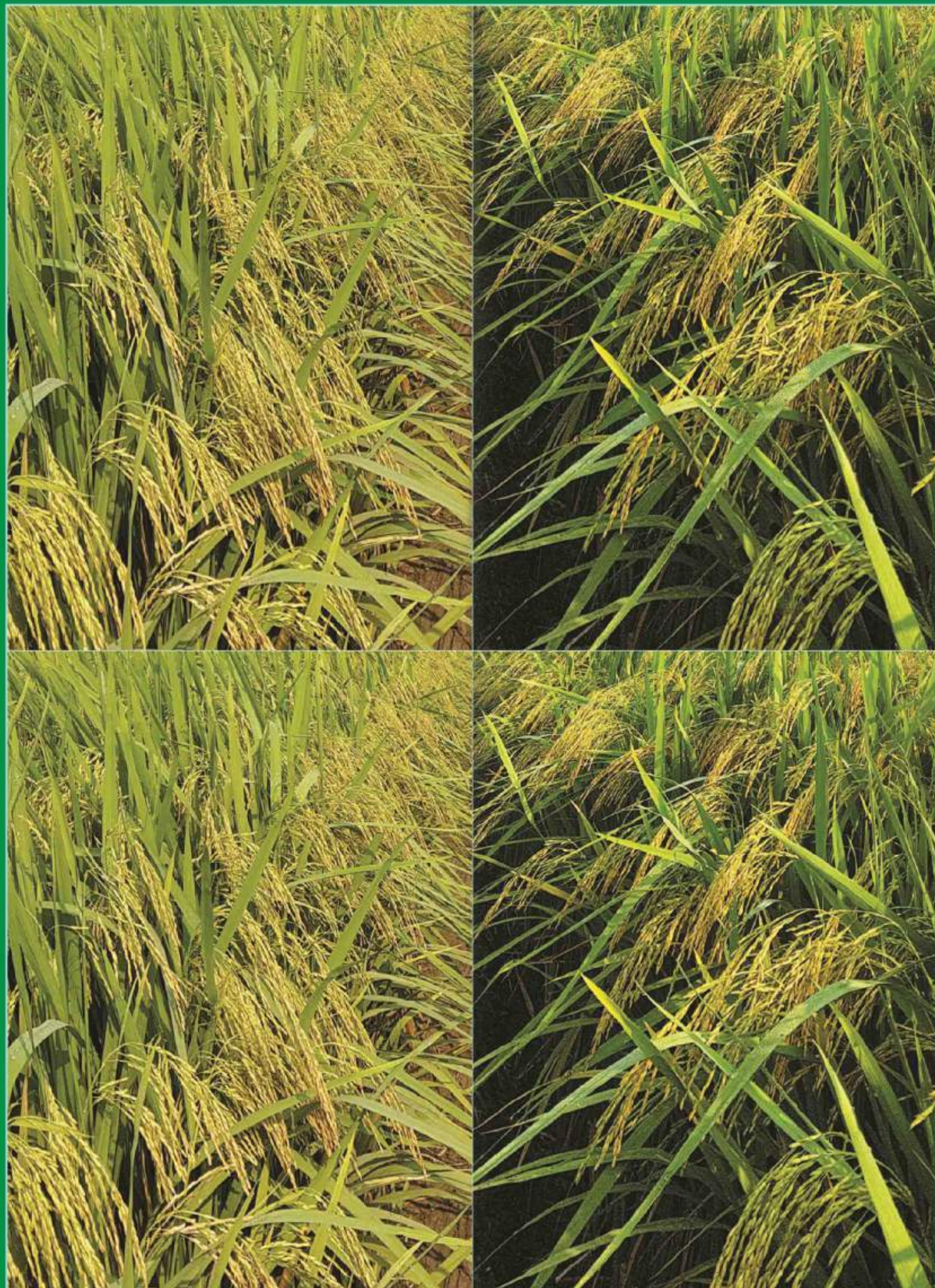

BRRI ANNUAL REPORT 2018-2019 BANGLADESH RICE RESEARCH INSTITUTE

BRRI ANNUAL REPORT
2018-2019

BANGLADESH RICE RESEARCH INSTITUTE

BRRI ANNUAL REPORT

For July 2018-June 2019

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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 2018 to June 2019. 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.

