with two check BRRI dhan28

Table 4. Yield and ancillary character of IRR lines, Boro 2017-18, BRRI Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR8339-6-2-5-2	103.3	153	7.67
BR8340-5-6-1	102.1	155	7.10
BR8340-5-8-4	94.5	151	7.44
BR3 (Std. ck)	83.9	161	6.42
BRRI dhan28 (Std. ck)	95.8	145	6.56
T27A (T. ck)	113.3	146	4.93
$LSD_{(0.05)}$	3.92	1.58	0.36

DS: 29 Nov 2017, DT: 20 Jan 2018, Spacing: 20 cm × 15 cm.

Table 5. Yield and ancillary character of GSR lines, Boro 2017-18, BRRI, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
HHZ12-Y4-Y1-DT1	87.0	148	7.09
BRRI dhan69 (ck.)	90.0	154	6.66
$LSD_{(0.05)}$	4.40	1.37	0.12

DS: 30 Nov 2017, DT: 20 Jan 2018, Spacing: 20 cm × 15 cm.

and BRRI dhan58 were evaluated. IR09A235 produced significantly the highest yield among the entries and about 1.70 t ha^{-1} higher yield than check BRRI dhan58 with two days earlier. Entries IR12A288, IR99090-B-B-62 and BR8938-30-2-4-2-1 also produced about 0.96, 0.93 1.10 t ha^{-1} higher yield respectively, than BRRI dhan58 with similar duration (Table 6).

RYT (FB-Biotechnology) Boro 2017-18

Four advanced lines along with check BRRI dhan58 were evaluated. The genotypes BR(Bio)9777-26-4-3 gave the highest grain yield than the check variety BRRI dhan58 with similar duration. BR (Bio) 9777-118-6-4 also produced significantly higher yield than BRRI dhan58 with two days longer duration (Table 7).

AYT of Abed's materials, Boro 2017-18

A total of 22 genotypes were evaluated under wet direct seeded condition at BRRI RS, Habiganj. Kanihati-2 produced the highest yield (6.62 t ha^{-1}) with 149 days growth duration followed by Kanihati-4 (6.12 t ha^{-1}) with 140 days growth duration. The highest shattering problem was found in Dumai (kalo) genotype (Table 8).

AYT of Nepali varieties, Boro 2017-18

A total of 12 genotypes with check BRRI dhan28 were evaluated at BRRI RS farm, Habiganj. None of the genotype produced higher yield than the check variety BRRI dhan28. The highest number of panicle (24/hill) and yield (6.0 t ha^{-1}) was found in Khumal-7 among the test entries with 159 days growth duration. The highest spikelet degeneration was observed in the genotype Khumal-5 (Table 9).

PVT, FBR, Boro 2017-18

FBR (short duration). PVT was conducted along with check varieties BRRI dhan28 at Baghjour, Baniachong, Habiganj. The proposed line BRRI dhan29-SC3-28-16-10-8-HR1(Com) produced higher yield (4.82 t ha^{-1}) than check BRRI dhan28 (4.35 t ha^{-1}) with similar growth duration. Yield was lower due to submerge at harvest caused by heavy rainfall.

FBR (long duration). PVT was conducted along with check BRRI dhan29 at Balikhal, Baniachong, Habiganj. The tested line BR (Bio) 9786-BC2-59-1-2 produced higher yield (5.38 t ha^{-1}) than the check BRRI dhan29 (4.68 t ha^{-1}) with three days earlier. Yield was lower due to water shortage caused by failure of irrigation scheme at the reproductive stage.

SOCIO-ECONOMIC

Higher adoption of BRRI released Aus varieties in Sylhet region are BRRI dhan48 (43.6%) followed by BRRI dhan28 (17.2%) and BR26 (8.3%). Among the districts of Sylhet region, higher adoption of BRRI dhan48 was observed in Habiganj (60.3%) followed by Moulvibazar (46.6%) and Sylhet (32.1%). In case of BRRI dhan28, higher adoption

Table 6. Yield and ancillary character of FBR lines, Boro 2017-18, BRRI, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
IR12A288	95.4	152	8.07
IR09A235	101.9	152	8.78
IR99090-B-B-62	105.4	154	8.04
BR8938-30-2-4-2-1	99.5	153	8.25
BRRI dhan58 (ck)	95.2	154	7.11
$LSD_{(0.05)}$	3.97	1.67	0.42

DS: 30 Nov 2017, DT: 21 Jan 2018, Spacing: 25 cm × 15 cm.

Table 7. Yield and ancillary character of FBR lines (Biotech.), Boro 2017-18, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR(Bio) 9777-26-4-3	84.3	151	7.21
BR(Bio) 9777-118-6-4	95.1	152	6.79
BRRI dhan58 (ck)	86.9	150	6.40
$LSD_{(0.05)}$	2.00	1.19	0.37

DS: 2 Dec 2017, DT: 21 Jan 2018, Spacing: 25 cm × 15 cm.

Table 8. Yield and ancillary character of DS materials, Boro 2017-18, BRRI RS, Habiganj.

Designation	Plant ht. (cm)	Panicle hill^{-1}	Growth duration (day)	Yield (t ha^{-1})	Comments
Dumai (Kalo)*	105.9	17	114	1.86	Lodging & shattering
Kanihati-2	98.4	16	149	6.62	No lodging
Kanihati-4	100.8	18	140	6.12	No lodging
$LSD_{(0.05)}$	3.81	3.93	0.85	0.46	

D/soaking: 12 Dec 2017, D/seeding: 15 Dec 2017, line spacing: 25 cm *Highly shattering problem.

Table 9. Yield and ancillary character of Nepali varieties, Boro 2017-18, BRRI RS, Habiganj.

Designation	Plant height (cm)	Panicle hill^{-1}	Growth duration (day)	Yield (t ha^{-1})	Comment
Khumal-5	128.1	18	149	5.44	Lodging and spikelet degeneration
Khumal-7	112.5	24	159	6.15	No lodging
BRRI dhan28 (ck)	95.7	18	146	6.45	No lodging
$LSD_{(0.05)}$	4.24	3.95	1.54	0.60	

DS: 23 Nov 2017, DT: 4 Jan 2018, Spacing: 20 cm × 20 cm.

was observed in Moulvibazar (26.3%) followed by Habiganj (20.7%) and Sunamganj (15.6%). In case of BR26, higher adoption was observed in Sunamganj (14.1%) followed by Sylhet (8.2%) and Moulvibazar (7.5%) (Table 10).

Higher adoption of BRRI released Aman varieties in Sylhet region are BRRI dhan49 (22.1%) followed by BR11 (18.0%), BR22 (8.8%) and BRRI dhan52 (3.9%). Among the districts of Sylhet region, higher adoption of BRRI dhan49 was observed in Habiganj (32.8%) followed by Moulvibazar (25.9%), Sylhet (17.1%) and Sunamganj (16.0%). In case of BR11, higher adoption was observed in Moulvibazar (27.6%) followed by Sylhet (16.6%), Sunamganj (15.5%) and Habiganj (11.6%). In case of BR22, higher adoption was observed in Habiganj (22.1%) followed by Sunamganj (8.8%), Moulvibazar (5.8%) and Sylhet (3.6%) (Table 11).

CROP-SOIL-WATER MANAGEMENT

Long-term missing element trial for diagnosing the limiting nutrient in soil

This is a long term experiment that initiated at Habiganj farm in 2007-08 to identify the yield limiting nutrient (s). The experiment comprising 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 2016-17 was the 10th 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 dhan29 was used as a test crop. Balanced fertilization with complete treatment significantly increased grain yield and yield parameters of rice. The highest panicle m^{-2} was obtained with balanced fertilized (T_1) plot followed by NP omission plot (T_6). The highest grain yield was obtained in T_1 (6.21 t ha^{-1}) followed by T_4 (4.48 t ha^{-1}). The K omission treatment (T_4) produced significantly lower yield (4.48 t ha^{-1}) than the other treatments. From the experiment it may be concluded that, besides N, P, K is the most yield limiting nutrient element in BRRI Habiganj farm (Table 12).

Suitability study of BRRI dhan62 in comparison with BRRI dhan28 in low-land *haor* areas using Boro season

The experiment was conducted at BRRI RS farm, Habiganj during Boro 2017-18 to observe the suitability of BRRI dhan62 in *haor* areas. The experiment was laid out in split-plot design with three replications. Fertilizer dose was 120-30-50-10-3 kg N-P-K-S-Zn ha^{-1}, respectively. Thirty-five-day-old seedling was transplanted in 20 cm × 20 cm spacing using 2-3 seedlings hill^{-1}. BRRI dhan28 and BRRI dhan62 were matured at the same time. The grain yield of BRRI dhan62 was lower than BRRI dhan28 in all transplanting dates. So, in terms of growth duration and yield BRRI dhan62 is not suitable for cultivation in Boro season in comparison with BRRI dhan28 in low land *haor* areas (Table 13).

Table 10. Adoption (%) and yield (t ha^{-1}) (within parenthesis) of different BRRI released Aus varieties in Sylhet region of Bangladesh, 2017-18.

Variety	Habiganj	Mouluvibazar	Sunamganj	Sylhet	Sylhet region
BR26	7.44 (3.81)	7.47 (3.90)	14.13 (4.20)	8.21 (3.82)	8.24 (3.93)
BRRI dhan28	20.74 (3.81)	26.26 (3.91)	15.62 (4.50)	8.18 (3.73)	17.21 (3.99)
BRRI dhan48	60.29 (4.28)	46.59 (3.61)	29.60 (4.91)	32.10 (3.91)	43.62 (4.18)

Source: Field survey 2017.

Table 11. Adoption (%) and yield (t ha^{-1}) (within parenthesis) of different BRRI released Aman varieties in Sylhet region of Bangladesh, 2017-18

Variety	Habiganj	Mouluvibazar	Sunamganj	Sylhet	Sylhet region
BR11	11.58 (4.48)	27.60 (4.19)	15.44 (4.45)	16.56 (4.46)	17.98 (4.40)
BR22	22.11 (4.33)	5.76 (3.96)	8.76 (4.29)	3.64 (4.16)	8.81 (4.18)
BRRI dhan46	6.22 (4.40)	-	4.86 (4.14)	3.03 (4.12)	3.30 (4.22)
BRRI dhan49	32.76 (4.48)	25.88 (4.18)	15.94 (4.31)	17.08 (4.35)	22.09 (4.33)
BRRI dhan52	4.25 (4.26)	2.66 (4.19)	5.06 (4.17)	3.87 (4.18)	3.88 (4.20)

Source: Field survey 2017.

Table 12. Effects of nutrient element omission from the complete treatment on grain yield of BRRI dhan29, Boro 17-18, Habiganj.

Treatment	Panicle m^{-2}	Grain yield (t ha^{-1})
T_1	358	6.21
T_2	266	5.51
T_3	339	5.36
T_4	344	4.48
T_5	330	5.19
T_6	220	4.68
T_7	302	5.25
T_8	187	3.96
$LSD_{(0.05)}$	34.23	0.33

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).

Table 13. Suitability study of BRRI dhan62 in comparison with BRRI dhan28 at BRRI Habiganj farm, Boro 2017-18.

Treatment (sowing time)	Grain yield (t ha^{-1})	
	BRRI dhan62	BRRI dhan28
T_1	6.71	7.34
T_2	5.41	5.49
T_3	6.08	7.01
T_4	6.74	7.60
T_5	5.38	6.49
$LSD_{(0.05)}$	0.53	0.41

T_1= 20 Nov 2017, T_2= 28 Nov 2017, T_3= 05 Dec 2017, T_4= 12 Dec 2017, T_5= 19 Dec 2017.

Effect of planting time on yield of different Boro varieties in *haor* area

The experiment was conducted at BRRI RS farm, Habiganj during Boro 2017-18 to observe the appropriate transplanting time of released Boro rice in *haor* ecosystem. The experiment was laid out in split-plot design with three replications. Fertilizer dose was 120-30-50-15-3 kg N-P-K-S-Zn ha^{-1}, respectively. Thirty-five-day-old seedling was transplanted in 20 cm × 20 cm spacing using 2-3 seedlings $hill^{-1}$. BRRI dhan63 and BRRI dhan74 matured 4-9 days earlier than BRRI hybrid5, BRRI dhan58 and BRRI dhan69. Yield of BRRI dhan63 was lower than other Boro variety in all transplanting date. Regarding BRRI dhan63, T_2 (1 January using forty-day-old seedling) is the best time for transplanting. In case of BR14, BRRI dhan74 and BRRI hybrid dhan5, T_3 (15 January using forty-day-old seedling) is the best option for transplanting. Therefore, it could be concluded that T_2 and T_3 had the best transplanting times for Boro season in BRRI Habiganj farm (Table 14).

Table 14. Effect of planting time on the yield of different Boro varieties at BRRI Habiganj farm, Boro 2017-18.

Date of TP	Grain yield (t ha^{-1})					
	BRRI H5	BR14	BRRI dhan58	BRRI dhan63	BRRI dhan69	BRRI dhan74
15 Dec 2017	7.18	4.75	6.57	5.15	5.74	6.58
1 Jan 2018	6.49	5.73	6.65	5.15	7.25	7.79
15 Jan 2018	7.80	6.76	5.77	5.14	6.45	8.33
01 Feb 2018	6.84	5.72	5.22	4.60	4.76	6.93
$LSD_{(0.05)}$	0.41	0.65	0.18	0.36	0.44	0.46

PEST MANAGEMENT

Survey and monitoring of rice arthropods in Sylhet region

This survey was done to determine incidence and abundance patterns of insect pests and their natural enemies in Sylhet region during T. Aus and T. Aman 2017. Short horned grasshopper was predominant in Aus field but rice hispa was in Aman field. In case of natural enemies, damsel fly> spider> and lady bird beetle were predominant in Aus field but spider> lady bird beetle> and damsel fly were in Aman field.

BRRI RS, Rajshahi

In RYT Aus 2017, a total of 26 breeding lines were evaluated in replicated trials of which three entries appeared promising for further evaluation. For proposed variety trial (PVT), proposed lines BR6848-3B-12 yielded higher against their respective check and has been released as B. Aus variety namely BRRI dhan83. In T. Aman 2017, a total of 45 breeding lines were evaluated in RYT and eight entries were found promising for further advancement. Ten genotypes (GSRIR2-1-Y16-S1-R2, IR15L1135, IR14L108, IR15L1122, IR15L1141, IR14L374, IR12A329, IR11N313, IR13L337, and IR 98925-11-1-2-1) were selected from AYT drought for PVS trial in T. Aman season 2018. In GSR-RYT, HHZ8-SAL12-Y2-DT1 gave the highest yield (4.83 t/ha) in T. Aman season. In Boro 2017-18, eleven breeding lines appeared promising for further advancement. For proposed variety trial (PVT), breeding line BRRI dhan29-SC3-28-16-10-8-HR1(Com) produced similar yield with the check variety BRRI dhan28. The tested Biotechnology FBR line BR (Bio) 9786-BC2-59-1-2 produced similar grain yield with the check variety while LWR line BR (BE) 6158RWBC2-1-2-1-1 produced 0.89 t/ha higher yield than the check variety BRRI dhan29. In GSR-RYT, HHZ15-DT7-SAL4-SAL1 (7.32 t/ha and 153 days) produced higher grain yield than all the check varieties during Boro 2017-18. From a survey during T. Aman 2017, it was found that bacterial blight, brown spot and false smut were more frequent disease irrespective of variety across the locations whereas BRRI dhan49 was found to be infected by false smut and BRRI dhan34 was infected by sheath rot and blast in those locations. Twenty-one chemicals including one standard (Nativo) were tested against sheath blight disease in T. Aman 2017 and reduced disease by less than 80%. Compared with conventional, gross margin remained higher in strip tillage and bed planting system and thus this tillage system could be beneficial to the farmers. The farmers also can be benefitted if they cultivated BRRI dhan71 jute + rice relay system along with strip/bed planted wheat. Moreover, 25 and 14 tons of breeder and TLS seeds were produced respectively considering three seasons (Aus, T. Aman and Boro).

VARIETY DEVELOPMENT

Regional yield trial (RYT), B. Aus 2017

Twelve breeding lines were evaluated in RYT at BRRI RS, farm Rajshahi against standard checks of BRRI dhan43 and BRRI dhan65. Advanced line BR8235-2B-12-4 (3.2 t/ha and 99 days) and BRRI dhan29-SC3-28-16-10-2-HR3-HR9 (Com) produced higher yield (3.2 t/ha and 98 days) against the check BRRI dhan43 and BRRI dhan65 and was selected for further evaluation.

RYT, T. Aus 2017

For Plant Breeding Division, nine breeding lines were evaluated in RYT at BRRI RS farm, Rajshahi against standard checks of BRRI dhan48 and BRRI dhan65. None of the entries produced higher yield than the check variety BRRI dhan65, while genotype BR9640-2B-9-1 produced higher yield (3.30 t/ha) than the check variety BRRI dhan48 (2.10 t/ha) with four days shorter growth duration. In case of Biotechnology Division, five breeding lines were evaluated in RYT transplanted Aus at BRRI RS farm, Rajshahi along with standard check BRRI dhan48. None of the breeding lines performed better over the checks.

Proposed variety trial (PVT), B. Aus 2017

The proposed B. Aus line BR6848-3B-12 produced higher yield (3.32 t/ha and 99 days) than the check variety BRRI dhan43 (3.22 t/ha and 101 days) with two days shorter growth duration.

RYT, T. Aman 2017

For Plant Breeding Division, 41 breeding lines were evaluated in seven different RYT (one for insect resistance rice-IRR, one for zinc enriched rice-ZER, one for GRS materials, two for rainfed low land rice-RLR, two for premium quality rice-PQR, one for high yielding rice-Biotechnology materials) at BRRI RS farm, Rajshahi against 12 different standard checks (BRRI dhan33, BRRI dhan37, BRRI dhan39, BRRI dhan46, BRRI dhan49, BRRI dhan72, BINA dhan-7, BINA dhan-13, Kalizira, Kataribog, Rajashail and Monibandhobi). Among them, one entry BR8692-15-4-2-1 gave higher yield in RYT-IRR, one genotype BR8442-12-1-3-1-B5 produced higher yield in RYT-ZER, three entries showed higher yield in RYT-PQR, two entries

IR10F102 and BRRI dhan29-SC3-28-16-15-HR2 (Com) gave higher yield in RYT-RLR and in RYT-GRS, Monibandhobi (2.77 t/ha) produced higher yield than Rajashail and BRRI dhan46 (2.14-2.23 t/ha).

Regional yield trial (RYT) from Biotechnology Division, T. Aman 2017

Four genotypes along with the check BRRI dhan49 were evaluated. The genotype BR (Bio) 8961-AC22-14 produced higher yield and similar growth duration (3.74 t/ha and 128 days) and was selected for advancement.

International Network for Genetic Evaluation of Rice (INGER), T. Aman 2017

Fifty-five tested genotypes along with two checks; BRRI dhan49 and BRRI dhan71 were evaluated at the BRRI farm. The tested entry TP 30565 gave higher yield (5.32 t/ha and 116 days) than BRRI dhan49 (3.59 t/ha and 115 days) but lower yield than the check BRRI dhan71 (5.44 t/ha and 112 days).

PVT, T. Aman 2017

Two PVT, one rainfed lowland rice (RLR) and one high yielding rice (Biotechnology materials) were conducted against the standard checks (BR11 and BRRI dhan49) in farmers' field of Rajshahi district. The proposed line BR-SF (Rang)-PL1-B (5.26 t/ha and 133 days) produced higher grain yield than the check BRRI dhan49 (5.17 t/ha and 131 days) but lower yield with one day earlier growth duration than the check BR11 (5.60 t/ha and 134 days). In case of Biotechnology, the tested line BR (Bio) 9786-BC2-132-1-2 (5.50 t/ha and 125 days) produced higher grain yield with five days earlier growth duration than the check BRRI dhan49 (4.93 t/ha and 132 days).

Observational yield trial (OYT) of STRASA drought lines, T. Aman 2017

A total of 96 advanced lines with two checks (BRRI dhan66 and BRRI dhan71) were tested under both stress and control conditions at on-farm Alimganj, Paba, Rajshahi. Thirty-six genotypes gave more than 4,000 kg/ha grain yield under controlled condition. Among them, 26 genotypes produced higher yield than all the checks (3998-4152 kg/ha). The genotype IR16L1857 produced the highest yield (4932 kg/ha). On the other hand, 24 genotypes gave more than 4,000 kg/ha grain yield in stress condition. Forty genotypes produced higher yield than all the checks (3490-3679 kg/ha). The genotype IR16L1800 produced the highest yield (4,946 kg/ha). Considering stress and control condition data, 39 genotypes were selected for AYT trial at the next season.

Advanced yield trial (AYT) of STRASA drought lines, T. Aman 2017

Four AYT trials (AYT#1, AYT#2, AYT#3 and AYT#4) were conducted at on-farm Alimganj, Paba, Rajshahi. A total of 121 genotypes including standard checks; BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan56, BRRI dhan66 and BRRI dhan71 were grown in controlled and stressed conditions. In AYT#1, fourteen genotypes produced higher yield than all the checks (4169-4271 kg/ha). The genotype IR15L1135 produced the highest yield (4,720 kg/ha). On the other hand, 12 genotypes produced higher yield than all the checks (4148-5,869 kg/ha). The genotype GSRIR2-1-Y16-S1-R2 produced the highest yield (5,869 kg/ha). In AYT#2, eleven genotypes gave higher yield than all the checks (3347-3493 kg/ha). The genotype IR15L1746 produced the highest yield (4,181 kg/ha). On the other hand, nine genotypes produced higher yield than all the checks (3146-3356 kg/ha). The genotype R15L1746 produced the highest yield (3866 kg/ha). In AYT#3, six genotypes produced higher yield than all the checks (3,188-4,049 kg/ha). The genotype IR99784-255-29-1-1-1-2 gave the highest yield (4,371 kg/ha). On the other hand, six genotypes gave more than 4,000 kg/ha grain yield in stress condition and produced higher yield than all the checks (2,950-3,554 kg/ha). The genotype IR99784-156-87-2-4-1 gave the highest yield (4,251 kg/ha). In AYT#4, in controlled condition, IR96321-315-323-B-3-1-1 genotypes (4.48 t/ha) produced higher yield than all the check except BRRI dhan71 (5.01 t/ha). In stress condition, IR96321-1447-521-B-2-1-2 (4.28 t/ha) produced higher yield than BRRI dhan51 (3.64 t/ha) and BRRI dhan52 (3.43 t/ha) with 9-12 days earlier growth duration but lower yield than BRRI dhan56 (4.57 t/ha) and BRRI dhan71 (5.33 t/ha).

Considering stress and control condition data, ten genotypes (GSRIR2-1-Y16-S1-R2, IR15L1135,

IR14L108, IR15L1122, IR15L1141, IR14L374, IR12A329, IR11N313, IR13L337, and IR 98925-11-1-2-1) were selected for PVS trial at the next season.

Head to head trial of STRASA drought lines, T. Aman 2017

In controlled condition, all the entries produced higher yield than BRRI dhan71 (3.52 t/ha) with 3-4 days earlier growth duration but produced lower yield than local Swarna (4.51 t/ha). In stress condition, IR 88965-39-1-6-4 (3.52 t/ha) produced higher yield than all the checks with 4-24 days earlier growth duration.

Donor materials, STRASA, T. Aman 2017

Four genotypes, out of eight, produced higher yield than the check BRRI dhan71 (2.04 t/ha and 107 days). DA 28 genotype produced the highest yield among all the genotypes (2.69 t/ha and 105 days) with two days earlier growth duration.

Green super rice (GSR), T. Aman 2017

SYT. Seven genotypes along with two checks BRRI dhan39 and BRRI dhan75 were evaluated in Paba and Duragpur. The four genotypes HHZ15-SAL13-Y3, HHZ22-Y3-OT1-Y1, HHZ8-Y7-DT2-SAL1 and IR75416-R-R-R-R-152-4 (4.19-4.84 t/ha with 109-111 days) gave the higher yield having 7-9 days earlier growth duration than the check variety BRRI dhan39.

RYT. Three advanced lines along with the check BRRI dhan73 were evaluated at on-farm condition of Paba and Duragpur. In Paba site, all the genotypes produced higher yield than the check variety BRRI dhan73 (4.14 t/ha and 118 days) with 6-12 days earlier growth duration. The genotype HHZ11-DT7-SAL1-SAL1 (4.83 t/ha and 113 days) produced the highest yield among all the entries. At Durgapur site, similar results were found. The genotype HHZ8-SAL12-Y2-DT1 (4.95 t/ha with 113 days) produced the highest yield among all the entries.

Regional yield trial (RYT), Boro 2017-18

Thirty-six breeding lines were evaluated in seven different RYT (1 for favourable Boro rice-FBR, three for zinc enriched rice-ZER, one for premium quality rice-PQR, one for disease resistant rice and one for favourable Boro rice-Biotechnology) at BRRI RS farm, Rajshahi against seven different standard checks (BRRI dhan28, BRRI dhan29, BRRI dhan50, BRRI dhan58, BRRI dhan63, BRRI dhan74 and IRBB60).

Findings

RYT#1 (FBR). The tested six genotypes (5.14-6.17 t/ha) produced higher yield than all the check varieties (4.07-4.25 t/ha) and selected for further advancement. The genotype IR99056-B-B-15 (6.47 t/ha) produced the highest yield followed by IR14N126 (6.45 t/ha).

RYT#2 (ZER-1). All of the genotypes produced higher yield than the check variety except those entries affected by severe cold. The tested seven genotypes (5.80-7.10 t/ha) produced the higher yield than all the checks (5.39-5.61 t/ha). The genotype BR8634-23-1-1-BHA-5 produced the highest yield (6.86 t/ha) followed by BR8634-23-1-1-BHA-10 (6.65 t/ha).

RYT#3 (ZER-2). None of the genotype performed better than the check varieties BRRI dhan28 and BRRI dhan74.

RYT#4 (ZER-3). BRRI dhan57 produced the highest yield (6.58 t/ha with 152 days) than the check BRRI dhan28 (6.32 t/ha and 146 days) having six days longer growth duration. BRRI dhan62 produced similar yield (6.47 t/ha and 150 days) with the check BRRI dhan28.

RYT#5 (PQR). All of the tested genotypes performed better than the check variety except Shampakatari. The genotype BR9207-45-2-2 produced the highest yield (6.80 t/ha) than all the check varieties (4.79-5.76 t/ha). The tested entry BR8590-5-2-5-2-2 (6.48 t/ha) produced higher yield than BRRI dhan28 and BRRI dhan63 (4.79-5.51 t/ha).

RYT#6 (Disease resistant). The bacterial blight (BB) resistance genotype BR9650-35-4-3 (7.73 t/ha) gave higher yield than all the check varieties (5.06-6.33 t/ha) with three days shorter growth duration than BRRI dhan29 (5.06 t/ha and 166 days) followed by BR9943-2-2.

RYT, Biotechnology, Boro 2017-18

Four genotypes along with the standard check BRRI dhan58 were evaluated at BRRI farm. Two genotypes BR(Bio)9777-118-6-4 (6.98 t/ha) and

BR(Bio)9777-113-12-5 (6.81 t/ha) gave the highest yield than the check variety BRRI dhan58 (5.27 t/ha) and selected for further advancement.

Yield maximization trial (YMT), Boro 2017-18
One advanced breeding line along with two checks BRRI dhan28 and BRRI dhan58 were evaluated at the BRRI farm. The advanced lines did not give higher yield than the check variety BRRI dhan28 and BRRI dhan58 (6.44-6.67 t/ha).

PVT, Boro 2017-18
Three PVT, one favourable Boro rice (FBR) from Breeding Division, one favourable Boro rice (FBR) and low water requirement (LWR) rice from Biotechnology Division, were conducted against the standard checks (BRRI dhan28 and BRRI dhan29) in farmers field of Rajshahi district. The proposed line BRRI dhan29-SC3-28-16-10-8-HR1(Com) produced almost similar yield (7.53 t/ha) with two days earlier growth duration to the check variety BRRI dhan28 (7.48 t/ha). The tested Biotechnology FBR line BR(Bio) 9786-BC2-59-1-2 gave similar yield (8.31 t/ha with 159 days) having three days earlier growth duration to the variety BRRI dhan29 (8.14 t/ha and 162 days). In PVT for LWR, the tested LWR line BR (BE) 6158RWBC2-1-2-1-1 produced higher yield (8.71-8.98 t/ha) than the check variety BRRI dhan29 (7.85 -8.09 t/ha) with two days longer growth duration.

Green super rice (GSR), Boro 2017-18
OYT. A total of 25 genotypes including four check varieties; BRRI dhan28, BRRI dhan63, BRRI dhan75 and BRRI dhan69 were evaluated at Paba and Tanore, Rajshahi. In Paba site, the genotype GSR-IR1-DQ157-R6-D1 (6.93 t/ha and 146 days) produced similar grain yield with three days shorter growth duration to the check variety BRRI dhan69 (6.93 t/ha and 149 days) but gave higher grain yield than the check varieties BRRI dhan28, BRRI dhan63 and BRRI dhan75 (6.11-6.76 t/ha). At Tanore site, 12 genotypes produced the highest grain yield than all the check varieties (5.60-6.50 t/ha). Among 12 genotypes, GSR-IR2-9-L1-L2-Y3 and GSR-IR1-DQ126-R4-Y1 (6.96 t/ha) gave the highest grain yield.

SYT#2. Thirty genotypes along with four check varieties BRRI dhan28, BRRI dhan63, BRRI dhan69 and BRRI dhan75 were evaluated at Paba and Tanore, Rajshahi. In Paba site, the five genotypes produced higher grain yield (7.75-8.40 t/ha) than all the check varieties (5.04-7.16 t/ha). The genotype GSR IR 1-DQ157-R6-D1 (8.19 t/ha) produced significantly higher grain yield than all the check varieties (6.21-7.41) at Tanore site. Ten genotypes (7.57-8.08 t/ha) produced similar grain yield to the check variety BRRI dhan75 (7.41 t/ha) but higher grain yield than the check variety BRRI dhan28, BRRI dhan63 and BRRI dhan69.

SYT#3: Forteen genotypes along with the four check varieties; BRRI dhan28, BRRI dhan63, BRRI dhan69 and BRRI dhan75 were evaluated at Paba and Godagari, Rajshahi. In Paba and Tanore, none of the genotypes produced significantly higher grain yield than all the check varieties.

RYT. Three genotypes along with the check varieties BRRI dhan28, BRRI dhan63 and BRRI dhan69 were evaluated at Paba and Tanore, Rajshahi. The genotype HHZ15-DT7-SAL4-SAL1 (7.32 t/ha and 153 days) produced higher grain yield than all the check varieties (6.24-6.58 t/ha) both in Paba and Tanore.

CROP-SOIL-WATER MANAGEMENT

Nitrogen management in drought tolerant rice varieties at drought prone area, T. Aman 2017
BRRI dhan71 was evaluated under drought condition at Alimgonj, Paba, Rajshahi region (Table 1). The experiment was laid out in RCB design with three replications. Treatments were T_1-application of USG (1.8g and 2.7g) at 3-5 days after transplanting, T_2-prilled urea application (25,50 and 75 kg N/ha), and T_3-control were assigned. Twenty-four-day-old seedlings were transplanted at the spacing of 20 × 15 cm. Recommended crop management practices were followed as and when necessary. Data on tillering pattern at maximum tillering stage, yield and yield contributing parameters were taken.

Findings. In the experiment, USG treated plots showed the highest plant height (131.1 cm) and yield (3.27 t/ha) followed by 50 kg N/ha treated plot having 129.7 cm and with 3.26 t/ha yield, respectively except growth duration. The lowest plant height (121.8 cm) and yield (2.10 t/ha) were found in the control plot.

Table 1. Yield and ancillary characters of nitrogen management materials during T. Aman 2017.

Treatment	Plant height (cm)	Growth duration (day)	Yield (t/ha)
Control	121.8	110	2.10
25 kg N/ha	124.9	113	3.24
50 kg N/ha	129.7	113	3.26
USG (1.8 g)	129.4	114	3.20
75 kg N/ha	130.0	114	3.24
USG (2.7 g)	131.1	114	3.27
Mean	127.82	113	3.05
LSD at 5%	2.75		0.22
CV (%)	1.2		2.9

DS: 19 Jul 2017, DT: 12 Aug 2017.

PEST MANAGEMENT

Survey and monitoring of rice diseases

A survey was conducted in five upazilas namely, Goadagari, Paba, Tanore, Durgapur and Mohanpur in Rajshahi district during T. Aman 2017. Severity and incidence data of major diseases were recorded at the mature stage by following SES, IRRI. Bacterial blight, brown spot, sheath blight, false smut, sheath rot, blast were prevailed on guti swarna, BRRI dhan49 and BRRI dhan34, BINA dhan-7, BRRI dhan39 and Khato10. Among them, bacterial blight, brown spot and false smut were more frequent irrespective of variety across the locations. Incidence of bacterial blight, brown spot, false smut and sheath rot ranged from 2-100 (DS1-9), 3-100 (DS1-3), 1-100 (DS1-7) and 1-50 (DS1-9) respectively. Incidence and severity of blast were minimum. In all the locations, BRRI dhan49 was found to be infected by false smut and BRRI dhan34 was infected by sheath rot and blast.

Evaluation of new chemicals against sheath blight

A field experiment was conducted to find out the effective chemicals suitable for sheath blight control. A total of 21 chemicals including one standard (Nativo) were tested against ShB in T. Aman 2017. The experiment was conducted following appropriate methodology. Data on % RLH and % tiller infection from the inoculated hills were recorded (Table 2). Percent disease reduction was calculated from % RLH data. Test chemicals reduced ShB ranging from 8.24 to 65.13%. The highest reduction (65.13%) was observed in Dlink

Table 2. Effect of new fungicide on sheath blight disease development in T. Aman 2017-18 at Rajshahi farm.

Chemical	Generic name	Dose/ha	% RLH	% reduction
Lustre 37.5SC	Flusilazole 12.5%+ Carbendazim 25%	960mL	41.11	8.24
Prodifen 50EC	Difenoconazole 25%+Propiconazole25%	750mL	30.75	31.36
Success 30EC	Difenoconazole 15%+Propiconazole15%	225mL	21.59	51.81
Recovery 30EC	Difenoconazole 15%+Propiconazole15%	100mL	24.55	45.20
Active 75WG	Tebuconazole+Trifloxistrobin	5g/L	34.94	22.01
Mzole 32.5 SC	Difenoconazole2.5%+ Azoxystrobin20%	1mL/L	19.70	56.03
Pelert 5EC	Hexaconazole	500mL	31.10	30.58
Hayprozim 500WP	Iprodione25%+Carbendazim25%	500g	34.74	22.46
Sega-Star 32.5SC	Azoxystrobin+Difenoconazole	1mL/L	16.99	62.08
SB- Conazole 32.5SC	Azoxystrobin 20%+Difenoconazole12.5%	1mL/L	18.94	57.72
Ingenious 32.5SC	Azoxystrobin 20%+Difenoconazole12.5%	1mL/L	31.68	29.29
Alix 32.5SC	Azoxystrobin 20%+Difenoconazole12.5%	1mL/L	20.99	53.15
SB-Sativo 75WG	Tebuconazole+Trifloxistrobin	5g/L	23.18	48.26
Tebu-Plus 75WP	Tebuconazole50%+Trifloxistrobin25%	250g	19.05	57.48
Azotop 32.5 SC	Azoxystrobin +Difenoconazole	500mL	25.37	43.37
Cibazole 32.5 SC	Azoxystrobin +Difenoconazole	500mL	18.55	58.59
Quickout 50WP	Iprodione25%+Carbendazim25%	250g	34.34	23.35
Dlink 32.5 SC	Azoxystrobin 20%+Difenoconazole12.5%	1mL/L	15.62	65.13
Wintop 28SC	Azoxystrobin +Cyproconazole	0.8mL/L	28.27	36.90
Troy	Cyproconazole+ Tebuconazole+Azoxstrobin	300mL	20.85	53.46
Nativo 75WDG	Tebuconazole50%+Trifloxistrobin 25%	300g	19.91	55.56
Control			44.80	-

treated plants, which was followed by 62.08% (Segastar), 58.59% (Cibazole) and 57.72% (Ingenious). The lowest reduction (8.24%) was in Lustre treated plants.

RICE FARMING SYSTEM

Effects of tillage with crop establishment methods under Aman Rice-Wheat-Mungbean pattern

The trial was conducted at BRRI RS, Rajshahi during 2017-18 in split-plot design with three replications to increase productivity, profitability and to maintain soil health. The treatments were T_1. Direct seeding of Aman rice (dry), wheat and MB by strip tillage (ST), T_2. Direct seeding of Aman rice, wheat and MB by bed planter (BP), T_3. Transplanting Aman rice by transplanter, wheat and MB by ST, T_4. Transplanting Aman rice by transplanter, wheat and MB by BP, T_5. Farmers' practice. The grain yield of rice remained higher in T_5 treatment which was statistically similar with all other treatments except T_1. In contrast, grain yield of wheat was found lower in T_5 treatment, which was statistically similar to the rest of the treatments except T_1. The grain yield of mungbean was not influenced by the tillage and crop establishment methods. The higher cost of cultivation was found in T_5 followed by T_4 while the lower cost of cultivation was found in T_1. The gross margin was found lower in T_5 treatment, although the gross return remained higher in this treatment than the others (Table 3). The highest gross margin was found in T_4 followed by T_2. Compared with conventional, it is also noted that the gross margin was considerably higher in all other tillage and crop establishment options.

Farmers' participatory evaluation of conservation tillage and crop establishment methods under Aman Rice-Maize-Mungbean-pattern

The trial under Rice-Maize-Mungban pattern was conducted in six dispersed farmer's field at Paba upazila of Rajshahi to evaluate conservation tillage and crop establishment methods (Table 4). The grain yield of rice remained higher in T_3 and that was the lower in T_2. In contrast, grain yield of maize was found significantly lower in T_3 while the higher maize yield was recorded in T_1 closely followed by T_2. The grain yield of mungbean was not influenced by the tillage and crop establishment methods. Although the REY as well as gross return remained higher in T_3, the gross margin was found lower in this treatment due to higher cultivation cost. The higher gross margin in T_1 followed by T_2 indicated that strip tillage and bed planting system could be beneficial to the farmers.

Long term effects of different cropping patterns on crop productivity and soil health

The experiment was conducted at BRRI RS, Rajshahi to increase crop productivity and soil health. The highest REY (24.8 t/ha) was found in Potato-Boro-T. Aman cropping pattern followed by Potato-Maize-T. Aman cropping pattern (Table 5). Next to potato based patterns, Maize-Mungbean-T.

Table 3. Yield and economics as affected by tillage and crop establishment options under Rice-Wheat-Mungbean cropping system, BRRI RS, 2017-18.

Treatment	Grain yield			REY (t/ha)	TVC (Tk)	GR (Tk)	GM (Tk)
	Rice	Wheat	Mungbean				
T_1	4.75	4.12	0.94	12.2	132500	252200	119700
T_2	5.14	3.81	1.05	12.6	136200	260300	124100
T_3	5.50	3.90	0.95	12.7	142300	265000	122700
T_4	5.46	3.78	1.08	13.0	144360	268500	124140
T_5	5.49	3.73	1.11	13.1	164500	269300	104800
LSD (0.05)	0.49	0.33	0.31	0.69	-	-	-

Price Rice Tk 20/ha, Wheat Tk 20/ha, Mungbean Tk70/ha, TVC= Total variable cost. T_1. Direct seeding of Aman rice, wheat and MB by strip tillage (ST), T_2. Direct seeding of Aman rice, wheat and MB by bed planter (BP), T_3. Transplanting Aman rice by transplanter, wheat and MB by ST, T_4. Transplanting Aman rice by transplanter, wheat and MB by BP, T_5. Farmers' practice.

Table 4. Yield and economics of Aman Rice-Maize-Mungbean pattern as affected by conservation tillage with crop establishment methods, Rajshahi, 2017-18.

Treatment	Yield (t ha^{-1})			REY	TVC (Tk)	GR (Tk)	GM (Tk)
	Rice	Maize	Mungbean				
T_1. Direct seeding of Aman rice, maize and mungbean by strip tillage (ST) system	4.66	10.6	0.85	16.9	172800	338000	165200
T_2. Direct seeding of Aman rice, maize and mungbean, by bed planting (BP) system	4.55	10.4	0.91	16.8	177500	336000	158500
T_3. Farmers practice of Aman rice, maize and mungbean	5.03	9.66	1.03	17.1	198400	342000	143600
$LSD_{0.05}$	0.51	0.72	0.22	0.71			

Price, Rice Tk 20/ha, Maize Tk 17.5/ha, Mungbean Tk70/ha.

Table 5. Yield of different crops and REY of cropping patterns at BRRI RS, Rajshahi, 2015-16.

Cropping pattern	Yield (t ha^{-1})			
	Rabi	Kharf-I	Kharfi-II	REY
Potato-Boro-T. Aman	24.3	5.55	4.65	24.8
Maize-Mungbean-T. Aman	10.3	0.80	4.87	16.7
Potato-Maize-T. Aman	22.7	6.66	5.12	24.5
Wheat-Mungbean-T. Aman	3.60	0.95	5.75	12.7
Boro-T. Aus-T. Aman	6.40	5.12	5.62	16.1
Boro-Fallow-T. Aman (ck)	7.26	-	5.66	12.9
$LSD_{0.05}$	-	-	-	1.8

Price: Potato 12 Tk/kg, Maize 17.5 Tk/kg, Mungbean 70 Tk/kg, Boro rice 20 Tk/kg, Wheat 20 Tk./kg, Aman rice 20 Tk/kg, Aus rice 20 Tk/kg.

Aman cropping pattern (16.7 t/ha) gave higher REY followed by Boro-T. Aus-T. Aman (16.1 t/ha) cropping pattern.

Evaluation of rice varieties under Jute+Rice-Wheat cropping pattern along with conservation tillage system

The experiment was conducted in Charghat and Paba upazila of Rajshahi district to increase the productivity and profitability of the farmers. Six farmers fields were selected and BRRI dhan39 and BRRI dhan71 were relayed with jute and the seeds of rice were directly seeded in jute field before 15-20 days of jute harvesting in mid July. In wheat, seeds were sown on directly by bed planter or power tiller operated seeder in all the treatments except farmers' practice. Compared to the conventional transplanting, the results showed that BRRI dhan39 gave similar yield when it was grown after jute harvest. The result also showed that BRRI dhan71 gave significantly higher yield compared to BRRI dhan39 when both the varieties relayed with jute. The wheat yield was remained higher in strips followed by beds while the lower yield was found in conventional planting treatment. The gross return as well as gross margin remained lower in jute-transplanted BRRI dhan39-conventnional wheat treatment. Thus the result concluded that the farmers might be benefitted if they cultivated BRRI dhan71 jute+rice relay system along with strip/bed planted wheat (Table 6).