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

Weather information

Weather is an instantaneous state of atmosphere, describing for example the degree to which it is hot or cold, wet or dry, calm or stormy, clear or cloudy. It influences growth and development of crops as well as pest and disease incidence. We present here the available weather parameters viz maximum and minimum temperature (°C), rainfall (mm), evaporation (mm), humidity (9 am and 2 pm), sunshine hours (hours/day) and solar radiation (Cal/cm^2/day) during the reporting period (July 2018-June 2019) as recorded from BRRI headquarters and seven regional stations Rangpur, Barishal, Habiganj, Bhanga, Rajshahi, Sonagazi and Cumilla by Plant Physiology Division.

Temperature. The mean maximum temperature was higher in June and September for most of the stations during reporting period. The highest maximum temperature was recorded at Rajshahi (38.76°C) in June followed by Cumilla (35.8°C), while it was in May at Gazipur (35.26°C) and Barishal (34.75°C), June at Rangpur (32.0°C), September at Bhanga (34.31°C), Habiganj (33.78°C) and Sonagazi (33.63°C) (Fig. 1). Mean minimum temperature was lower during December to January in Rangpur compared to the other stations. Mean minimum temperature was the lowest in January for all stations. The lowest temperature (10.9°C) was recorded during January in Rangpur.

Rainfall and pan evaporation. During the reporting period, total rainfall was the highest in Habiganj (2226 mm), and it was the lowest in Rajshahi (612 mm). Monthly highest rainfall was recorded in July 2018 at Sonagazi (599.5 mm), Gazipur (361 mm), Barishal (347.4 mm), Bhanga (334.8 mm) and Cumilla (331.52 mm). While, it was the highest in June at Habiganj (2226 mm), Rangpur (297.4 mm) and Rajshahi (91.6 mm). However, no rainfall occurred during November' 2018 to January 2019 except Rajshahi (Fig. 2). Irrespective of station, low pan evaporation was recorded during cool period (November to January) of the year. However, the highest pan evaporation was recorded in April.

Solar radiation and solar hours. Monthly mean solar radiation ranged from 132 to 447.72 cal/cm^2/day in all the stations (Fig. 3). It was relatively lower in December to February. The highest mean solar radiation prevailed in April at Barisal (447.72 cal/cm^2) followed by Bhanga (444.52 cal/cm^2), Habiganj (428 cal/cm^2) and Gazipur (405.56 cal/cm^2). However, it was the highest in March at Rangpur (384.01 cal/cm^2), May at Cumilla (447.15 cal/cm^2), June at Sonagazi (419.03 cal/cm^2) and July at Rajshahi (437.94 cal/cm^2). The bright solar hours per day were lowest during the rainy season and the highest in November (Fig. 3).

Relative humidity. Relatively lower humidity was recorded during November to March. Humidity was recorded higher at morning irrespective of stations, but it was decreased gradually till noon (Fig. 4).

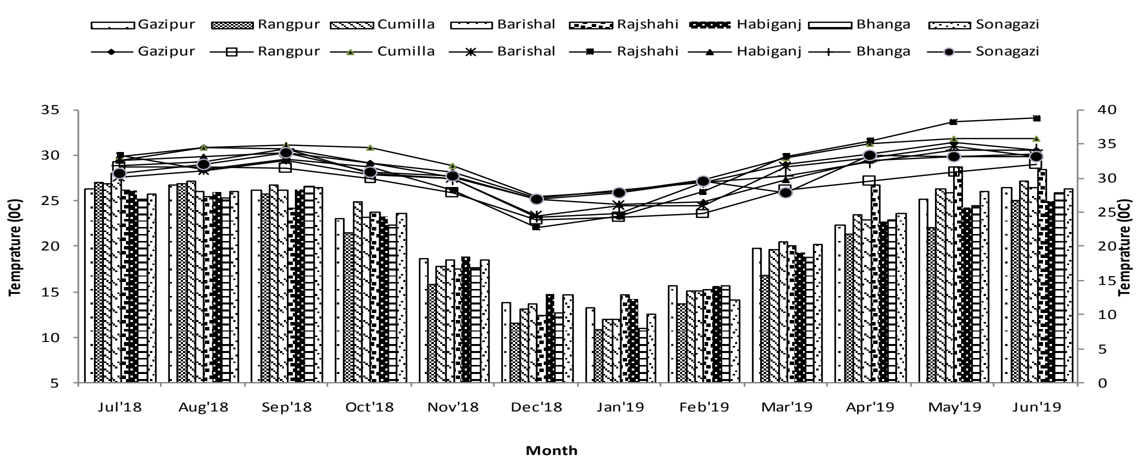


Fig. 1. Maximum and minimum temperature of BRRI headquarters and seven BRRI regional stations during July 2018 to June 2019. Bar and line graph shows minimum (value in primary axis) and maximum temperature (value in secondary axis) respectively.