SOCIO-ECONOMICS AND POLICY

Stability snalysis of BRRI developed T. Aman rice varieties

Thirty-seven varieties were evaluated at BRRI RS, Rajshahi farm. Among the 37 varieties, BRRI dhan31 ranked top in terms of yield (6.45 t/ha) followed by BRRI dhan72 (6.30 t/ha). BRRI dhan38, BRRI dhan37, BRRI dhan62, BRRI dhan75

Table 6. Yield and economics of jute+rice relay-wheat cropping pattern as affected by rice varieties along with conservation tillage system, 2017-18.

Treatment	Grain yield (t/ha)		Cultivation cost (Tk)	Gross return (Tk)	Gross margin (Tk)
	Rice	Wheat			
Jute+relay BRRI dhan39-strip wheat	4.19	3.83	95900	168200	72300
Jute+relay BRRI dhan39-bed wheat	4.29	3.66	97600	166500	68900
Jute+relay BRRI dhan71-strip wheat	5.71	3.71	95700	196300	100600
Jute+relay BRRI dhan71–bed wheat	5.65	3.60	98300	193250	94950
Jute-transplant BRRIdhan39-con. wheat	4.30	3.33	115500	160400	44900
LSD (0.056)	0.51	0.31	-	-	-

Price: Rice Tk 20/kg, Wheat Tk 20/kg, Rice straw Tk. 1.5/kg.

and BRRI dhan34 were found low yielding with the yield ranging from 3.38 to 4.15 t/ha.

Stability analysis of BRRI developed Boro rice varieties

Thirty-seven varieties were evaluated at BRRI RS, Rajshahi farm. Top five varieties were BRRI hybrid dhan2 (7.01 t/ha), BRRI hybrid dhan3 (6.88 t/ha), BRRI hybrid dhan3 (6.52 t/ha), BRRI dhan 68 (6.32 t/ha) and BRRI dhan29 (6.02 t/ha) BRRI dhan63 (6.02 t/ha). BR17, BR12, BR14, BR18 and BRRI dhan35 were the low yielding varieties and the grain yield ranged from 3.88 to 4.19 t/ha.

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, Rajshshi arranged 13 training programs at different upazilas of of Rajshahj division.

Most of the farmers were very much impressed by taking part in this rice production training. About 100 kg BRRI dhan56 and 600 kg of BRRI dhan62 seeds were distributed among the participatnt farmers in different drought prone and vegetable producing areas for dissemination of those varieties.

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 each season, we executed about 35 demonstrations with latest released BRRI varieties at Rajshahi region. The farmers of Rajshahi areas were very much interested about these BRRI developed varieties. The DAE personnel can take initiative for rapid dissemination of the varieties.

Truthfully leveled and breeders seed production

The stock of the nucleus seeds 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 but TLS seed was produced in Aus and T. Aman and Boro seasons. Considering three seasons (Aus, T. Aman and Boro), 25 and 14 tons of breeder and TLS seeds were produced 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 Agricultural Extension (DAE), Bangladesh Agricultural Development Corporation (BADC), Barind Multipurpose Development Authority (BMDA) and Seed Certification Agency (SCA). Field visit to address seed sterility at flowering and blast incidence after flowering during T. Aman, information communication, providing support service in training etc were the main aspects. Clinical services were also provided to the farmers and extension workers.

BRRI RS, Rangpur

SUMMARY

For developing high yielding improved modern rice varieties, 20 single crosses were made and fourteen crosses were confirmed as true F_1s. A total of 1,200 plants were selected from F_2 population using field rapid generation advance (FRGA) technique.

Thirty-six genotypes were selected from different yield trials (OT and PYT). One genotype, BRRI dhan49 NILs, BR10050-32-181-257-2-10 showed lodging tolerance and free from false smut disease. It produced significantly higher grain yield (4.37 t/ha) than BRRI dhan49 (3.99 t/ha) with 17 days earlier growth duration. A total of 272 tolerant progenies were selected from segregating generations' (F_3 to F_7) for development submergence and medium stagnant flood tolerant rice.

In AYT, IR13F548 performed the best for the highest survival percent (80.5%), effective tiller production (17) and grain yield (6.47 t/ha). In PVS mother trial under rainfed condition, PVS-10 (BRRI dhan52) and PVS-6 (IR13F457) at Kulaghat and PVS-3 (IR13F441) and PVS-10 (BRRI dhan52) at Mogholhat were chosen by the farmers.

Effect of time of submergence on survival, recovery and yield of submergence tolerant genotype BRRI dhan52, the highest survival (78.6%) was found in T_5 (20 days later submergence) while the lowest (24.6%) was in T_1 (just transplanting day). T_5 (20 DAT) also showed the highest yield (4.40 tha^{-1}) among the treatments.

A total of 24 advanced promising breeding lines were selected from RYT in T. Aus (01), T. Aman (11) and Boro (12) seasons. BR(Bio)9787-BC2-63-2-4 showed 0.9 t/ha yield advantage over BRRI dhan48 in T. Aus. BR9392-6-2-1B and BR10248-5-1 produced the highest yield (5.4 t/ha) than BR11 (4.9 t/ha) and Swarna5 (5.3 t/ha) with similar growth duration (136-138 days). These materials were selected for ALART in Rangpur region.

BR8634-23-1-1-BHA-1 showed 0.47 t/ha more yield than BRRI dhan29 with 8 days earlier growth duration in Boro season.

Under TRB project, 28 promising genotypes were selected including four T. Aus, 14 T. Aman and ten Boro.

In PVT for T. Aus, proposed line NERICA10-7-PL2-B produced 0.84 t/ha yields advantage over BRRI dhan48 with five days earlier growth duration (Finally this line approved as BRRI dhan82). In PVT for FBR, the proposed line BRRI dhan29-SC3-28-16-10-8-HR1 (Com) yielded better than the check variety BRRI dhan28. Proposed line BR (Bio) 9786-BC2-59-1-2 and BR (Bio) 9786-BC2-59-1-2 gave better yield over the check BRRI dhan29 for Boro season.

A total of 19 metric tons seed (TLS and breeder) of recently released different BRRI varieties were produced in three seasons. Eighteen farmers, 12 in-house training programmes and 15 field days were arranged during this reporting period. Moreover, two workshops were conducted on 'Increasing rice cultivation area and production in Rangpur-Dinajpur region' during Aus, Aman and Boro seasons.

VARIETY DEVELOPMENT

Regional yield trial (RYT), Aus 2017. Two RYTs were conducted under Aus season: one Broadcast Aus and another T. Aus were tested against standard check varieties.

RYT#1 (B. Aus). Twelve genotypes along with the two checks; BRRI dhan43 and BRRI dhan65 were evaluated. None of the materials were found suitable against the check variety BRRI dhan65.

RYT#1 (T. Aus). Five genotypes along with one check BRRI dhan48 were evaluated. BR (Bio) 9787-BC2-63-2-4 showed 0.9 t/ha yield advantage over check variety BRRI dhan48 with two days longer growth duration.

Preliminary yield trial (PYT, T. Aus, TRB project). Sixteen genotypes along with two checks; BR26 and BRRI dhan48 were evaluated. Plant height ranged from 95 to 125 cm. Growth duration ranged from 112 to 124 days. The highest yield was observed in BR9006-10-2-1-1(5.67 t/ha) followed by BRRI dhan48 (5.45 t/ha) and BR9029-51-3-5 (5.17 t/ha). BR9006-10-2-1-1 gave 0.22 t/ha yields advantage over the check BRRI dhan48 with similar growth duration (112 days).

RYT#1, T. Aus, TRB project. A total of 14 entries with two checks (BR26 and BRRI dhan48) were evaluated. Plant height ranged from 100 to 119 cm and maturity duration ranged from 114 to 121 days. Among the tested entries, two genotypes viz BR9011-34-3-2 (5.07 t/ha) and BR9011-67-4-

1 (5.39 t/ha) yielded higher than the check BRRI dhan48 (4.89 t/ha). BR9011-67-4-1 produced 0.5 t/ha yields advantage over the check BRRI dhan48 with four days earlier.

RYT#2, T. Aus, TRB project. Nine genotypes along with two checks; BRRI dhan48 and BRRI dhan65 were evaluated. Plant height ranged from 91 to 132 cm and maturity duration ranged from 104 to 122 days. All the tested entries did not perform better than the check variety BRRI dhan48.

PVT. One PVT for T. Aus was conducted in Pirganj, Rangpur. The proposed line NERICA10-7-PL2-B showed 0.84 t/ha yield advantage over BRRI dhan48 with five days earlier growth duration.

Development of rice varieties suitable for Rangpur region, T. Aman 2017. The major aim of the project was to develop improved genotypes with high yield potential (>7 t/ha), earliness (100-130 days) and tolerance to drought with acceptable grain quality in Rangpur region. Nine single crosses were made using eleven parents (donors and recipients) and 880 F_1 seeds were produced. Twelve crosses were confirmed from 13 crosses as true F_1s. 1,200 plants were selected from five F_2 population using FRGA technique. Sixteen lines were selected from observational trial (OT) based on growth duration, homogeneity, agronomic parameters and yield. Ten genotypes were selected from PYT for secondary yield trial (SYT). BR10050-32-181-257-2-10 gave higher yield than all the checks having lodging tolerance and free from false smut disease. It performed better with the 0.38 and 1.06 t/ha yields advantage over the check varieties BRRI dhan49 and Swarna5 respectively (Table 1). This genotype showed 17 and 27 days earliness compared to BRRI dhan49 and Swarna5 respectively.

RYT, T. Aman, 2017. Nine RYTs were conducted under T. Aman season: two rainfed lowland (RLR), two premium quality (PQR), one zinc enriched rice (ZER), one insect resistance (IRR), one Biotechnology, one GRSD and one Rangpur regional station against standard check varieties.

Table 1. Performance of the selected BRRI dhan49 NILs, T. Aman 2017.

Designation	Duration (day)	PHt. (cm)	Yld. (t/ ha)
BR10050-32-181-299-1-1	111	105	4.19
BR10050-32-181-257-2-10	113	109	4.37
BR10050-27-2-1-2	113	108	4.34
Swarna5	140	122	3.31
BRRI dhan49	130	115	3.99
LSD (0.05)	0.78	7.71	0.74

RYT#1 (RLR-1). Eleven genotypes along with two checks BRRI dhan39 and BRRI dhan49 were evaluated. One genotype BR8841-22-2-4-2 having 0.3 t/ha yield advantage over check variety BRRI dhan49 with similar growth duration (128 days).

RYT#2 (RLR-2). Seven genotypes along with two checks BRRI dhan39 and BRRI dhan49 were evaluated. One genotype BR8503-1-2-3-5 gave 0.5 t/ha yield advantage over check variety BRRI dhan49 (4.2 t/ha) with eight days longer growth duration.

RYT#3 (PQR-1). Seven genotypes along with two checks Kalizira and BINA dhan-13 were evaluated. The highest yield was found in genotypes BR8493-3-5-1 (Com) (3.4 t/ha) followed by BR8493-16-5-1 (Com) (2.8 t/ha) and BR8493-12-7-4 (Com) (2.6 t/ha) having higher yield over the check varieties Kalizira (1.4 t/ha) and BINA dhan13 (2.3 t/ha).

RYT#4 (PQR-2). Seven genotypes along with two checks BRRI dhan37 and Kataribhog were evaluated. BR8846-32-2-4-2 and BR8846-38-2-4-2 having 0.9 t/ha yield advantage over Kataribhog (1.8 t/ha) with 20 days earlier growth duration.

RYT#5 (ZER). Six genotypes along with four checks BRRI dhan33, BRRI dhan39, BRRI dhan72 and BINA dhan-7 were evaluated. None of the tested materials was found better than BRRI dhan72.

RYT#6 (IRR). Six genotypes along with two checks BRRI dhan33 and BRRI dhan49 were evaluated. None of the tested materials was found better than BRRI dhan49.

RYT#7 (Biotechnology). Four genotypes along with one checks BRRI dhan49 were evaluated. BR (Bio) 8961-AC26-16 showed 0.2 t/ha yield advantage over BRRI dhan49 with four days earlier growth duration.

RYT#8 (GRSD). Three varieties: Rajasail, Monibandhobi and BRRI dhan46 were evaluated. Monibandhobi gave the highest yield (3.8 t/ha) where as Rajasail and BRRI dhan46 gave 3.2 and 3.6 t/ha yield.

RYT#9 (Rangpur regional station). Four genotypes along with six checks Sumon swarna, Ranjit swarna, Nepali swarna and Swarn5, BR11 and BRRI dhan49 were evaluated in three locations of Rangpur region. BR9392-6-2-1B and BR10248-5-1 gave the highest yield (5.4 t/ha) followed by BR8189-10-2-3-1-5 9 (5.3) t/ha among the tested materials over the check varieties. Growth duration of the selected materials ranged from 135 days to 138 days, which was similar to the check varieties BR11 (138 days) and Swarna5 (136 days). These materials were found suitable for ALART in Rangpur region.

Breeding for submergence and water stagnation tolerance (STRASA project), T. Aman 2017

Growing and screening of pedigree generations. In total 858 tolerant progenies of 2 F_3, 7 F_5, 8 F_6, 6 F_7 and 6 F_8 populations were grown under control submergence condition. In total, 272 tolerant progenies which showed better plant type were selected from F_3 to F_7 pedigree populations.

Advanced yield trial (AYT), submergence and water stagnation tolerance, T. Aman 2017. Fifteen entries with five checks; BRRI dhan51, BRRI dhan52, BINA dhan-11, BINA dhan-12 and BRRI dhan44 were evaluated. The experiment was set up in on station submergence tank. The crop was submerged at the depth of 100 cm for a period of 17 days. IR13F548 performed the best for the highest survival percent (80.5%), effective tiller production (17) and grain yield (6.47 t/ha) among the tested genotypes. IR13F452 gave the second highest yield (5.29 t/ha). Growth duration was similar with BRRI dhan52 and BINA dhan-12 (170 days).

Participatory variety selection (PVS) under rainfed and submergence conditions in on station - mother trial. Eight submergence and medium stagnant water tolerant high yielding genotypes along with four standard check varieties BRRI dhan51, BRRI dhan52, BINA dhan-11, BINA dhan-12 having submergence tolerance genotypes were evaluated. The experiment was set up in a rainfed plot and a submergence tank in on station experimental field. In submergence trial, the crop was submerged at the depth of 100 cm for a period of 17 days. In control submergence trial, the tested entries didn't survive 17 days of submergence. The considerable reasons were outbreak of *Naiasgraminea, Monchoriahastata, Nymphoidesindica* and *Azollapinnata* type aquatic weeds during submergence period. So, no entries were selected from this trial. In rainfed trial, all genotypes under this evaluation observed similar plant height, tiller production and yield. No entry was found as the best for yielding than the check varieties.

PVS under rainfed conditions in on farm - mother trial. There were two on-farm PVS mother trials in the northern districts, one in Khatamari, Kulaghat, (Sadar, Lalmonirhat) and another in Kodalkhata, Mogholhat, (Sadar, Lalmonirhat) (Table 2). At Kulaghat PVS trial, crop was submerged 19 days after transplanting at the depth of 2.4 meter for a period of 12 days with six days stagnation water pressure. PVS-3 (IR13F441) gave the highest survival percent (95.8%) with the highest yield (4.54 t/ha) performance. At Mogholhat PVS trial, crop was submerged 16 days after transplanting at the depth of 3.0 meter for a period of eight days with 11 days stagnation water pressure. Same observation of this trial was PVS-3 (IR13F441) showed the highest survival percent (79.4%) with the highest yield (4.17 t/ha) performance. However, all the genotypes showed longer growth duration under submergence conditions. In PVS function, 30 farmers including 20 male and 10 female participated in the voting activities. Farmers have chosen PVS-10 (BRRI dhan52) and PVS-6 (IR13F457) at Kulaghat and PVS-3 (IR13F441) as well as PVS-10 (BRRI dhan52) at Mogholhat.

Effect of submergence time on survival, recovery and yield of submergence tolerant genotypes. The trial was conducted in control submergence condition. BRRI dhan52 was evaluated

Table 2. Preference analysis of participatory variety selection, T. Aman 2017, Kulaghat and Mogholhat, Sadar, Lalmonirhat.

Location	Farmers' preference ranking and score			
	1st Positive	2nd Positive	1st Negative	2nd Negative
Kulaghat, sadar Lalmonirhat	BRRI dhan52 (0.867)	IR13F457 (0.400)	IR13F458 (-0.700)	IR 92466-SUB-SUB-59-1-B (-.0600)
Mogholhat, sadar Lalmonirhat	IR13F441 (0.667)	BRRI dhan52 (0.633)	BINA dhan-11 (-0.567)	IR 92471-SUB-SUB-39-3-B (-0.300)

under different treatments in this trial. Time of submergence significantly influenced on survival. The highest survival (78.6%) was found in T_5 (20 days later submergence) while the lowest (24.6%) was in T_1 (just transplanting day). T_5 (20 DAT) also showed the highest yield (4.40 t/ha^{-1}) among the treatments. The data revealed that plants which submerged on the transplanting day to five days suffered much and gave poor survival and yield. On the other hand, when submergence occurred at 10-20 days later after transplanting crop gave better survival and yield. Therefore, if submergence is occurred in few days later after transplanting, submergence tolerant rice can survive (Table 3).

Breeding for submergence (SUB) and water stagnation (SFT) tolerance rice under TRB project

Observational yield trial (OYT). Eight entries with four checks were evaluated in two locations. Thirty-five-day-old seedlings were transplanted at a spacing of 25 cm × 15 cm with single seedling per hill. The unit plot size was 5.4 m × 4 rows. The field was laid out with Latinized Row-Column design with two replications. In Darshona, the crop was submerged 25 days after transplanting at the depth of 1.55 meter for a period of 10 days with four days stagnation water pressure. Seven entries were survived under this evaluation. Among the tested entries, the highest survival percent was observed in IR94391-131-358-19-B-1-1-1(34.0) followed by IR96321-558-257-B-5-1-2 (29.9) and IR96321-1447-651-B-1-1-2 (27.1). The genotype IR94391-131-358-19-B-1-1-1 gave the highest yield (3.78 t/ha) followed by IR96321-558-257-B-5-1-2 (3.17 t/ha) with this flood situation. In Badorganj, the crop was submerged 19 days after transplanting at the depth of 2.66 meter for a period of 15 days with 10 days stagnation water pressure. None of the entries survived under this evaluation.

Preliminary yield trial (PYT# 1, 2 and 3). A total of 12 (PYT#1), 41 (PYT#2) and eight (PYT#3) entries with four checks were evaluated in two locations. In Darshona, the crop was submerged 25 days after transplanting at the depth of 1.55 meter for a period of 10 days with four days stagnation water pressure. In PYT#1, four entries survived under this evaluation. BR8449-2-1-1-1-8-1 gave the highest survival percent (15.5) and yield (1.44 t ha^{-1}) among the genotypes. However no entry was found satisfactory for survival and yield performance. In PYT#2, thirty-nine entries survived under this evaluation. Among the genotypes, IR13F450-5 showed the highest survival percent (45.8) and yield (4.01 t/ha). However the genotype showed longer growth duration. In PYT#3, five entries survived under this evaluation. However no entry was found satisfactory for survival and yield performance. In Badorganj, the crop was submerged 19 days after transplanting at the depth of 2.66 meter for a period of 15 days with 10 days stagnation water pressure. None of the entries survived under this evaluation (PYT-1, PYT-2 and PYT-3).

Advanced yield trial (AYT). A total 15 entries with five checks were evaluated in the experiment in two locations. In Darshona, the crop was submerged 25 days after transplanting at the depth of 1.55 meter for a period of 10 days with four days stagnation water pressure. Five entries survived under this evaluation. The highest survival percent (24.31) and yield (2.87 t ha^{-1}) were found in IR91545-SUB-SUB-4-1-2 among the genotypes. However no entry was found satisfactory for survival and yield performance. In Badorganj, the crop was submerged 19 days after transplanting at the depth of 2.66 meter for a period of 15 days with 10 days stagnation water pressure. None of the entries survived under this evaluation.

Table 3. Effect of submergence time on survival percent, yield and yield component, BRRI RS, Rangpur, T. Aman 2017.

Treatment	Survival (%)	PHt. (cm)	Tiller hill^{-1}	Panicle hill^{-1}	Yld. t/ ha	Duration (day)	Sterility (%)	TGW (gm)
T_1: 0 DAT	24.6	98	12	12	1.99	152	21.5	23.0
T_2: 5 DAT	40.7	99	11	10	2.43	153	19.9	23.5
T_3: 10 DAT	57.7	99	10	9	3.80	155	25.6	24.0
T_4: 15 DAT	73.9	99	11	10	4.18	156	27.4	24.6
T_5: 20 DAT	78.6	97	12	11	4.44	158	24.4	25.7
$LSD_{0.05}$	15.76	4.09	1.58	1.84	0.56	0.91	4.77	1.21

Preliminary yield trial (PYT for development of drought tolerant rice). Fourteen genotypes along with three standard checks (BRRI dhan56, BRRI dhan66 and BRRI dhan71) were evaluated in the experiment. Plant height ranged from 105 to 126 cm and maturity duration ranged from 108 to 127 days. The highest yield was found in IR94391-131-358-19-B-6-1-4 (6.25 t/ha) followed by IR11N202 (5.78 t/ha) and IR96321-327-153-B-2-1-1 (5.47 t/ha). IR94391-131-358-19-B-6-1-4 gave 1.92 t/ha yield advantage over BRRI dhan66 with similar growth duration (117 days).

Regional yield trial (RYT for development of drought tolerant rice). Nine genotypes along with three standard checks (BRRI dhan56, BRRI dhan66 and BRRI dhan71) were evaluated. Plant height ranged from 106 to 125 cm and maturity duration ranged from 110 to 117 days. IR88965-39-1-6-4 gave 0.17 t/ha yield advantage over BRRI dhan71 with five days earlier growth duration.

PYT for the development of rainfed lowland rice (RLR). Sixteen genotypes along with two standard checks (BRRI dhan32 and BRRI dhan39) were evaluated. Plant height ranged from 106 to 128 cm and growth duration ranged from 119 to 126 days. Yield ranged from 3.46 t/ha (IR 83142-B-57-B) to 5.55 t/ha (IR 101465-5:33) where the check variety BRRI dhan32 gave 4.96 t/ha.

RYT# 1 and 2 for the development of rainfed lowland rice (RLR). Ten and six genotypes along with four standard check varieties were evaluated at RYT#1 and RYT#2, respectively. In RYT#1, plant height ranged from 117 to 130 cm and growth duration ranged from 117 to 125 days. Yield ranged from 2.16 t/ha to 5.03 t/ha. The tested entries did not perform better than the check BRRI dhan32 but one genotypes BR9124-11-2-3-3 (4.62 t/ha) performed better than BRRI dhan39 (4.53 t/ha) with similar growth duration (125 days). In RYT#2, plant height ranged from 118 to 129 cm and growth duration ranged from 124 to 129 days. Yield ranged from 4.22 t/ha to 5.75 t/ha. The tested entries did not perform better than the standard check varieties (BR11 and BRRI dhan49).

PYT for the development of disease resistance (BB) rice. Five genotypes along with three standard checks BRRI dhan33, BRRI dhan39 and IRBB60 were evaluated. Plant height ranged from 86 to 105 cm and growth duration ranged from 123 to 132 days. Yield ranged from 2.63 t/ha to 3.55 t/ha. None of the tested entries performed better than the standard check varieties BRRI dhan33 (3.34 t/ha) and BRRI dhan39 (3.55 t/ha).

RYT for the development of disease resistance (BB) rice. Nine genotypes along with three standard checks (BRRI dhan39, BRRI dhan49 and IRBB60) were evaluated. The crop was submerged nine days after transplanting at the depth of 1.26 meter for a period of eight days with five days stagnation water pressure. Plant height ranged from 85 to 113 cm and growth duration ranged from 120 to 137 days. Yield ranged from 2.45 t/ha to 3.61 t/ha. BR9140-5-22-5-1 produced the highest yield (3.61 t/ha) over the check variety BRRI dhan49 (3.45 t/ha) with four days earlier growth duration.

Development of rice varieties suitable for Rangpur region (Boro, 2017-18). Main aim of the project was to develop improved genotypes with high yield potential (>8 t/ha), earliness (130-140 days) and accompanied with tolerance to cold with acceptable grain quality in Rangpur region. Ten single crosses were made using 11 parents (donors and recipients) and 200 F_1 seeds were produced. Two crosses were confirmed from 12 crosses as true F_1s.

RYT, Boro, 2017-18. Seven RYTs were conducted during Boro season: one rainfed lowland (FBR), one premium quality (PQR), one insect resistance (IRR), three zinc enriched rice (ZER) and one Biotechnology against standard check varieties.

RYT#1 (FBR). Ten genotypes along with two checks BRRI dhan28 and BRRI dhan58 were evaluated. The highest yield was found in genotypes BR8938-30-2-4-2-1 (7.2 t/ha) followed by IR09A235 (7.1 t/ha) and IR99092-B-B-91 (7.1 t/ha) having higher yield over the check varieties BRRI dhan28 (6.4 t/ha) and BRRI dhan58 (6.8 t/ha). BR8938-30-2-4-2-1 gave 0.4 t/ha yield advantage over BRRI dhan58 with similar growth duration (167 days).

RYT#2 (PQR). Four genotypes along with four checks Minikit, Shampakatari, BRRI dhan28, BRRI dhan50 and BRRI dhan63 were evaluated. None of the tested materials performed better than the check variety BRRI dhan63.

RYT#3 (IRR). Six genotypes along with three checks BR3, BRRI dhan28 and T27A were evaluated. BR8340-5-6-1 gave higher yield (7.80

t/ha) followed by BR8335-10-6-3-10 (7.37 t/ha). BR8340-5-6-1 produced 0.33 t/ha yield advantage over BRRI dhan28 (7.32 t/ha) with eight days longer growth duration.

RYT#4 (ZER-1). Ten genotypes along with three checks BRRI dhan28, BRRI dhan29 and BRRI dhan74 were evaluated. The highest yield was found in BR8634-23-1-1-BHA-1 (6.13 t/ha in 166 days) followed by BR8634-23-1-1-BHA-5 (5.76 t/ha in 162 days) and BR8634-23-1-1-BHA-3 (5.73 t/ha in 163 days) among the tested entries. BR8634-23-1-1-BHA-1 produced 0.47 t/ha yield advantage over BRRI dhan29 (5.66 t/ha in 174 days) with eight days earlier growth duration.

RYT#5 (ZER-2). Three genotypes along with two checks BRRI dhan28 and BRRI dhan74 were evaluated. None of the genotype produced better yield than the check varieties BRRI dhan28 and BRRI dhan74.

RYT#6 (ZER-3). Three varieties BRRI dhan28, BRRI dhan27 and BRRI dhan62 were evaluated. BRRI dhan62 yielded the highest (6.2 t/ha and 150 days) followed by BRRI dhan57 (5.6 t/ha in 170 days) and BRRI dhan28 (5.4 t/ha in 145 days).

RYT#7 (Biotechnology, FBR). Four genotypes along with check BRRI dhan58 were evaluated. Growth duration of the materials ranged from 166 to 173 days and plant height ranged from 86 to 93 cm. None of the tested materials performed better than the standard check BRRI dhan58.

Yield maximizing trial (YMT). One genotype along with two checks BRRI dhan28 and BRRI dhan58 were evaluated. BRH11-9-91-4-5B produced the highest yield (6.26 t/ha and 162 days) followed by BRRI dhan28 (5.72 t/ha in 147 days) and BRRI dhan58 (5.43 t/ha in 145 days).

Proposed variety trial (PVT). In total four PVT were conducted at Mithapukur, Rangpur and Parbotipur, Dinajpur during Boro season. In PVT#1(FBR), proposed line BRRI dhan29-SC3-28-16-10-8-HR1 (Com) yielded 1.19 t/ha yields advantage over BRRI dhan28. In PVT#2 (LD), BR(Bio)9786-BC2-59-1-2 produced 1.0 t/ha yield advantage than BRRI dhan29 with almost similar growth duration. Both PVT#3 and PVT#4 for low water requirement, one genotype BR (Bio) 9786-BC2-59-1-2 was tested against the check variety BRRI dhan29. The proposed line yielded higher grain yield over the check in both trial. It gave 0.04 and 0.19 t/ha yields advantage over the BRRI dhan29 in both the locations with almost similar growth duration.

Observational yield trial (OYT) for the development of cold tolerant rice under TRB project. A total of 196 cold tolerant rice genotypes were evaluated along with standard check BRRI dhan28, BRRI dhan36 and BRRI dhan69. Growth duration ranged from 143 to 170 days. Among the tested entries 54 genotypes were selected based on homogeneity. The highest yield was found in BR10712-5R-186 (7.10 t/ha in 158 days) followed by BR10707-5R-5R-68 (7.06 t/ha in 168 days) and BR10709-5R-262 (7.03 t/ha in 163 days)**.** Genotype BR10712-5R-186 gave 1.59 and 1.59 t/ha yields advantage over BRRI dhan28 and BRRI dhan69 respectively.

Preliminary yield trial (PYT) for the development of cold tolerant rice under TRB project. A total of 33 genotypes were evaluated along with three standard check BRRI dhan28, BRRI dhan69 and BRRI dhan36. Plant height was the highest in BR8244-5-1-1-1-1-CS1-2-CS2-2-2-1 (120 cm) and lowest in BR8909-B-12-2-CS1-4-CS2-P2-3-2 (86 cm). Growth duration ranged from 143 to 168 days. The highest yield was observed in BR9989-23-CS1-1-CS2-18-2-3 (6.98 t/ha) followed by BR9989-23-CS1-1-CS2-16-1-10 (6.89 t/ha) with similar growth duration (155 days). BR9989-23-CS1-1-CS2-18-2-3 showed 1.49 t/ha yields advantage over BRRI dhan28 (5.49 t/ha).

Advanced yield trial (AYT) for the development of cold tolerant rice under TRB project. A total of five genotypes were evaluated along with three standard check BRRI dhan28, BRRI dhan69 and BRRI dhan36. Plant height was the highest in BR8562-11-2-6-2-5-2 (94 cm) and the lowest in BR8562-11-2-6-1-1-2 (85 cm). Growth duration ranged from 144 to 161 days. The highest yield was observed in BR8562-11-2-6-1-1-1 (6.96 t/ha). BR8562-11-2-6-1-1-1 gave 1.35 and 2.36 t/ha yield advantage over BRRI dhan28 (5.61 t/ha) and BRRI dhan36 (4.60 t/ha) respectively.

PYT#1 and 2 for the development of disease resistance (BB) rice. Seven genotypes for PYT#1 and 12 genotypes for PYT#2 along with the BB resistant check IRBB60 and the susceptible check BRRI dhan28, BRRI dhan29 and BRRI dhan58 were evaluated. In PYT#1, plant height ranged from 85 to 108 cm and growth duration ranged from 144 to159 days. None of the tested entries performed better than the standard check BRRI dhan58. The highest yield was found in BRRI dhan58 (6.32 t/ha) where as the lowest was in IRBB60 (4.45 t/ha). In PYT#2, plant height ranged from 85 to 109 cm and growth duration ranged from 152 to 165 days. The highest yielding genotype was found in BR9943-40-3-2 (7.84 t/ha) followed by BR9943-40-3-2 (7.69 t/ha) and BR9650-108-2-3 (7.39 t/ha). BR9943-40-3-2 gave 1.21 and 1.55 t/ha yields advantage over BRRI dhan29 (6.63 t/ha) and BRRI dhan58 (6.29 t/ha) respectively. BR9943-40-3-2 gave higher yield with similar growth duration to BRRI dhan29 (164 days) but 10 days longer than BRRI dhan58 (154 days).

Regional yield trial (RYT). Regional yield trial consisting of four genotypes along with the BB resistant check IRBB60 and the susceptible check the BRRI dhan58 and BRRI dhan29 were evaluated in the trial. The field layout was in RCB with three replications. Plant height was the highest in BR9942-38-4 (117 cm) and lowest in IRBB60 (86 cm). Growth duration ranged from 154 to 165 days. The highest yield was observed in BR9943-2-1 (7.63 t/ha) where as the lowest was in IRBB60 (4.32 t/ha). BR9943-2-1 gave 1.23 and 1.26 t/ha yield advantage over BRRI dhan29 (6.40 t/ha) and BRRI dhan58 (6.37 t/ha) respectively. BR9943-2-1 had similar growth duration to BRRI dhan29 (165 days) but 11 days longer than BRRI dhan58 (154 days).

CROP-SOIL-WATER MANAGEMENT

Effect of crop establishment methods and nutrient management on the performance of newly developed Boro, T. Aus and T. Aman varieties at Rangpur region

An experiment was conducted at BRRI RS farm, Rangpur during T. Aus, T. Aman and Boro seasons to find out the effect of crop establishment methods and nutrient management on yield and yield contributing factors. The experiment was laid down in RCBD with three replications. The treatment combinations were three nutrient management and four crop establishment methods. A: nutrient management; N_1- AEZ based BRRI recommended nutrient, N_2: BRAC fertilizer recommended guide 2012 based and N_3: Control. B: Crop establishment methods; M_1: BRRI recommended management (40-day-old seedling, two seedling per hill, 20 × 20 cm spacing), M_2: SRI management (12-day-old one seedling per hill, 30 × 30 cm spacing with SRI water management, M_3: Sprouted seed at 20 cm apart by line sowing, M_4: Spouted seed by broadcasting. Tested varieties in T. Aus, T. Aman and Boro season were BRRI dhan48, BRRI Dhan71 and BRRI dhan63 respectively.

In Boro season treatment N2M2 (6.68 t/ha) and in Aus N2M1 (4.00 t/ha) performed higher grain yield than the other treatments (Table 4).

Table 4. Interaction between nutrient management and crop establishment method of yield and yield attribution of BRRI dhan63.

Treatment	Panicle length	1000-grain weight	Grain yield	Straw yield	Biological yield	Harvest index
N_1M_1	20.74ab	19.09de	4.40cd	5.18b	9.91bc	40.40f
N_1M_2	20.46abc	22.82ab	5.73b	4.89b	10.62b	55.22a
N_1M_3	20.60abc	20.40cd	4.32cd	3.86c	8.19d	52.80abc
N_1M4	20.10abc	20.38cd	3.25e	4.90b	8.46d	38.51g
N_2M_1	21.81a	23.16a	4.52cd	3.62c	7.81d	53.60ab
N_2M_2	22.76a	23.58a	6.45a	6.68a	13.13a	49.05de
N_2M_3	20.20abc	21.34bc	4.49cd	4.96b	8.78cd	47.57def
N_2M_4	20.34abc	21.16c	4.08ed	4.74b	9.01cd	46.33ef
N_3M_1	18.76bcd	22.82ab	4.21cd	4.34bc	8.54d	49.49cde
N_3M_2	18.54bcd	22.74ab	4.75c	5.17b	9.92bc	47.88def
N_3M_3	17.74cd	18.31e	3.96d	3.89c	7.84d	51.04bcd
N_3M_4	16.54d	18.14e	1.86f	2.17d	4.03e	46.43ef
LS	***	*	**	**	**	**
CV(%)	7.55	4.11	9.51	10.24	8.01	3.93

TECHNOLOGY TRANSFER

Truthfully labeled seed (TLS) and breeder seed production

TLS was produced in T. Aus. T. Aman and Boro seasons. In T. Aus season 2,250 kg TLS (BR24, BR26, BRRI dhan48, BRRI dhan55 and BRRI dhan65) was produced and 2,189 kg of TLS of BR24, BR26, BRRI dhan48, BRRI dhan55, BRRI dhan65 were distributed among the farmers or agricultural related different GO/NGOs. In T. Aman, 5,286 kg TLS of different varieties were produced and distributed 3,868 kg TLS. A total of 4,892 kg of TLS of different popular as well as newly released varieties were distributed in Boro season. A total of 1,880 kg (BRRI dhan52, BRRI dhan66 and BRRI dhan71) breeder seeds in T. Aman and 4,750 kg (BRRI dhan58) in Boro season were produced.

Demonstration of BRRI released varieties

A total of 153 demonstrations (variety and technology) were conducted at different locations of Rangpur region during T. Aus 2017, T. Aman 2017 and Boro 2017-18. In T. Aus, BRRI dhan48; in T. Aman, BRRI dhan49, BRRI dhan57, BRRI dhan66, BRRI dhan71, BRRI dhan72 and BRRI dhan75; and in Boro, BRRI dhan58, BRRI dhan63, BRRI dhan74 and BRRI dhan81 were used. Farmers were very much interested about these newly released varieties.

Training, field day, fair and workshop

Eighteen farmers' training programmes on modern rice production technology were conducted at different upazilas of Rangpur region. A total of 540 farmers were trained through this program. This training program is very much useful to build up their knowledge on modern rice production technologies. A total of twelve in-house training were arranged at the BRRI RS to improve the capability in office management of the staffs. Fifteen field days were conducted in three seasons. Two workshops were arranged on 'Increasing rice cultivation area and production in Rangpur-Dinajpur region' during Aus and Boro seasons.

BRRI RS, Satkhira

SUMMARY

A total of 646 and 269 progenies were selected from 62 and 18 crossing populations from F_2 to F_4 in Aman and Boro season, respectively. Seventy-eight lines were selected from F_5 for observational trial (OT) in both the seasons. In rapid generation advance (RGA) trial, 5,716 and 3,347 panicles were collected from $4F_3$, and $7F_4$ populations respectively. Thirty-four lines were selected from 127 lines under OT. Among 87 genotypes, 32 and 19 lines were selected for next salinity breeding programme during Aman 2017. Aside from this, 25 and 19 entries were selected from Assasuni and Koyra respectively during Boro 2017-18. From 127 STBN entries, 34 and 21 genotypes were selected in Aman 2017; where 25 and 35 were selected in Boro 2017-18 at Assasuni and Koyra respectively based on their saline tolerance ability and yield.

IR100638-6-CMU3-CMU1, IR100661-SBN11-1-AJY1, IR103513-B-AJY15-3, IR103960-CMU1-CMU2-2 and IR100674-274-IFT1-CMU3 showed higher yield in preliminary yield trial (PYT) under three locations of Assasuni, Kaliganj and Koyra. BR9627-1-3-1-10 (9.63 t ha^{-1}) yielded higher among the 17 lines compared with BRRI dhan28, BRRI dhan67 and Bina dhan-10 during Boro 2017-18 in PYT at three same locations. Among the tested 17 entries, 5 entries yielded more than 9 ton ha^{-1} those were higher than all the checks irrespective of location.

In secondary yield trial (SYT), BR8729-B-7-3-2 gave higher yield compared to BR11, BRRI dhan54 and BRRI dhan73 in Aman 2017.

From regional yield trial (RYT) in Aman season; yield performance of IR10F102 and BRRI dhan29-SC3-28-16-15-HR2(Com) was better in RLR. BR8493-12-7-4 (Com), BR8851-12-4-2-3, BR8850-10-12-3-1, BR8846-38-2-4-2 and BR8846-32-2-4-2 was higher yielder in RYT of PQR. BR8692-1-4-2-1 and BR8693-17-6-2-1 showed higher yield in RYT of IRR.

From RYT in Boro 2017-18; BR (Bio) 9777-113-12-5 showed higher yield compared to BRRI dhan58 in RYT-FBR (Bio) where BR8938-30-2-4-2-1 and IR06N220 showed higher yield than BRRI dhan28 and BRRI dhan58 (5.26 t ha^{-1}) in RYT of FBR. BR8634-23-1-1-BHA-2, BR8634-23-1-1-BHA-10 and BR7528-2R-19-16-RILL-1 yielded higher than BRRI dhan74 and the tested entries in RYT of ZER. Four entries of Dinajpur Minikat (Rangpur), BR8590-5-2-5-2-1, Shampakatari (Shingra-Natore) and BR9207-45-2-2 yielded better than the checks in RYT for PQR with similar growth duration. BRH11-911-4-5B yield better than the checks in YMTs. HHZ5-DT20-DT2-DT1 and WANXIAN7777-P18 performed better against BRRI dhan58, BRRI dhan29, BRRI dhan67 and Bina dhan-10 in RYT of GSR.

BRRI dhan73 ranked first positive in two locations; BRRI dhan54 and BR8727-B-2-1-1 ranked first positive in one location against 11 entries tested at Assasuni, Kaliganj, Debhata and Koyra during Aman 2017. BRRI dhan67, Bina dhan-10 and BR8982-9 individually ranked first positive in one location each of Assasuni, Debhata and Koyra against 10 entries in Boro 2017-18.

Based on the result of missing element trial, balanced fertilizer application is needed for higher yield in saline and non-saline gher where N is the most critical nutrient element. The second most critical nutrient is K and P for saline and non-saline gher respectively. Higher grain yield was found in 25% and 50% higher dose of N (155 kg ha^{-1}) and K (90 kg ha^{-1}) respectively in saline ecosystem.

Among T. Aman varieties, BRRI hybrid dhan6, BRRI hybrid dhan4, BRRI dhan73, BRRI dhan44 and BR23 yielded relatively higher (>5.50 ton ha^{-1}) and in Boro varieties, BRRI hybrid dhan5 as well as BRRI hybrid dhan3 produced the highest yield. BRRI dhan30 showed more adaptable for rice-fish system in saline area.

In total 58 demonstrations (Aus, Aman and Boro) were conducted during 2017-18 under SPDP programme. Fifteen farmer's training (360 farmers) and 18 field days were arranged and we attended two agricultural fairs this year as well as participated in different respective technical activities.

VARIETY DEVELOPMENT

Selection from pedigree nursery (F_2-F_5)

In Aman season, 646 progenies were selected from 62 crossing populations where 240, 185 and 221 progenies were selected from $27F_2$, $16F_3$ and$19F_4$ populations and 78 lines were bulked from F_5 populations for observational trial respectively. On the other hand, 156 and 113 progenies were selected from $7F_3$, $11F_4$ populations and 78 lines were bulked from F_5 populations for observational trial respectively during Boro 2017-18.