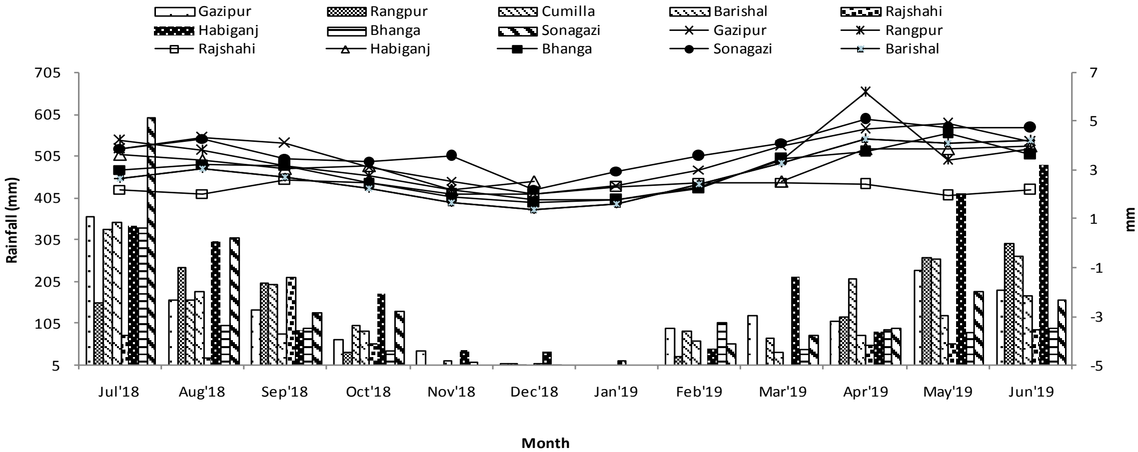


Fig. 2. Rainfall data of BRRI headquarters and seven regional stations during July 2018 to June 2019. Bar and line graph show rainfall (value in primary axis) and evaporation (value in secondary axis) respectively.

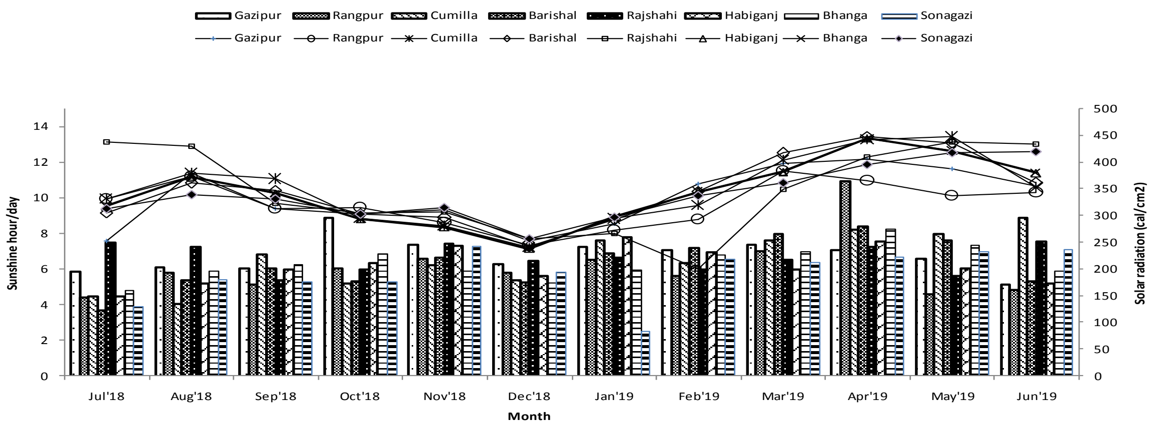


Fig. 3. Sunshine hour and solar radiation of BRRI headquarters and seven regional stations during July 2018 to June 2019. Bar and line graph show sunshine hour (value in primary axis) and solar radiation (value in secondary axis) respectively.