RGA trial

A total of 5,716 and 3,347 panicles were collected from $4F_3$ and $7F_4$ populations respectively from 11 crossing populations under this trial.

Observational trial (OT)

Thirty-two lines from 87 genotypes were selected for next programme in saline area tested at Assasuni, Satkhira and 19 were selected at Koyra, Khulna during Aman 2017. Twenty-five entries were selected at Assasuni from 94 entries and 30 entries were selected from 87 genotypes at Koyra, Khulna during Boro 2017-18. From 127 STBN entries, 34 genotypes were selected at Assasuni and 21 genotypes were selected at Koyra in Aman season 2017 where 25 were selected at Assasuni and 35 were selected at Koyra in Boro 2017-18 based on their saline tolerance ability and grain yield.

Preliminary yield trial (PYT)

IR100638-6-CMU3-CMU1, IR100661-SBN11-1-AJY1, IR103513-B-AJY15-3, IR103960-CMU1-CMU2-2 and IR100674-274-IFT1-CMU3 showed higher yield against BR11, BRRI dhan54 and BRRI dhan73 in PYT-1 under three locations of Assasuni, Kaliganj and Koyra (Table 1).

BR9627-1-3-1-10 (9.63 t ha^{-1}) yielded higher among the 17, lines compared with BRRI dhan28, BRRI dhan67 and Bina dhan-10 during Boro 2017-18 in PYT-2 tested at three previous locations (Table 2).

Five entries, out of 17 yielded more than 9 ton ha^{-1} those were higher than all the checks irrespective of location (Table 3).

Secondary yield trial (SYT)

Among the 14 tested entries, BR8729-B-7-3-2 gave higher yield in Assasuni (5.65 t ha^{-1}) and Koyra (4.09 t ha^{-1}) compared with BR11, BRRI dhan54 and BRRI dhan73 during Aman 2017 (Table 4).

Table 1. Performance of PYT entries at Khulna and Satkhira during T. Aman 2017.

Entry/Variety	Growth duration (day)			Yield (t ha^{-1})		
	Assasuni	Kaligannj	Koyra	Assasuni	Kaligannj	Koyra
IR 100638-6-CMU 3-CMU 1	damaged	125	126	damaged	4.13	3.89
IR 100661-SBN 11-1-AJY 1	132	129	119	4.14	3.93	3.68
IR 100679-AJY 30-AJY 2-CMU 2	damaged	132	117	damaged	4.13	3.60
IR 92831-22-BAY 3-1-1-3-AJY 1	133	128	119	3.38	3.38	3.56
IR 103513-B-AJY 15-3	130	127	121	3.93	4.18	3.87
IR 103960-CMU 1-CMU 2-2	130	121	121	3.18	4.27	4.12
IR 100701-AJY 50-AJY 1-CMU3-CMU3	125	119	117	2.48	3.99	3.40
IR 100674-274-IFT 1-CMU 3	126	122	118	4.01	5.36	3.82
IR 100677-290-IFT 2-CMU 1	121	118	114	3.38	3.77	2.76
IR 103899-9-1-AJY 2	121	117	117	2.63	3.06	3.36
IR 103499-B-2-AJY 1	122	115	117	2.89	4.31	3.65
IR 103499-B-55-AJY 3	126	116	124	2.30	3.20	3.58
IR 103499-B-87-AJY 3	122	115	116	2.96	3.03	2.53
IR 103509-B-1-AJY 3	123	122	119	4.05	4.17	3.63
IR 103509-B-75-AJY 2	129	127	125	3.45	4.59	3.18
IR 103522-B-44-AJY 1	119	116	116	3.05	3.11	2.98
IR 103432-B-B-AJY 5	128	123	122	1.84	4.81	3.57
IR 91833-7-BAY 3-2-3-2-AJY 2-3	134	120	120	3.99	4.21	2.63
IR 92844-18-2-2-1-AJY1-CMU 3	136	122	124	3.19	4.15	3.59
BRRI dhan54 (R. ck)	126	121	123	3.28	6.12	3.52
BRRI dhan73 (R. ck)	121	118	118	3.02	3.60	3.67
BRRI dhan67 (R. ck)	117	119	130	2.79	4.15	3.50
BR11 (S. ck)	134	134	130	5.02	4.01	3.61
CV (%)	0.51	0.55	1.04	5.24	13.79	3.12
$LSD_{0.05}$	1.34	1.38	2.61	0.36	1.18	0.22

Table 2. Performance of PYT-1 entries at Khulna and Satkhira during Boro 2017-18.

Entry/Variety	Growth duration (day)			Yield (t ha^{-1})		
	Assasuni	BRRI farm	Koyra	Assasuni	BRRI aarm	Koyra
BR9620-2-7-1-1	157	158	154	7.63	9.41	6.94
BR9620-4-3-2-2	151	147	145	6.34	7.69	5.76
BR9620-2-4-1-5	148	148	145	7.55	7.81	6.34
BR9621-B-3-6	157	160	154	7.37	8.22	6.93
BR9621-B-1-2-11	143	146	147	5.52	6.48	4.05
BR9621-B-2-3-22	149	147	148	6.85	7.95	7.19
BR9621-4-3-2-30	Germ. failed	Germ. failed	146	Germ. failed	Germ. failed	6.24
BR9625-B-1-4-6	157	154	153	5.89	9.50	7.15
BR9625-4-1-2-8	156	156	152	6.94	7.88	6.34
BR9625-B-2-4-9	157	155	162	7.66	8.79	6.73
BR9625-3-1-12	154	148	154	7.69	7.40	6.41
BR9626-B-1-3	151	147	149	6.53	7.66	4.95
BR9626-1-2-12	152	147	160	6.6	7.62	7.29
BR9626-B-2-3-15	153	147	162	6.8	8.67	6.91
BR9627-4-7-3-7	157	154	155	6.32	7.29	7.33
BR9627-1-3-1-10	155	154	154	7.77	9.63	7.47
BR9144-B-1-2-6	150	148	155	7.14	5.94	6.98
BRRI dhan28 (S. ck)	147	146	145	5.65	6.27	5.49
BRRI dhan67 (ck)	150	148	147	6.44	7.86	5.87
BINA dhan10 (ck)	148	151	152	8.06	7.40	6.01
CV (%)	0.66	0.82	1.13	1.94	5.49	8.06
$LSD_{0.05}$	2.11	2.60	2,11	0.28	.90	.28

Table 3. Performance of PYT-2 entries at Khulna and Satkhira during Boro 2017-18.

Entry/Variety	Growth duration (day)			Yield (t ha^{-1})		
	Assasuni	BRRI farm	Koyra	Assasuni	BRRI farm	Koyra
IR 100638-6-CMU 3-CMU 1	160	159	162	5.17	9.39	7.06
IR 100661-SBN 11-1-AJY 1	154	153	148	4.29	8.21	5.04
IR 100679-AJY 30-AJY 2-CMU 2	156	152	149	3.96	6.76	7.39
IR 92831-22-BAY 2-1-CMU 1	Germ. failed	149	149	Germ. failed	5.81	4.90
IR 92831-22-BAY 3-1-1-3-AJY 1	160	159	163	3.53	8.04	5.89
IR 96184-24-1-1-AJY2	158	159	161	5.69	9.12	5.88
IR 103512-B-AJY 2-2	161	158	159	6.54	9.23	6.26
IR 106466-30-CMU 3	159	158	153	6.36	9.33	5.57
IR 104002-CMU 28-CMU 1-CMU 3	159	159	162	6.39	8.55	6.34
IR 100701-AJY 50-AJY 1-CMU 3-CMU 3	157	154	151	5.27	8.04	6.02
IR 100677-290-IFT 2-CMU 1	153	152	153	5.68	7.40	5.98
IR 103854-8-3-AJY 1	158	156	155	6.60	8.66	5.50
IR 103499-B-2-AJY 1	158	153	153	6.11	8.49	6.51
IR 103499-B-45-AJY 1	161	158	161	4.23	7.87	6.15
IR 103499-B-55-AJY 3	152	153	160	4.69	7.11	5.67
IR 103499-B-87-AJY 3	160	158	162	6.00	9.11	5.10
IR 91833-7-BAY 3-2-3-2-AJY 2-3	151	159	153	5.99	8.55	6.44
BRRI dhan67 (R. ck)	150	153	148	6.45	7.81	6.39
BINA dhan10 (R. ck)	150	152	151	7.41	8.66	6.97
BRRI dhan28 (ck)	146	147	148	5.68	6.70	6.06
CV (%)	0.94	1.14	0.91	4.47	4.25	5.62
$LSD_{0.05}$	3.10	3.69	2,.93	0.52	0.72	0.71

Table 4. Performance of SYT entries at Khulna and Satkhira in T. Aman 2017.

Entry/Variety	Growth duration (day)			Yield (t ha^{-1})		
	Assasuni	Kaliganj	Koyra	Assasuni	Kaliganj	Koyra
IR77674-3B-8-1-3-10-3-AJY2	121	118	116	3.85	3.68	3.12
BR8729-B-7-3-2	122	121	127	5.65	3.48	4.09
BR9779-1-1	111	114	118	1.96	2.55	3.19
BR9538-3-1-2	123	121	124	4.69	4.00	2.79
BR9534-15-23-17	111	117	119	2.51	4.51	3.00
BR9072-B-4-1-1		119	128		4.13	3.72
BR9072-B-4-1-3	123	119	126	3.72	4.14	3.89
BR9072-B-4-2-5	123	118	128	2.20	3.69	3.99
BR9073-B-1-3-3	124	117	121	3.71	4.14	2.75
BR9079-B-3-1-3	Poor germ.	Germ. failed	121	Germ. failed	Germ. failed	2.52
BR9080-B-10-8-8	Poor germ.	Germ. failed	124	Germ. failed	Germ. failed	2.78
BR9080-B-10-8-9	Poor germ.	Rat damaged	122	Germ. failed	Germ. failed	2.21
IR11T174	121	117	120	3.01	3.28	2.58
IR12T246	Poor germ.	118	129		3.35	3.26
BRRI dhan54 (R. ck)	124	123	122	3.94	4.91	3.07
BRRI dhan73 (R. ck)	123	120	119	4.26	4.92	3.27
BR11 (S. ck)	133	134	130	4.66	4.62	3.57
CV (%)	0.63	0.61	1.09	3.37	10.79	7.09
$LSD_{0.05}$	1.69	1.57	2.99	0.27	0.92	0.50

Regional yield trial (RYT) in T. Aman 2017-18

Nine RYT's comprised of one for high yielding rice (HYR), one for low input (LI) monibandhobi type, two for rainfed lowland (RLR) rice, two for premium quality rice (PQR), one for zinc enriched rice (ZER), one for disease resistant (DR) and one for insect resistant (IRR) were conducted at BRRI RS, Satkhira during T. Aman 2017-18 (Table 5). Yield performance of IR10F102 and BRRI dhan29-SC3-28-16-15-HR2 (Com) was better in RLR. BR8493-12-7-4 (Com), BR8851-12-4-2-3, BR8850-10-12-3-1, BR8846-38-2-4-2 and BR8846-32-2-4-2 were higher yielder in RYT of PQR. BR8692-1-4-2-1 and BR8693-17-6-2-1 showed higher yield in RYT of IRR.

RYT in Boro 2017-18

Nine RYTs consisting of one for favourable Boro rice (FBR Bio), one for favourable Boro rice (FBR), one for disease resistant rice (DR), three for zinc enriched rice (ZER), one for premium quality rice (PQR), one for insect resistant rice (IRR) and one for yield maximization trial (YMT) under recommended management practices were conducted with respective check varieties at BRRI RS, Satkhira farm during Boro 2017-18. Table 6 presents the results.

BR(Bio)9777-113-12-5 showed higher yield compared to BRRI dhan58 in RYT-FBR (Bio). In RYT-FBR, BR8938-30-2-4-2-1(6.05 t ha^{-1}) and IR06N220 (5.84 t ha^{-1}) showed statistically higher yield among the tested entries and check varieties of BRRI dhan28 (5.04 t ha^{-1}) and BRRI dhan58 (5.26 t ha^{-1}).

BR8634-23-1-1-BHA-2 (6.85 t ha^{-1}), BR8634-23-1-1-BHA-10 (6.72 t ha^{-1}) and BR7528-2R-19-16-RILL-1 (7.23 t ha^{-1}) yielded higher among the entries and the check variety of BRRI dhan74 in RYT of ZER. Four entries of Dinajpur Minikat (Rangpur), BR8590-5-2-5-2-1, Shampakatari (Shingra-Natore) and BR9207-45-2-2 yielded better than the checks in RYT for PQR with similar growth duration. BRH11-911-4-5B yield better than the checks in YMTs under recommended management practices.

RYT of green super rice (GSR) during Boro 2017-18

Among the tested eight entries, HHZ5-DT20-DT2-DT1 and WANXIAN7777-P18 performed better against BRRI dhan58, BRRI dhan29, BRRI dhan67 and Bina dhan-10 in all the three locations of BRRI farm, Assasuni and Koyra in RYT of GSR (Table 7).

Table 5. Performance of different entries under RYT during Aman 2017, BRRI RS, Satkhira.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
	RYT for HYR (Biotechnology)		
BR(Bio) 8961-AC14-9	113	133	3.87
BR(Bio) 8961-AC15-10	114	136	5.22
BR(Bio) 8961-AC22-14	95	133	5.07
BR(Bio) 8961-AC26-16	121	138	5.23
BRRI dhan49 (ck)	90	136	5.21
$LSD_{0.05}$	6.80	1.19	0.26
	RYT for LI (Monibandhobi type)		
Monibandhobi	126	137	5.16
Rajasail (Local ck)		*	
BRRI dhan46 (Std. ck)	120	138	5.58
$LSD_{0.05}$	2.48	2.86	0.58
	RYT-1 for RLR		
BR8841-24-1-1-2	104	138	4.16
BR8841-24-1-1-3	100	135	3.79
BR8841-38-1-2-1	116	134	4.30
BR8526-38-2-1	104	127	4.23
BR8824-68-3-2-4	115	136	4.07
BR8826-38-3-2-2	117	137	4.14
IR10F102	104	141	4.88
BR7781-10-2-3-2	100	129	4.55
IRRI132	111	130	3.59
BR8522-21-4-8	106	139	4.22
BRRI dhan39 (ck)	105	129	4.41
BRRI dhan49 (ck)	95	136	4.50
$LSD_{0.05}$	5.11	0.93	0.22
	RYT-2 for RLR		
BR8214-3-7-2-1	121	137	4.17
BR8214-5-1-16	124	138	4.14
BR8226-13-1-2	104	137	3.87
BR8822-56-2-5-2	112	138	3.96
BR8822-48-1-1-5	130	140	3.69
BR8503-1-2-3-5	115	141	3.48
BRRI dhan29-SC3-28-16-15-HR2 (Com)	109	133	5.47
BRRI dhan39 (ck)	112	128	4.48
BRRI dhan49 (ck)	99	136	4.60
$LSD_{0.05}$	5.64	1.12	0.37
	RYT-1 for PQR		
BR8850-10-12-2-3	100	135	3.06
BR8850-10-12-3-1	103	139	3.20
BR8850-33-4-4-2		*	
BR8851-12-4-2-3	102	135	3.23
BR8493-12-7-4 (Com)	108	141	3.46
BR8493-16-5-1 (Com)	106	136	2.52
BR8493-3-5-1 (Com)	115	137	2.78

* Germination failed.

Table 5. Continued.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
Kalizira (ck)	140	138	1.73
Binadhan-13 (ck)	139	141	2.89
$LSD_{0.05}$			
RYT-2 for PQR			
BR8526-2-1-1-4 (Com)	116	135	2.75
BR8846-32-2-4-2	122	137	3.49
BR8846-38-2-4-2	117	138	4.11
BRRI dhan37 (ck)	120	140	3.32
Kataribhog (Local ck)	124	137	2.55
$LSD_{0.05}$	10.51	2.15	0.36
RYT for ZER			
BR8442-12-1-3-1-B1	122	142	4.63
BR7528-2R-19-HR16-E5-136-1	114	138	4.43
BR7833-19-2-3-5-P8-4	116	137	4.73
BR7528-2R-19-HR16-E5-136-5	123	138	4.62
BR8444-66-1-2-1	105	135	4.77
BR8442-12-1-3-1-B5	128	143	4.49
BRRI dhan33 (ck)	103	126	3.25
BRRI dhan39 (ck)	107	128	4.63
BRRI dhan72 (ck)	118	128	5.78
Binadhan-7 (ck)	110	139	4.50
$LSD_{0.05}$	3.54	1.35	0.34
RYT for IRR			
BR8692-15-4-2-1	109	131	5.53
BR8693-4-1-1-1	111	137	4.77
BR8693-8-4-2-1	110	136	5.38
BR8693-17-6-2-1	123	129	5.86
BR8698-12-5-3-2	106	131	5.46
BR8693-17-6-2-2	108	134	5.23
BRRI dhan49 (ck)	96	134	5.08
BRRI dhan33 (R. ck)	100	124	3.52
$LSD_{0.05}$	2.97	1.29	0.32
RYT for DR			
BR9140-11-2-3-2	101	127	3.89
BR9140-5-22-5-1	112	134	4.13
BR9140-8-25-6-3	104	131	4.06
BR8547-5-3-5-13	84	131	3.83
BR8548-7-6-4-2	85	133	4.19
BR8548-6-5-2-12	86	132	4.31
BR8548-8-22-5-15	104	133	4.15
BR9138-8-10-5-3	104	135	4.76
BR10390-35-8	93	137	4.03
BRRI dhan39 (Sus. ck)	102	127	4.84
BRRI dhan49 (Sus. ck)	91	135	4.79
IRBB60 (Res. ck)	73	138	3.79
$LSD_{0.05}$	3.16	1.06	0.28

Table 6. Performance of different entries under RYT during Boro 2017-18, BRRI, Satkhira.

Designation	Growth duration (day)	Plant height (cm)	Yield (t ha^{-1})
	RYT-FBR (Bio)		
BR(Bio)9777-26-4-3	142	94	4.85
BR(Bio)9777-106-7-4	143	90	4.44
BR(Bio)9777-113-12-5	143	102	5.78
BR(Bio)9777-118-6-4	146	91	4.90
BRRI dhan58 (ck)	140	87	4.63
LSD $_{0.05}$	1.61	11.52	0.24
	RYT-FBR		
IR06N220	150	96	5.84
IR99061-B-B-7	141	94	5.05
IR12A288	138	97	5.52
IR09A235	141	95	5.38
IR14N126	139	98	5.30
IR99056-B-B-15	138	101	4.72
IR99090-B-B-62	142	99	5.23
IR99092-B-B-91	146	109	5.08
IR14D111	144	103	5.78
BR8938-30-2-4-2-1	141	103	6.05
BRRI dhan28 (ck)	137	89	5.04
BRRI dhan58 (ck)	143	94	5.26
LSD $_{0.05}$	1.40	5.90	0.30
	RYT for DR		
BR9942-38-4	144	99	5.19
BR9943-2-1	142	101	5.77
BR9943-2-2	144	97	5.35
BR9650-35-4-3	147	102	5.90
BRRI dhan58 (Sus.ck)	142	84	5.06
BRRI dhan29 (Sus.ck)	145	75	5.95
IRBB60 (Res. ck)	147	97	5.45
LSD $_{0.05}$	1.14	6.20	0.34
	RYT-1 for ZER		
BR8269-60-2-HR2-1-1-BHA-2	141	95	6.17
BR8634-23-1-1-BHA-1	138	98	6.26
BR8634-23-1-1-BHA-10	141	101	6.72
BR8634-23-1-1-BHA-2	138	105	6.85
BR8634-23-1-1-BHA-3	137	105	5.91
BR8634-23-1-1-BHA-5	140	103	5.23
BR8634-23-1-1-BHA-6	140	97	4.88
BR8634-23-1-1-BHA-7	143	100	5.63
BR8634-23-1-1-BHA-8	141	105	6.34
IR101762-1-1-1	145	101	5.65
BRRI dhan28	139	95	5.37
BRRI dhan29	146	96	5.54

Table 6. Continued.

Designation	Growth duration (day)	Plant height (cm)	Yield (t ha^{-1})
BRRI dhan74	142	94	6.50
LSD $_{0.05}$	1.01	5.68	0.40
	RYT-2 for ZER		
BR7528-2R-19-16-RILL-1	140	116	7.23
BR7528-2R-19-16-RILL-15	142	119	6.79
BR7528-2R-19-16-RILL-18	142	115	4.92
BR7528-2R-19-16-RILL-49		*	
BRRI dhan28 (ck)	140	103	6.12
BRRI dhan74 (ck)	140	103	7.09
LSD $_{0.05}$			
	RYT-3 for ZER		
BRRI dhan57	121	92	4.07
BRRI dhan28 ck	138	96	5.42
BRRI dhan62 ck	121	92	4.07
LSD $_{0.05}$	3.79	6.57	0.63
	RYT for PQR		
BR8590-5-2-5-2-1	139	106	7.12
BR9207-45-2-2	138	119	6.74
BR8590-5-2-5-2-2	140	102	6.40
BR8590-5-3-3-4-2	138	96	6.43
Dinajpur Minikat (Rangpur)	135	97	7.23
Shampakatari (Shingra-Natore)	140	86	6.91
BRRI dhan28 (ck)	137	91	6.01
BRRI dhan50 (ck)	141	82	6.30
BRRI dhan63 (ck)	139	84	6.45
LSD $_{0.05}$	1.80	4.87	0.43
	RYT-IRR		
BR8335-10-6-3-10	139	83	4.76
BR8336-5-7-2-4	138	84	4.31
BR8336-7-4-3-7	140	85	4.67
BR8339-6-2-5-2		*	
BR8340-5-6-1		*	
BR8340-5-8-4	139	86	4.17
BR3 (ck)	146	87	4.66
BRRI dhan28 (ck)	139	93	4.87
T27A (T. ck)	139	83	4.76
$LSD_{0.05}$	1.13	3.66	0.47
	YMT under recommended management		
BRH11-9-11-4-5B	140	95	6.50
BRRI dhan28 ck	138	93	5.31
BRRI dhan58 ck	144	94	5.45
$LSD_{0.05}$	1.19	5.15	0.54

* Germination failed.

Table 7. Performance of GSR RYT entries in Boro 2017-18.

Entry/Variety	Growth duration (day)			Grain yield (t ha^{-1})		
	BRRI farm	Koyra	Assasuni	BRRI farm	Koyra	Assasuni
WANXIAN7777-P8	154	154	154	6.37	4.98	6.83
WANXIAN7777-P9	155	154	152	5.90	5.93	7.39
WANXIAN7777-P10	154	155	154	6.52	6.83	5.97
WANXIAN7777-P12	156	155	155	5.95	6.17	5.87
WANXIAN7777-P18	156	158	154	7.46	6.07	4.58
WANXIAN7777-P68	156	157	157	6.80	6.04	4.16
HHZ12-SAL2-Y3-Y2	157	154	156	7.16	6.48	6.05
HHZ5-DT20-DT2-DT1	157	157	158	7.92	6.53	6.36
BRRI dhan58 (ck)	155	154	151	5.52	6.45	4.22
BRRI dhan29 (ck)	159	161	160	7.29	6.37	4.76
BRRI dhan67 (ck)	151	148	150	6.08	5.73	6.43
BINA dhan10 (ck)	153	153	154	5.62	6.49	5.98
$LSD_{0.05}$	1.23	2.42	1.87	0.26	0.52	0.58

Participatory varietal selection (PVS)

BRRI dhan73 ranked first positive in two locations; BRRI dhan54 and BR8727-B-2-1-1 ranked first positive in one location against 11 entries tested at Assasuni, Kaliganj, Debhata and Koyra during Aman 2017 (Table 8).

BRRI dhan67, Bina dhan-10 and BR8982-9 individually ranked first positive in one location each of Assasuni, Debhata and Koyra against 10 entries during Boro 2017-18 (Table 9).

CROP-SOIL-WATER MANAGEMENT

Missing element trial on Boro rice in 2017-18

In saline gher, nutrient omitted plots yielded much lower than fertilized plot. In non-saline gher and in BRRI farm, nutrient omitted plots yielded close to the fertilized plot except control and urea omitted plots (Table 10). However, balanced fertilizer is recommended for all conditions for optimum yield.

Table 8. Performance of PVS entries at Khulna and Satkhira in T. Aman 2017.

Entry/variety	Assasuni		Debhata		Kaliganj		Koyra	
	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank
BR9534-1-1-2		-		-		-		-
BR9535-3-1-9	3.95	-	3.55	-	3.31	-	4.13	-
BR9536-B-10-1-26	4.97	2nd (+)	2.35	-	2.56	2nd (-)	3.25	-
IR84095-AJY-301-SDO4-B	3.73	2nd (-)	3.91	-	3.64	-	4.39	-
IR78761-B-SATB1-52-1	*			-	3.17	-	3.66	2nd (-)
IR10T116	*			-	2.58	-	2.54	
IR83484-3-B-7-1-1-1	*			-	3.10	-	3.48	1st (-)
BR9539-B-12-11-13	**			-		-	-	-
BR8727-B-2-1-1 (SYT)	3.21	1st (-)	2.56		4.51		4.80	1st (+)
BR8743-B-1-2-2 (SYT)	*		3.68	-	3.40	-	3.46	
BR8747-B-3-3-5 (SYT)	*			1st (-)	2.80	1st (-)	3.34	2nd (+)
BRRI dhan73 (ck)	5.16	-	3.81	1st (+)	4.14	1st (+)	4.83	-
BRRI dhan54 (ck)	3.77	1st (+)	3.96	2nd (+)	4.32	2nd (+)	5.07	-
BR11 (S. ck)	5.45			2nd (-)	5.04		6.05	-
CV (%)	2.90	-	4.61	-	4.90		3.28	
$LSD_{0.05}$	0.31	-	0.44	-	0.38		0.32	

* Poor germination, ** Germination failed.

Table 9. Performance of PVS entries at Khulna and Satkhira in Boro 2017-18.

Entry/variety	Assasuni		Debhata		BRRI farm		Koyra	
	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank
IR 87872-7-1-1-2-1-B		-	6.77	-	7.99	-	6.22	-
BR8980-4-6-5	8.33		4.30	-	7.48	1^{st} (-)	5.32	-
BR8980-B-1-1-1	6.94	1^{st} (-)	4.22	-	6.85	2nd (-)	6.84	-
BR8980-B-1-3-5	6.28	2^{nd} (-)	3.50	-	8.51	-	7.13	-
IR 87870-6-1-1-1-1-B	6.81		5.62	-	8.37	-	6.40	
BR8943-B-1-2-7	8.38		5.65	-	8.81	-	6.56	1^{st} (-)
BR8982-5	7.73		4.19	-	7.95	-	6.10	
BR8982-9	7.19	1^{st} (+)	4.44	-	6.80	-	5.82	
IR83484-3-B-7-1-1-1	5.91		4.25		6.57		5.31	
IR 87870-6-1-1-1-1-B	6.57		6.41	-	8.49	2^{nd} (+)	6.10	2^{nd} (+)
BRRI dhan67 (R. ck)	8.38	2^{nd} (+)	4.46	-	6.65		6.52	1^{st} (+)
BINA dhan10 (R. ck)	7.13		5.65	-	8.74	1st (+)	7.22	-
BRRI dhan28 (ck)	8.66		2.71	--	6.16		5.42	2^{nd} (-)
CV (%)	6.33		4.38	-	3.98		6.05	-
$LSD_{0.05}$	2.74		0.45	-	0.66		3.28	

Table 10. Effect of missing element on grain yield and panicle number of BRRI dhan67 in Boro 2017-18.

Treatment	Panicle m^{-2}	Yield (t ha^{-1})	Grain yield decrease (%) due to missing nutrient
		BRRI farm	
PKSZn (-N)	268	5.30	24.82
NKSZn (-P)	277	6.57	6.81
NPSZn (-K)	275	6.74	4.4
NPKZn (-S)	275	6.52	7.52
NPKS (-Zn)	282	6.79	3.67
NPKSZn	288	7.05	-
Control	265	5.39	23.55
CV (%)	3.17	6.86	
$LSD_{(0.05)}$	15.58	0.77	
		Saline gher	
PKSZn (-N)	212	1.91	57.55
NKSZn (-P)	338	3.88	13.98
NPSZn (-K)	382	3.18	29.51
NPKZn (-S)	341	3.15	30.10
NPKS (-Zn)	342	4.08	9.40
NPKSZn	379	4.51	-
CV (%)	8.19	9.96	
$LSD_{(0.05)}$	50	0.62	
		Non-saline gher (BRRI dhan28)	
PKSZn (-N)	297	5.96	19.92
NKSZn (-P)	305	6.90	7.13
NPSZn (-K)	316	7.62	-2.56
NPKZn (-S)	320	7.32	1.48
NPKS (-Zn)	315	7.22	2.83
NPKSZn	326	7.43	-
Control	302	6.86	7.67
CV (%)	5.21	7.29	
$LSD_{(0.05)}$	28.91	0.91	

Yield maximization of Boro rice in saline coastal area through nutrient management

The experiment was done in farmer's field at Assasuni, Satkhira using BRRI dhan67. Basal fertilizers of P-S-Zn were used at final land preparation at the rate of 22.5-11-4 kg ha^{-1} respectively. Potassium was applied in half at final land preparation and half at five days before PI. Urea was applied in three equal splits at 10, 25 and 45 DAT. Higher grain yield was found in 25% and 50% higher dose of N (155 kg ha^{-1}) and K (90 kg ha^{-1}) respectively (Table 11).

SOCIO-ECONOMIC

Stability analysis of BRRI varieties at BRRI RS farm Satkhira in 2017-18

BRRI developed rice varieties were tested at BRRI RS farm, Satkhira during 2017-18 in Aus, T. Aman and Boro season. BRRI dhan48 (4.30 t ha^{-1}) and BRRI dhan42 (4.17 t ha^{-1}) yielded higher than other tested varieties. Among T. Aman varieties; BRRI hybrid dhan6, BRRI hybrid dhan4, BRRI dhan73, BRRI dhan44 and BR23 yielded higher than 5.50 ton ha^{-1}. BRRI hybrid dhan5 produced the highest yield (8.02 t ha^{-1}) followed by BRRI hybrid dhan3 (7.91 t ha^{-1}), BRRI dhan47 (7.62 t ha^{-1}), BRRI dhan28 (7.36 t ha^{-1}), BR14 (7.24 t ha^{-1}), BRRI dhan58 (7.14 t ha^{-1}) and BRRI dhan50 (7.09 t ha^{-1}) during Boro, 2017-18.

TECHNOLOGY TRANSFER

Varietal validation of BRRI developed rice varieties

Variety validations were done to address different ecosystems (favorable irrigated, saline & non-saline gher, coastal saline, water stagnant etc.) of Jashore and Khulna region.

BRRI dhan75, BRRI dhan73, BRRI dhan71 yielded better in Aman season. BRRI dhan62, BRRI dhan71 and BRRI dhan75 could be the best option to cultivate early winter vegetables after rice harvest. Taller seedling height have the advantage of BRRI dhan76, BRRI dhan77 and Naya Pajar for transplanting in stagnant water however BRRI dhan76 yielded much better than other varieties and could be a good genotype for stagnant water. BRRI dhan30 yielded better than BR10 and BRRI dhan78 as well as suitable for rice-fish system.

BRRI dhan58 yielded better in Boro season especially in non-saline gher syatem. BRRI dhan67 is the best one to fit in saline coastal region as well as saline gher syatem.

Training, field day and fair

Eleven farmers' training on rice production technology, quality seed production and preservation was conducted to train up 360 farmers of Satkhira, Khulna and Jashore districts. A total of eighteen field days were arranged during the reporting year. BRRI RS, Satkhira participated in two different agricultural and development fairs as well as workshop, seminar, regional and district agricultural coordination committee meetings, district coordination committee meetings, discussion meetings, farmers' field visit and provided advisory services in field level as well as on line basis.

Table 11. Plant height, number of panicle and yield as affected by different level of urea and potassium.

Treatment	Plant height (cm)			Panicle m^{-2}			Yield (t ha^{-1})		
	N1	N2	N3	N1	N2	N3	N1	N2	N3
K1	92	81	91	210	199	237	2.63	3.66	4.14
K2	95	100	105	263	263	268	3.07	3.74	4.41
K3	90	90	93	154	275	284	2.71	3.57	4.55

Kg ha^{-1}	N1 = 124 (Normal dose)	K1 = 60 (Normal dose)
	N2 = 139.5 (12.5% more)	K2 = 75 (25% more)
	N3 = 155 (12.5% more)	K3 = 90 (50% more)

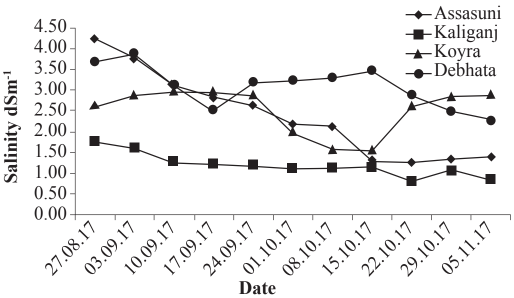


Fig. 1. Water salinity of experimental plots at Assasuni, Kaliganj and Debhata, Satkhira and Koyra, Khulna during T. Aman 2017.

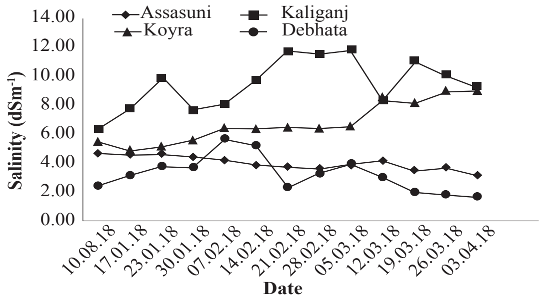


Fig. 2. Water salinity of experimental plots at Assasuni, Kaliganj and Debhata, Satkhira and Koyra, Khulna during Boro 2017-18.

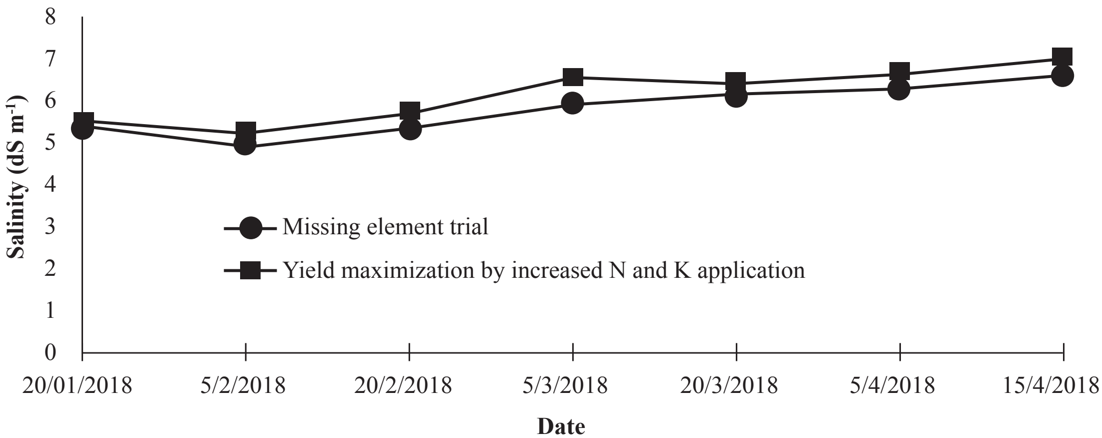


Fig. 3. Water salinity of missing element trial plots and yield maximization of Boro rice in saline coastal area through nutrient management experimental plots at Assasuni, Satkhira during Boro, 2017-18.

BRRI RS, Sonagazi

SUMMARY

Superior breeding lines were evaluated to test the yield performance through regional yield trial (RYT) at research field of BRRI RS, Sonagazi under the direct supervision of researchers. A total of 107 breeding lines were tested under this trial in Aus, T. Aman and Boro seasons from which 33 were found better than checks and recommended for advanced trial during the reporting period. Breeding lines were supplied from Plant breeding and Biotechnology Divisions. Twenty-eight lines along with standard checks BR26, BRRI dhan48 and BRRI dhan65 were tested during Aus from which the advanced lines BR9011-46-2-2, BR9011-48-4-3, BR9011-64-1-2, BR9011-19-1-2, BR9011-9-4-2, BR9039-9-1-3, BR8776-17-4-2, BR9640-2B-9-1, BR8235-2B-4-4 and BR(Bio)9785-BC2-63-2-4 were recommended for advanced trial. During T. Aman season two rainfed lowland rice (RLR), one zinc enriched rice (ZER), one disease resistant rice (DRR) were evaluated under on-station condition which were supplied from Plant Breeding Division. The RLR lines BR8841-24-1-1-2, BR8841-38-1-2-1, BR8214-3-7-2-1, BR8214-5-1-16, BR8822-56-2-5-2 and BR8822-48-1-1-5 were selected for further advancement. On the basis of growth duration, yield and yield contributing characters the DRR advanced lines BR9140-5-22-5-1, BR8548-7-6-4-2 and BR8548-6-5-2-1 were found better than the check variety. During Boro season, the advanced lines IR09A235, IR99056-B-B-15, IR99090-B-B-62, IR99092-B-B-91, IR14D111 and BR8938-30-2-4-2-1 were recommended for advanced trial as favourable Boro rice. Result demonstrations were conducted at farmers' field through SPDP during Aus, Aman and Boro seasons. The number of total demonstrations was 53 and direct beneficiary farmers were 182. Through these demonstrations 147 tons quality seeds produced and the farmers retained 37.77 tons of seeds. The proposed line NERICA10-7-PL2-B supplied from Plant Breeding Division was evaluated under PVT during T. Aus and was released as BRRI dhan82. Another proposed line (Bio) 9786-BC2-132-1-3 supplied from Biotechnology Division was evaluated under PVT during T. Aman and was released as BRRI dhan87. During the reporting period, BRRI RS, Sonagazi produced 14.11 tons of breeder seeds in Aman and Boro seasons. All the breeder seeds of different varieties were sent to Genetic Resource and Seed Division, BRRI, Gazipur. A total of 964 kg truthfully labeled seed (TLS) of BRRI dhan27, BRRI dhan43, BRRI dhan48 and BRRI dhan65 were produced during T. Aus, 9,064 kg of ten varieties during T. Aman and 310 kg of two varieties during Boro seasons. BRRI RS, Sonagazi arranged 20 farmers' training programmes on modern rice production technology for 700 farmers and 18 field days in different seasons. Field days were conducted mainly in demonstration sites in collaboration with DAE and local farmers at different locations. Nearly 3,600 progressive farmers, local leaders, DAE field stuff, public representatives and NGO workers participated in those occasions.

EVALUATION OF BREEDING MATERIALS

On-station evaluation through regional yield trial (RYT)

RYT Aus 2017. Twenty-eight breeding lines lines along with standard checks BR26, BRRI dhan48 and BRRI dhan65 were tested in Aus under three RYT designated as RYT-1, RYT-2 and RYT-Bio during T. Aus season. The advanced lines BR9011-46-2-2, BR9011-48-4-3, BR9011-64-1-2, BR9011-19-1-2, BR9011-9-4-2, BR9039-9-1-3, BR8776-17-4-2, BR9640-2B-9-1, BR8235-2B-4-4 and BR(Bio)9785-BC2-63-2-4 were recommended for advanced trial.

RYT in T. Aman 2017. Regional yield performance of 38 breeding lines were evaluated under the trials RLR-1, RLR-2, ZER, RYT-Bio, DRR and RYT-Monibandobi during T. Aman 2017. In the trial RLR-1, the lines BR8841-24-1-1-2 and BR8841-38-1-2-1 produced 3.89 and 3.76 t/ha yield respectively that were higher than the standard checks (Table 1) and recommended for advanced trial.

Seven advanced lines BR8214-3-7-2-1, BR8214-5-1-16, BR8226-13-1-2, BR8822-56-2-5-2, BR8822-48-1-1-5, BR8503-1-2-3-5 and BRRI dhan29-SC3-28-16-15HR2(Com) along with two checks BRRI dhan39 and BRRI dhan49 were tested under the trial RLR-2. The advanced lines BR8214-3-7-2-1, BR8214-5-1-16, BR8822-56-2-5-2 and BR8822-48-1-1-5 performed better regarding grain yield and growth duration (Table 2).

Table 1. Performance of the lines in regional yield trial (RLR-1) during T. Aman 2017 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR8841-24-1-1-2	108	135	3.89
BR8841-24-1-1-3	100	136	2.50
BR8841-38-1-2-1	118	133	3.76
BR8526-38-2-1	105	128	2.69
BR8824-68-3-2-4	116	127	3.26
BR8826-38-3-2-2	119	136	2.83
BR8841-22-2-4-2	109	137	2.64
IR10F102	103	137	2.72
BR7781-10-2-3-2	102	126	2.78
IRRI132	107	123	2.59
BR8522-21-4-8	111	132	2.80
BRRI dhan39 (ck)	106	123	2.74
BRRI dhan49 (ck)	100	137	3.42
$LSD_{(0.05)}$	2.85	NS	0.38
CV(%)	1.6	1.2	7.6

Table 2. Performance of some breeding lines in regional yield trial (RLR-2) during T. Aman at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR8214-3-7-2-1	118	143	3.21
BR8214-5-1-16	117	145	3.18
BR8226-13-1-2	89	144	2.32
BR8822-56-2-5-2	102	147	3.11
BR8822-48-1-1-5	112	152	3.44
BR8503-1-2-3-5	97	151	2.54
BRRI dhan29-SC3-28-16-15HR2 (Com)	92	139	1.98
BRRI dhan39 (ck)	100	125	2.44
BRRI dhan49 (ck)	94	139	2.76
$LSD_{(0.05)}$	3.37	NS	0.27
CV (%)	1.9	1.5	5.7

In the trial RYT-Bio, four advanced lines BR(Bio) 8961-AC14-9, BR(Bio) 8961-AC15-10, BR(Bio) 8961-AC22-14 and BR(Bio) 8961-AC26-16 along with one check BRRI dhan49 was tested from which the advanced lines BR (Bio) 8961-AC22-14 and BR (Bio) 8961-AC26-16 produced grain yield 3.05 and 3.63 t/ha respectively that were higher than the standard check (Table 3).

Nine advanced lines BR9140-11-2-3-2, BR9140-5-22-5-1, BR9140-8-25-6-3, BR8547-5-3-5-13, BR8548-7-6-4-2, BR8548-6-5-2-1, BR8548-8-22-5-15, BR9138-8-10-5-3 and BR10390-35-8 along with three checks were tested under RYT-DRR. All the tested lines submerged for three days due to high tide at flowering stage and yield was hampered. The advanced lines BR9140-5-22-5-1, BR8548-7-6-4-2 and BR8548-6-5-2-1 produced grain yield 1.75, 2.59 and 2.83 t/ha respectively that were higher than the standard checks (Table 4).

RYT in Boro 2017-18. A total of 41 breeding lines were evaluated under the trials FBR-1, FBR-2, PQR, DRR and ZER during Boro, 2017-18. None of the tested lines was found better than the heck variety under the trial FBR-1 and PQR.

Ten advanced lines IR06N220, IR99061-B-B-7, IR12A288, IR09A235, IR14N126, IR99056-B-B-15, IR99090-B-B-62, IR99092-B-B-91, IR14D111 and BR8938-30-2-4-2-1 along with checks BRRI dhan28 and BRRI dhan58 were tested under the trial FBR-2. All the tested lines performed better than BRRI dhan28 regarding yield but growth durations were higher than BRRI dhan28. The lines IR09A235, IR99056-B-B-15, IR99090-B-B-62, IR99092-B-B-91, IR14D111 and BR8938-30-2-4-2-1 yielded more than both the check varieties BRRI dhan28 and BRRI dhan58 but growth durations were 3-4 days higher than BRRI dhan58 (Table 5).

Table 3. Performance of some breeding lines in regional yield trial (RYT-Bio) during T. Aman 2017 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR(Bio) 8961-AC14-9	99	130	2.86
BR(Bio) 8961-AC15-10	100	135	2.79
BR(Bio) 8961-AC22-14	87	139	3.05
BR(Bio) 8961-AC26-16	114	137	3.63
BRRI dhan49 (ck.)	91	138	2.78
$LSD_{(0.05)}$	6.77	NS	0.22
CV(%)	3.7	1.6	3.9

Table 4. Performance of some breeding lines in regional yield trial (RYT-DRR) during T. Aman 2017 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR9140-11-2-3-2	106	120	1.75
BR9140-5-22-5-1	102	132	2.86
BR9140-8-25-6-3	103	126	1.87
BR8547-5-3-5-13	94	129	1.94
BR8548-7-6-4-2	91	129	2.59
BR8548-6-5-2-1	93	131	2.83
BR8548-8-22-5-15	114	119	2.51
BR9138-8-10-5-3	103	125	2.11
BR10390-35-8	94	128	2.05
BRRI dhan39 (Sus. ck.)	105	123	1.15
BRRI dhan49 (Sus. ck.)	96	137	2.18
IRBB60 (Res. ck.)	92	118	2.40
$LSD_{(0.05)}$	5.04	NS	0.26
CV(%)	3.0	1.4	7.1

Table 5. Performance of some breeding lines under the trial FBR-2 during Boro 2017-18 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
IR06N220	99	149	6.80
IR99061-B-B-7	103	136	6.39
IR12A288	96	139	6.64
IR09A235	100	146	7.17
IR14N126	99	140	6.54
IR99056-B-B-15	105	147	7.18
IR99090-B-B-62	101	150	7.59
IR99092-B-B-91	116	149	7.41
IR14D111	107	148	7.28
BR8938-30-2-4-2-1	114	148	7.35
BRRI dhan28 (ck)	92	133	5.48
BRRI dhan58 (ck)	99	143	6.62
$LSD_{(0.05)}$	4.40	NS	0.42
CV (%)	2.5	NS	3.7

Four advanced lines BR9942-38-4, BR9943-2-1, BR9943-2-2 and BR9650-35-4-3 along with checks BRRI dhan29 (Sus. ck), BRRI dhan58 (Sus ck) and IRBB60 (Res. ck) were tested under the trial RYT-DRR. The tested lines BR9943-2-1, BR9943-2-2 and BR9650-35-4-3 yielded more than the resistant check IRBB60 but with 8-10 days higher growth duration than the resistant check (Table 6). None of the lines was affected by any major disease.

A total of 17 breeding lines were tested under three categories of ZER trials named ZER-1, ZER-2 and ZER-3 in adjacent plots. In the trial ZER-1, tested lines BR8634-23-1-1-BHA-1 and BR8634-23-1-1-BHA-10 yielded more than standard check BRRI dhan28. But none of the tested lines performed better than the standard checks BRRI dhan29 and BRRI dhan74 (Table 7). The tested line BR7528-2R-19-16-RILL-49 yielded more than the

Table 6. Performance of some breeding lines under DRR during Boro 2017-18 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR9942-38-4	106	151	5.99
BR9943-2-1	107	156	6.43
BR9943-2-2	96	150	6.41
BR9650-35-4-3	104	155	6.48
BRRI dhan58 (Sus ck)	99	146	6.69
BRRI dhan29 (Sus ck)	95	153	7.07
IRBB60 (Res. ck)	81	141	5.61
$LSD_{(0.05)}$	3.10	NS	0.36
CV (%)	1.8	NS	3.2

Table 7. Performance of some breeding lines in (RYT, ZER) Boro, 2017-18 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
	ZER-1		
BR8269-60-2-HR2-1-1-BHA-2	94	144	5.81
BR8634-23-1-1-BHA-1	103	146	6.64
BR8634-23-1-1-BHA-10	105	145	6.57
BR8634-23-1-1-BHA-2	105	145	5.76
BR8634-23-1-1-BHA-3	102	146	5.98
BR8634-23-1-1-BHA-5	100	145	5.54
BR8634-23-1-1-BHA-6	97	146	4.53
BR8634-23-1-1-BHA-7	102	146	4.64
BR8634-23-1-1-BHA-8	102	145	4.95
IR101762-1-1-1	107	146	6.04
BRRI dhan28 (ck)	90	134	5.81
BRRI dhan29 (ck)	96	152	6.63
BRRI dhan74 (ck)	95	140	6.83
$LSD_{(0.05)}$	3.85	0.26	0.43
CV (%)	2.3	NS	4.5
	ZER-2		
BR7528-2R-19-16-RILL-1	98	138	5.52
BR7528-2R-19-16-RILL-15	94	140	4.73
BR7528-2R-19-16-RILL-18	99	142	4.97
BR7528-2R-19-16-RILL-49	92	148	6.21
BRRI dhan28 (ck)	90	134	5.83
BRRI dhan74 (ck)	94	140	6.67
$LSD_{(0.05)}$	4.05	0.21	0.34
CV (%)	2.4	NS	3.4
	ZER-3		
BRRI dhan62	100	100	5.16
BRRI dhan57	114	104	3.65
BRRI dhan28	91	135	5.27
$LSD_{(0.05)}$	6.03	NS	0.35
CV(%)	2.6	NS	3.3

standard check BRRI dhan28 but growth duration was eight days higher than BRRI dhan28 in ZER-2. None of the tested lines performed better than the standard check BRRI dhan74 in this trial. In ZER-3, BRRI dhan28 produced higher yield than BRRI dhan57 and BRRI dhan52 (Table 7).

On-farm evaluation of breeding lines through advanced lines adaptive research trial (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 of Adaptive Research Division (ARD) of BRRI HQ.

Five categories of ALARTs were conducted during T. Aman 2017 such as, RLR-1, RLR-2, ZER and BBR. The trials RLR-1, RLR-2 and ZER were conducted at Dagon Bhuiyan upazila of Feni district. The other two trials named BBR and GSR-salinity were conducted at Companyganj upazila of Noakhali district. The ALARTs were also conducted during Boro season such as FB-SD, BBR-Bio and LGI-BBR at Sonagazi upazila of Feni district. Data were collected on yield and yield contributing characters, phenotypic acceptance at vegetative and reproductive stage, insect and disease reaction and lodging records.

Collected results with reports were submitted to ARD of BRRI, HQ and those were analized, reported and presented by that division.

On-farm evaluation of breeding lines through proposed variety trial (PVT)
These trials were conducted at farmers' fields by the participation of researchers, extension people, BADC worker and employees of Seed Certification Agency just prior to the variety release. Trials were conducted both in T. Aus and T. Aman 2017. One trial was conducted using materials from Plant Breeding Division during T. Aus and another two were conducted using the lines from Biotechnology and Plant Breeding Division during T. Aman season.

The proposed line NERICA10-7-PL2-B produced 4.39 t/ ha having growth duration 104 days which was 0.69 t/ha higher than the check variety. The tested line having four days earlier growth duration than the check variety was released as BRRI dhan82.

The pure lines BR-RS(Raj)-PL4-B and BR-SF(Rang)-PL1-B were tested under PVT as a replicated trial along with checks BR11 and BRRI dhan49. The yield of tested lines and check varieties decreased drastically due to severe infestation of BLB and lodging at milking stage due to stormy wind. The line BR-RS(Raj)-PL4-B produced grain yield 3.01 t/ha, which was higher than the other line and check variety.

A proposed line (Bio) 9786-BC2-132-1-3 from Biotechnology Division produced grain yield 5.17 t/ha which was higher than the yield (4.90 t/ha) of check variety BRRI dhan49 having similar growth duration and released as BRRI dhan87.

PEST MANAGEMENT

Survey and monitoring of rice diseases
Survey was carried out at farmers' fields of Laxmipur, Noakhali, Feni and Chattogram districts both in T. Aman 2017 and Boro 2017-18. Sites were selected with the suggestion and collaboration of Sub Assistant Agricultural Officers (SAAO) who were the front line workers of the Department of Agricultural Extension (DAE) and very much familiar to the farmers as well as their fields.

Sheath blight, brown spot, sheath rot and BLB infestations were observed in different scores during T. Aman season. Neck blast was very much severe during Boro season where BRRI dhan28 was found as most susceptible. Others were also affected in different degrees such as BRRI dhan29 and BRRI dhan58. Farmers were very much afraid about neck blast during Boro season.

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 2017 to June 2018 at the experimental field of BRRI RS, Sonagazi. The abundance of yellow stem borer (YSB), leaf roller (LR), mole cricket (MC), field cricket (FC), rice bug (RB), green leafhopper (GLH), grasshopper (GH) and stink bug (SB) were found in the light trap during the reporting period. Among the insect pests, leaf roller (LR) populations were the highest.

Seed production and dissemination programme (SPDP) during upland Aus 2017

During upland Aus 2017, SPDPs were conducted in Subarnachar upazila of Noakhali district and Sandip upazila of Chattogram district. BRRI dhan43 was used as cultivar in those upazilas considering land suitability and seed availability. The demonstration area of each upzila was three bighas belonging to more than one farmer. A detailed research programme along with primary and final data sheets were sent to concerned Upazila Agriculture Office before conducting the trial. Seeds, fertilizers and signboards were supplied from BRRI RS, Sonagazi for the demonstrations. Data on growth duration, grain yield, total production, retained seeds, knowledge sharing and motivated farmers were recorded.

The highest yield (3.10 t/ha) was found in Subornochar upazila of Noakhali district followed by Sandip upazila of Chattogram district. A total of 2,438 kg seeds were produced in demonstrated areas from which the farmers retained 698 kg seeds for next year cultivation. A total of 465 farmers gained knowledge through the demonstration and 165 farmers were motivated who decided for next year cultivation.

Seed production and dissemination programme (SPDP) during T. Aus, 2017

The demonstrations were conducted in five upazila (Senbug, Companigonj, Potia , Mirsorai and Chokoria) of three coastal districts (Noakhali, Chattogram, Cox's Bazar) during T. Aus 2017. BRRI dhan48 was used as cultivar in those upazilas considering land suitability and seed availability. The demonstration area of each upzila was three bighas belonging to more than one farmer. A detailed research programme along with primary and final data sheets were sent to concerned Upazila Agriculture Office before conducting the trial. Seeds, fertilizers and signboards were supplied from BRRI RS, Sonagazi for the demonstrations. Data on growth duration, grain yield, total production, retained seeds, knowledge sharing and motivated farmers were recorded.

The highest yield (5.17 t/ha) was found in Mirsori upazila of Chattogram district followed by Companiganj upazila of Noakhali district. A total of 9711 kg seeds produced in the demonstrated areas from which farmers retained 2,539 kg seeds for next year cultivation. A total of 1,529 farmers' gained knowledge and 951 farmers were motivated through the demess who decided for next year cultivation.

Seed production and dissemination programme (SPDP) during T. Aman, 2017

The demonstrations on SPDP were conducted in 19 upazilas of eight districts of jurrisdicted areas of BRRI RS, Sonagazi during T. Aman season under core programme. BRRI dhan41, BRRI dhan46, BRRI dhan49, BRRI dhan76 and BRRI dhan77 were used as cultivar in different upazilas considering land suitability, agro-ecology and seed availability. A total of 50 demonstrations were conducted in 62 farmers' fields having two bighas of each demonstration.

The total seed production of BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan49, BRRI dhan76 and BRRI dhan77 were 4,386 kg, 4,423 kg, 5,577 kg, 13,229 kg, 1,197 kg and 1,000 kg whereas retained seeds were 1,914 kg, 1,330 kg, 2,019 kg, 4,338 kg, 250 kg and 410 kg of those varieties respectively. The grand total of seed production from demonstrated plots were 29,812 kg and farmers retained 10,261 kg of seeds for next year cultivation and distribution to other interested farmers. The knowledge gained farmers were 1,070, 768, 1,156, 2,756, 184 and 302 about BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan49, BRRI dhan76 and BRRI dhan77 respectively. The grand total of knowledge gained farmers were 6,236 and motivated farmers were 3,053 for different varieties demonstrated in 62 farmers' fields.

The demonstrations on SPDP were conducted in three upazilas of three districts of jurrisdicted areas of BRRI RS, Sonagazi during T. Aman under SPIRA project. BRRI dhan75 and BRRI dhan78 were used as cultivar in those upazilas considering land suitability, agro-ecology and seed availability. A total of 18 demonstrations were conducted in 22 farmers' fields having three bighas of each demonstration.

The total seed production of BRRI dhan75 and BRRI dhan78 were 6,297 kg and 5,101 kg whereas retained seeds were 1,515 kg and 1,510 kg of those varieties respectively. The grand total of seed production from demonstrated plots were 11,398 kg and farmers retained 3,025 kg of seeds for next year cultivation and distribution to other interested farmers. The knowledge gained farmers were 952 and 935 about BRRI dhan75 and BRRI dhan78 respectively. The grand total of knowledge gained farmers were 1,887 and motivated farmers were 995 for those two varieties demonstrated in 22 farmers fields.

SPDP during Boro 2017-18

The demonstrations on SPDP were conducted in 15 upazilas of six districts of jurrisdicted areas of BRRI RS, Sonagazi during Boro season under core programme. BRRI dhan28, BRRI dhan29 and BRRI dhan58 were used as cultivar in different upazilas. A total of 45 demonstrations were conducted in 50 farmers' fields having two bighas of each demonstration.

The total seed production of BRRI dhan28, BRRI dhan29 and BRRI dhan58 were 21,668 kg, 26,996 kg and 26,439 kg whereas farmers retained 5,517 kg, 7,254 kg and 7,303 kg seeds of those varieties respectively. The grand total of seed production from demonstrated plots were 75,103 kg and farmers retained 20,074 kg of seeds for next year cultivation and distribution to other interested farmers. The knowledge gained farmers were 5,351, 5,282 and 5,662 about BRRI dhan28, BRRI dhan29 and BRRI dhan58 respectively. The grand total of knowledge gained farmers were 16,295 and motivated farmers were 7,592 for different varieties demonstrated in 50 farmers' fields.

The demonstrations on SPDP were conducted in four upazilas of three districts of jurrisdicted areas of BRRI RS, Sonagazi during Boro season under SPIRA project. BRRI dhan67, BRRI dhan69 and BRRI dhan74 were used as cultivar in those upazilas considering land suitability, agro-ecology and seed availability. A total of 24 demonstrations were conducted in 27 farmers' fields having three bighas of each demonstration.

The total seed production of BRRI dhan67, BRRI dhan69 and BRRI dhan74 were 5,662 kg, 6,580 kg and 6,666 kg whereas retained seeds were 1,663 kg, 1,630 kg and 1,913 kg of those varieties respectively. The grand total of seed production from demonstrated plots were 18,908 kg and farmers retained 5,206 kg of seeds for next year cultivation and distribution to other interested farmers. The knowledge gained farmers were 1,461, 1,448 and 1,398 about BRRI dhan67, BRRI dhan69 and BRRI dhan74 respectively. The grand total of knowledge gained farmers were 4,307 and motivated farmers were 2,337 for those varieties demonstrated in 27 farmers fields.

Farmers training

Farmers' trainings were arranged in Noakhali, Feni, Chattogram, Cox's bazar and Rangamati districts in collaboration with 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 20 farmers trainings on 'Modern Rice production technology' were conducted in five different districts during the reporting period. In every batch of farmers training 30 farmers and five 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 700 farmers and DAE staffs were trained during the reporting period.

Field day

Field days were arranged for awareness building and create interest among the farmers and concerned extension agents about the modern rice production technologies. These programmes were aimed at creating wide publicity and familiarity about the institute, our technologies and BRRI's contribution towards national economy. About 150-200 personnel (farmers, researchers, extension service providers, local leaders, public representatives and administrative people etc) were invited in a field day. A total of 18 field days were arranged during Aus, T. Aman and Boro seasons. Nearly 3,600 progressive farmers, local leaders, DAE field stuff, 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 conducted at BRRI research field during Aus and Aman 2017 and Boro 2017-18. 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 Aus, Aman and Boro were 964 kg, 9,064 kg and 310 kg respectively.

Breeder seed production

Nucleus seeds were supplied from Genetic Resources and Seed (GRS) Division for breeder seed production during Aman and Boro seasons. BRRI dhan34 and BRRI dhan70 were cultivated during Aman season whereas BRRI dhan28, BRRI dhan29, BRRI dhan33 and BRRI dhan63 were cultivated during Boro season. All the produced seeds were sent to GRS Division of BRRI HQ, Gazipur. In total, breeder seeds produced during Aman and Boro were 2.80 tons and 11.31 tons respectively.

BRRI RS, Kushtia

SUMMARY

A total of 27 experiments were conducted during Aus 2017 to Boro 2017-18 under variety development, Socio-Economics and Policy and Crop-Soil-Water management programme areas. Under variety development programme area 20 regional yield trials (RYT) were conducted, of which two were in Aus, nine in T. Aman and nine in Boro season. In addition, ten proposed variety trials (PVT) were conducted of which three were in Aus, two in T. Aman and five in Boro season.

In the RYT, T. Aus, BR8776-L7-4-2 out yielded check BR26 significantly but the yield difference with BRRI dhan48 was not significant. In RYT for T. Aus (Biotech), none of the tested lines performed better than the check. Two sets of PVT were conducted in B. Aus in which the advanced line BR6848-3B-12 out yielded the check BRRI dhan43.

A total of nine RYTs and two PVTs were carried out in T. Aman 2017. In RYT for rainfed lowland rice (RLR), IRRI132 out yielded all other lines and the checks with 119 days of growth duration. In another RYT for RLR, two lines BRRI dhan29-SC3-28-16-15-HR2 (Com) and BR8822-56-2-5-2 exhibited better yield performance. Two RYTs were conducted for premium quality rice (PQR) development. In one trial, BR8493-3-5-1(Com) and BR8850-10-12-3-1 yielded the highest (4.11-4.13 t/ha). In another trial, three tested lines yielded significantly higher than the local check Kataribhog and similar to the yield of BRRI dhan37. In RYT for the development of high yielding rice (Biotech), BR(Bio)8961-AC26-16 yielded significantly higher than the check BRRI dhan49 and other tested lines. In RYT for zinc enriched rice (ZER), BR8442-12-1-3-1-B1 yielded higher than the check BRRI dhan33 but lower than BRRI dhan72. The lines BR8698-12-5-3-2 and BR8693-4-1-1-1were promising in RYT for insect resistant rice (IRR). However, growth duration of the mentioned lines was much longer than the checks. In RYT for disease resistant rice (DRR), BR9140-5-22-5-1 yielded the highest. The test entry Monibandhobi yielded identical to BRRI dhan46 with 10 days shorter growth duration, in RYT for green super rice (GSR).

In PVT for RLR, BR-RS(Raj)-PL4-B and BR-SF(Rang)-PL1-B yielded higher than BRRI dhan49 but lower than BR11. Moreover, their growth duration was longer than the checks. In another PVT, BR(Bio)9786-BC2-132-1-3 yielded 0.73 ton more than BRRI dhan49 with seven days shorter growth duration.

A total of ten RYTs and five PVTs were carried out in Boro 2017-18 encompassing the fields with favourable Boro rice (FBR), PQR, ZER, DRR, IRR and GSR. In the trial for PQR, Dinajpur Miniket (Rangpur) and BR8590-5-2-5-2-1 were promising test entries. In RYT for DRR, BR9650-35-4-3 yielded higher than the checks but the yield difference was not significant. Two advanced lines BR8340-5-6-1 and BR8339-6-2-5-2 showed better performance in RYT for IRR. In RYT for FB ten advanced lines yielded higher than BRRI dhan28 but lower than BRRI dhan58. Several of the lines can be selected for further evaluation. In RYT for GSR, HHZ15-DT7-SAL4-SAL1was the highest yielder with growth duration close to BRRI dhan58. Three RYTs were conducted for ZER. In one trial, six promising lines yielded more than 7 t/ha with growth duration shorter than BRRI dhan29. In another trial, two advanced lines BR7528-2R-19-16-RILL-49 and BR7528-2R-19-16-RILL-1 performed better than the others. Two of tested lines BR (Bio) 9777-26-4-3 and BR (Bio) 9777-118-6-4 were promising in RYT for FBR (Biotech).

PVT for variety development with low water requirement (Biotech) was conducted in three locations, namely, Meherpur, Chuadanga and Kushtia. The average grain yield of the three locations was 7.8 tons (slightly higher than the check BRRI dhan29) in 163 days. Likewise, in another PVT for FBR, the proposed material BR (Bio) 9786-BC2-59-1-2 yielded slightly higher (7.2 t/ha) than the check variety BRRI dhan29 with five days shorter growth duration. In PVT for FBR (Breeding), BRRI dhan29 SC3-28-16-10-8-HR1(Com) yielded about 0.8 ton higher than the check BRRI dhan28 with similar growth duration.

In an experiment for optimization of irrigation water for maximum year round production, it was observed that BRRI dhan49 required more irrigation than BRRI dhan75 due to longer growth duration (136 days). During Rabi/Boro season, rice (BRRI dhan28) required highest number of irrigation (13) followed by maize (4). Lentil did not require any irrigation.

Stability analysis of BRRI varieties were conducted to observe their performance under Genotype × Environment interaction. In T. Aus, the highest yielder was BRRI dhan48 and the lowest was BRRI dhan43. In T. Aman, the highest yield was scored by BRRI dhan51 and the lowest by BRRI dhan37. Several varieties lodged during T. Aman. In Boro season, the highest yielder was BRRI hybrid dhan5 and the lowest was BRRI dhan27.

A total of 13 batches of farmers' training were organized in the reporting year in which 420 farmers were trained. Modern rice varieties and relevant technologies were disseminated through seven field days in which more than 700 farmers participated. Also BRRI developed technologies were demonstrated in development fair held in Kushtia.

VARIETY DEVELOPMENT

Aus 2017

Regional yield trial, T. Aus. Twelve genotypes and two standard checks BR26 and BRRI dhan48 were tested under this experiment. The highest yielder was the genotype BR8776-L7-4-2 (5.28 t/ha) which outyielded check BR26 significantly. However the yield difference with BRRI dhan48 was not significant. Also, the growth duration was much longer than that of the checks.

RYT (Biotechnology), T. Aus, 2017. Four genotypes and one standard check BRRI dhan48 were evaluated in this trial. None of the tested lines performed better than the check.

PVT B. Aus, Bheramara. One genotype and one standard check BRRI dhan43 was evaluated under this trial to recommend the proposed genotype as a new variety by the NSB team. Two experiments were set in Bheramara and Kushtia sadar. In Bheramara, the proposed material out yielded the check variety BRRI dhan43 (2.46 t/ha) with 0.5 ton yield advantage although the yield difference was not statistically significant.

In Boria, Kushtia, the proposed material BR6848-3B-12 significantly out yielded the check variety BRRI dhan43 with 1.5 ton yield advantage.

PVT, T. Aus 2017. One promising line NERICA 10-7-PL2-B was evaluated with standard check BRRI dhan48 in this trial. The proposed variety and the check scored statistically similar yield.

T. Aman 2017

RYT (PQR-1: Kalizira type). Seven genotypes and two standard checks Kalizira and BINA dhan-13 were evaluated under this trial. All the lines outyielded the check varieties. Among these, BR8493-3-5-1(Com) and BR8850-10-12-3-1 yielded the highest (4.11- 4.13 t/ha). Growth duration of BR8850-10-12-3-1 was 13 days shorter than the check and can be considered for further evaluation.

RYT (PQR-2: BRRI dhan37+ Kataribhog type). Three genotypes and two standard checks BRRI dhan37 and Kataribhog (local) were evaluated in this trial. The tested lines yielded significantly higher than the local check Kataribhog and statistically similar to the yield of BRRI dhan37 (3.45 t/ha). Therefore, all the lines can be considered for further evaluation.

RYT (RLR-1). Eleven genotypes and two standard checks BRRI dhan39 and BRRI dhan49 were evaluated under this experiment. None of the tested lines performed better than the checks since the yields of the lines and checks were statistically similar. However, IRRI132 yielded 5.27 t/ha with 119 days growth duration and can be considered for further evaluation.

RYT (RLR-2). Seven genotypes and two standard checks BRRI dhan39 and BRRI dhan49 were evaluated under this experiment. Two of the tested lines BRRI dhan29-SC3-28-16-15-HR2 (Com) (4.0 t/ha) and BR8822-56-2-5-2 (3.96 t/ha) exhibited better yield performance than the checks BRRI dhan39 and BRRI dhan49, although the yield was not significantly different.

RYT (Biotechnology), development of high yielding rice, T. Aman. Four genotypes and one standard check BRRI dhan49 was evaluated under this experiment. One of the tested lines BR (Bio) 8961-AC26-16 recorded significantly higher yield (5.26 t/ha) than the check BRRI dhan49 (4.59 t/ha) and other tested lines.

RYT (ZER), T. Aman. Six genotypes and four standard checks BRRI dhan33, BRRI dhan39, BRRI dhan72 and BINA dhan-7 were evaluated under this experiment. Among the tested lines BR8442-12-1-3-1-B1 yielded higher (4.58 t/ha) than the check BRRI dhan33 but lower than BRRI dhan72. In addition, its growth duration (141 days) was much longer than the checks.

RYT, IRR, T. Aman. Six genotypes and two standard checks BRRI dhan33 and BRRI dhan49 were tested under this experiment to evaluate specific and general adaptability of the advanced breeding lines compared to standard checks in Kushtia region. The line BR8698-12-5-3-2 was the highest yielder (5.69 t/ha) followed by BR8693-4-1-1-1. However, growth duration of the mentioned line was 17 and 4 days longer than BRRI dhan33 and BRRI dhan49 respectively.

RYT, DRR, T. Aman. Nine genotypes and three standard checks BRRI dhan39 (susceptible), BRRI dhan49 (susceptible) and IRBB60 (resistant) were evaluated under this experiment. The line BR9140-5-22-5-1 yielded the highest (5.57 t/ha). The yield differed significantly with BRRI dhan39 only but not with other checks.

RYT, Biotech, T. Aman. Four genotypes and one standard check BRRI dhan49 was evaluated under this experiment. It was observed that the line BR (Bio) 8961-AC26-16 yielded the highest (5.25 t/ha) with highest panicle/m^2 among all the lines and check, with similar growth duration.

Regional yield trial, GSR. Two genotypes and one standard check BRRI dhan46 was tested in this trial. The tested genotype Monibandhobi yielded identical to the standard check BRRI dhan46 (4.81 t/ha) with 10 days shorter growth duration.

PVT, RLR, T. Aman. Two genotypes and two standard checks BR11 and BRRI dhan49 was evaluated under this trial to recommend the proposed genotype as a new variety by the NSB team. Both the proposed materials BR-RS(Raj)-PL4-B and BR-SF(Rang)-PL1-B yielded higher (5.25 and 5.04 t/ha) than the check BRRI dhan49 (4.63 t/ha) but could not outyield BR11(5.41 t/ha).

PVT (Biotechnology) T. Aman, 2017. One proposed line along with one check BRRI dhan49 was evaluated to observe the performance of the proposed line for releasing as variety. The proposed material BR (Bio) 9786-BC2-132-1-3 performed better (5.09 t/ha) than the check variety BRRI dhan49 with seven days shorter growth duration. Thus, this promising line can be considered for recommending as a new variety.

Boro, 2017-18

RYT (PQR). Six genotypes along with BRRI dhan28, BRRI dhan50 and BRRI dhan63 were evaluated in this trial. Among the tested genotypes, Dinajpur Miniket (Rangpur) and BR8590-5-2-5-2-1 yielded higher (6.74 t/ha and 6.63 t/ha) than the check varieties. However, the yield difference with the check varieties was not statistically significant.

RYT(DRR), Boro. Four genotypes were tested against three checks BRRI dhan28 (susceptible), BRRI dhan29 (susceptible) and IRBB60 (resistant). Among the tested lines BR9650-35-4-3 yielded higher (7.44 t/ha) than the checks and others genotypes but the yield difference was statistically insignificant. However, its growth duration (167 days) was too long.

RYT (IRR), Boro. Six genotypes along with three checks BR3 (susceptible), BRRI dhan28 (susceptible) and T27A (tolerant) were tested in this experiment. Among the tested genotypes BR8340-5-6-1 yielded the highest (7.89 t/ha) followed by BR8339-6-2-5-2 (7.19 t/ha). However, the growth duration of the former was more than 160 days.

RYT favoruable Boro rice. Ten genotypes and two standard checks BRRI dhan28 and BRRI dhan58 were tested under this experiment. In this trial, all the genotypes yielded higher than the check BRRI dhan28 (5.87 t/ha) but lower than BRRI dhan58.

RYT GSR, Boro. Three genotypes and three standard checks BRRI dhan28, BRRI dhan58 and BRRI dhan69 were evaluated in this trial. Among the tested lines HHZ15-DT7-SAL4-SAL1 was the highest yielder (7.81 t/ha) with growth duration close to BRRI dhan58.

RYT (ZER-1), Boro. Ten genotypes and three standard checks BRRI dhan28, BRRI dhan29 and BRRI dhan74 were tested under this experiment. Among the tested lines, the highest yielder was BR8634-23-1-1-BHA-8 (7.66 t/ha) which was similar to BRRI dhan29. Out of 10 entries, six lines (V1, V2, V3, V5, V6 and V9) yielded more than 7 t/ha with growth duration shorter than BRRI dhan29. Hence these promising lines can be advanced for further evaluation.

RYT (ZER-2), Boro. Four genotypes and two standard checks BRRI dhan28 and BRRI dhan74 were tested under this experiment. Among the tested lines BR7528-2R-19-16-RILL-49 yielded highest (6.95 t/ha) followed by BR7528-2R-19-16-RILL-1. Growth duration of both the lines was slightly longer than the checks.

RYT (ZER-3), Boro. Two genotypes and one standard check BRRI dhan28 were tested under this experiment. Grain yield of all the tested entries and the check was statistically similar (6.03-6.16 t/ha).

RYT (FBR- Biotech.), Boro. Four advanced lines along with one check vareity BRRI dhan58 were evaluated under this experiment. Among the tested lines, BR(Bio)9777-26-4-3 (7.58 t/ha) yielded the highest followed by BR (Bio) 9777-118-6-4 (7.38 t/ha). The yield was significantly higher than the check BRRI dhan58 (6.73 t/ha) having similar growth duration.

PVT (Low water requirement-Biotech.), Boro. One genotype was evaluated against one standard check BRRI dhan29 to recommend the proposed genotype as a new variety. The trial was conducted in three locations, such as: 1. Jorpukuria, Gangni, Meherpur; 2. Binodpur, Alamdanga, Chuadanga and 3. Baradi sadar, Kushtia. In Gangi, the proposed material BR (BE) 6158RWBC2-1-2-1-1 yielded statistically similar to the check with three days longer growth duration.

In Alamdanga and Kushtia sadar, BR (BE) 6158RWBC2-1-2-1-1 yielded statistically similar to the check variety with similar growth duration. The average grain yield of the three locations was 7.8 tons in 163 days.

PVT (FB, Breeding), Boro. One genotype was evaluated against one standard check BRRI dhan28 at Baradi sadar Kushtia to recommend the proposed genotype as a new variety. The proposed material BRRI dhan29SC3-28-16-10-8-HR1(Com) yielded about 0.8 ton higher than the check with similar growth duration (145 days). Thus, the line can be considered to be released as a variety.

PVT (FB-Biotech), Boro. One genotype and one standard check BRRI dhan29 was evaluated under this trial. The proposed material yielded slightly higher (7.2 t/ha) than the check variety BRRI dhan29 with five days shorter growth duration.

CROP-SOIL-WATER MANAGEMENT

Optimization of irrigation water for maximum year round production

The experiment was evaluated at BRRI RS, Kushtia during starting season T. Aman 2017 to evaluate the productivity and irrigation water requirements of the cropping patterns. Both short (BRRI dhan75) and long duration (BRRI dhan49) T. Aman varieties were transplanted in the optimum time. Rabi crops were grown after short duration T. Aman harvest. Short duration Boro variety was transplanted after long duration T. Aman harvest. Irrigation water was applied as per crop requirement. Four recommended cropping patterns were evaluated. These are CP_1= Maize-T. Aus-T. Aman, CP_2= Potato-Late Boro-T. Aman, CP3=Lentil-T. Aus-T. Aman and CP4=Boro-Fallow-T. Aman or local popular pattern. The experiment was designed in RCB with three replications. The unit plot size was 5m × 5m= 25 m^2. Three Rabi crops (Maize, Lentil and Potato) were cultivated. The varieties of each crop were as follows: 1. T. Aman-BRRI dhan49 (long) BRRI dhan75 (short), 2. Rabi-Maize (BARI hybrid Vutta-9)/Potato (Cardinal)/Lentil (BARI Masur-6), 3. Boro-BRRI dhan28 (short) and 4. Late Boro/Aus-BRRI dhan48.

Severe fungal infestation was observed in lentil, which could not be recovered using fungicide. This resulted in lower lentil yield. From the results, it is observed that BRRI dhan49 yielded slightly higher than BRRI dhan75, but required more irrigation due to its longer growth duration (136 days) (Table 1). During Rabi/Boro season, rice (BRRI dhan28) required the highest number of irrigation (13) followed by maize (4) (Table 2). Lentil was totally rainfed.

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 8, 36 and 38 respectively. The unit plot size was 3 m × 2 m with 20 cm × 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 25 days, 30 days and 40 days in Aus, T. Aman and Boro seasons respectively.

Among the eight tested varieties in T. Aus, the highest yield was scored by BRRI dhan48 (3.3 t/ha) and the lowest by BRRI dhan43 (1.7 t/ha). Lodging tendency was not observed during T. Aus (Table 3).

Table 1. Yield, growth duration and irrigation requirement of crops, T. Aman 2017.

Cropping pattern	No. of irrigation	Irrigation applied (mm)	Eff. tiller/m^2	Plant ht (cm)	Growth (day)	Yield (t/ha)
CP_1=BRRI dhan75			238	102	117	5.13
CP_2=BRRI dhan75	4	200	253	103	117	5.18
CP_3=BRRI dhan75			250	100	117	5.16
CP_4=BRRI dhan49	5	250	259	94	136	5.41

Table 2. Mean yield and irrigation requirement of different crops, Rabi 2017-18.

CP	Crop	Growth duration (day)	No. of irrigation	Irrigation applied (mm)	Rainfall (mm)	Mean yield (kg/ha)
1	Maize	148	4	200	369.57	11200
2	Potato	90	3	150	6.25	29866
3	Lentil	105	0	0	6.25	793
4	BRRI dhan28	142	13	650	391.16	6350

Table 3. Stability analysis of BRRI varieties, T. Aus 2017.

Variety	Growth duration (day)	Standard growth duration (day)	Yield (t/ha)	Standard yield (t/ha)	Ranks
BR21	112	110	2.67	3.0	3
BR24	126	105	2.29	3.5	7
BR26	114	115	2.31	4.0	6
BRRI dhan27	126	115	2.42	4.0	5
BRRI dhan42	114	100	2.51	3.5	4
BRRI dhan43	112	100	1.70	3.5	8
BRRI dhan48	118	110	3.29	5.5	1
BRRI dhan65	110	99	2.71	3.5	2
$LSD_{0.05}$	6.1		0.62		
CV (%)	1.8		8.4		

DS-21 Apr 2016, DT-15 May 2016.

In T. Aman 2017, among 38 tested varieties the highest yielder was BRRI dhan51 (4.95 t/ha) and the lowest was BRRI dhan37 (2.64 t/ha). Lodging was observed at different magnitudes (20-35%) in case of six varieties namely BR22, BR25, BRRI dhan32, BRRI dhan34, BRRI dhan37 and BRRI dhan38 (Table 4).

In Boro 2017-18, among 36 tested varieties the highest yield was obtained by BRRI hybrid dhan5 (8.79 t/ha) and the lowest by BRRI dhan27 (4.62 t/ha) (Table 5). None of the varieties showed lodging during Boro season.

TECHNOLOGY TRANSFER

In the reporting year, 13 batches of farmers' training were organized in which 420 farmers were trained. Modern rice varieties and relevant technologies were disseminated through field demonstration and seven field days in which more than 700 farmers participated. A total of 36 demonstrations of the BRRI released HYVs were conducted under GOB, SPIRA, Harvest Plus and TRB projects in the farmers field in Kushtia, Chuadanga, Meherpur, Jhenaidah and Magura districts. Also BRRI developed technologies were demonstrated in Development Fair held in Kushtia.

Table 4. Stability analysis of BRRI varieties, T. Aman 2017.

Variety	Growth duration (day)	Standard growth duration (day)	Yield (t/ha)	Standard yield (t/ha)	Rank
BR3	143	145	4.24	6.5	10
BR4	147	145	3.47	5.0	31
BR5	144	150	3.07	3.0	35
BR10	152	150	4.67	5.5	3
BR11	138	145	3.71	5.5	27
BR22	144	150	3.67	5.0	29
BR23	161	150	3.37	5.5	33
BR25	147	135	3.76	4.5	25
BRRI dhan30	146	145	3.83	5.0	22
BRRI dhan31	139	140	4.12	5.0	12
BRRI dhan32	135	130	3.74	5.0	26
BRRI dhan33	126	118	3.90	4.5	17
BRRI dhan34	139	135	3.23	3.5	34
BRRI dhan37	141	140	2.64	3.5	38
BRRI dhan38	139	140	2.96	3.5	36
BRRI dhan39	127	122	4.10	4.5	13
BRRI dhan40	146	145	4.01	4.5	16
BRRI dhan41	140	148	3.64	4.5	30
BRRI dhan44	142	145	4.04	5.5	14
BRRI dhan46	142	150	3.82	4.7	23
BRRI dhan49	140	135	4.02	5.5	15
BRRI dhan51	153	142	4.95	4.5	1
BRRI dhan52	140	140	4.43	5.0	7
BRRI dhan53	134	125	4.29	4.5	9
BRRI dhan54	131	135	4.75	4.5	2
BRRI dhan56	125	110	3.76	4.5	24
BRRI dhan57	123	105	2.64	4.0	37
BRRI dhan62	125	100	3.83	4.5	21
BRRI dhan66	132	113	4.42	4.5	8
BRRI dhan70	141	130	3.70	5.0	28
BRRI dhan71	127	115	4.23	5.5	11
BRRI dhan72	140	125	4.62	6.0	5
BRRI dhan73	134	130	4.43	3.5-6.0	6
BRRI dhan75	126	117	3.88	5.5	18
BRRI dhan76	141	163	3.87	5.0	19
BRRI dhan77	147	155	3.85	5.0	20
BRRI hybrid dhan4	123	118	3.38	6.5	32
BRRI hybrid dhan6	127	120	4.64	6.5	4
$LSD_{0.05}$	6.14		0.64		
CV (%)	2.7		10.10		

DS: 15 Jul 2017, DT: 21 Aug 2017.

Table 5. Stability analysis of BRRI varieties, Boro 2017-18.

Variety	Growth duration (day)	Standard growth duration (day)	Yield (t/ha)	Standard yield (t/ha)	Rank
BR1	159	150	5.65	5.5	29
BR2	150	160	5.28	5.0	33
BR3	168	170	6.44	6.5	18
BR6	151	140	4.83	4.5	35
BR8	162	160	6.15	6.0	22
BR9	160	155	6.10	6.0	26
BR12	161	170	5.54	5.5	31
BR14	154	160	6.11	6.0	24
BR15	157	165	5.58	5.5	30
BR16	164	165	6.13	6.0	23
BR17	151	155	5.99	6.0	28
BR18	161	170	6.11	6.0	25
BR19	164	170	6.08	6.0	27
BR26	149	140	6.40	3.5	19
BRRI dhan27	153	122	4.62	4.5	36
BRRI dhan28	147	140	6.58	6.0	14
BRRI dhan29	162	160	7.82	7.5	4
BRRI dhan35	161	155	5.28	5.0	34
BRRI dhan36	148	140	5.33	5.0	32
BRRI dhan45	146	145	6.40	6.5	20
BRRI dhan47	154	152	6.62	6.0	13
BRRI dhan50	157	155	6.38	6.0	21
BRRI dhan55	151	145	7.14	6.0	7
BRRI dhan58	152	155	6.99	7.0	8
BRRI dhan59	147	153	6.81	7.0	12
BRRI dhan60	149	151	6.88	7.1	11
BRRI dhan61	153	150	6.54	7.3	16
BRRI dhan63	149	148	7.17	7.0	6
BRRI dhan64	148	152	6.46	6.5	17
BRRI dhan67	146	143	6.57	6.0	15
BRRI dhan68	150	149	6.89	7.3	10
BRRI dhan69	152	153	7.47	7.3	5
BRRI dhan74	148	147	6.97	7.1	9
BRRI hybrid dhan2	159	145	8.11	8.0	3
BRRI hybrid dhan3	156	145	8.61	9.0	2
BRRI hybrid dhan5	155	145	8.79	9.0	1
$LSD_{0.05}$	2.86		0.23		
CV (%)	1.10		2.20		

DS: 8 Dec 2017, DT: 22 Jan2018.