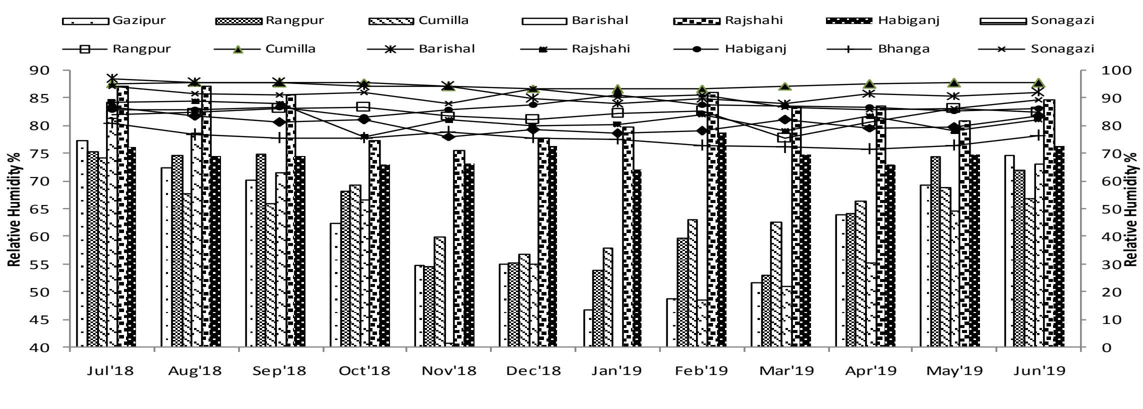


Fig. 4. Humidity of BRRI headquarters and six regional stations during July 2018 to June 2019. Bar and line graph show humidity at 2 pm (value in primary axis) and 9 am (value in secondary axis) respectively.

Abbreviation and acronyms

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

SUMMARY

As part of the rice variety development programme for different ecosystems, 413 crosses were made and 387 crosses were confirmed during 2018-19. In pedigree nursery, 28,734 individual plants were selected from F_3-F_7 generations based on phenotypic performance of each cross and 604 fixed lines were bulked. A total of 7,22,933 segregating progenies were advanced from F_2 to F_6 generations following single seed decent (SSD) method under Rapid Generation Advance (RGA) condition. From line-stage testing (LST), 5,966 lines were selected based on uniformity and other agronomic performances. A total of 588 genotypes from observational yield trial (OYT) and 524 advanced breeding lines were selected from different replicated yield trials (PYT, SYT, RYT, AYT, ALART and PVT) conducted at multi-location sites. In confined field trial condition, one transgenic GR2E BRRI dhan29 Golden Rice one line, IR112060 GR2-E:2-7-63-2-96 was evaluated across eight locations viz Gazipur, Cumilla, Rajshahi, Habiganj, Barishal, Satkhira, Rangpur and Sonagazi with the non-transgenic counterpart BRRI dhan29 as standard check. Moreover, three elite breeding lines, viz BRRI dhan29-SC3-28-16-10-8-HR1(Com) for favourable Boro ecosystem, BR8535-2-1-2 for premium quality rice (PQR) in T. Aman and BR10230-15-27-7B for semi-deep water Aman rice were evaluated by National Seed Board of Bangladesh (NSB) field evaluation team and have been released as BRRI dhan88, BRRI dhan90 and BRRI dhan91 respectively. BRRI dhan88 showed 0.2-0.6 t ha^{-1} higher yield with growth duration 2-3 days earlier than BRRI dhan28. BRRI dhan90 produced 1.0-1.4 t ha^{-1} higher yield than BRRI dhan34. The growth duration of the variety was around 22 days earlier than BRRI dhan34 in T. Aman 2018-19. BRRI dhan91 was released for semi-deep flooded B. Aman areas. It showed 1.33 t ha^{-1} higher yield than the check variety Fulkore in Broadcast Aman season of 2018-19.

VARIETY DEVELOPMENT

Development of upland rice (Aus). Upland rice (Aus) or direct seeded rice (DSR-Aus) or broadcast Aus rice is important in Bangladesh for increasing cropping intensity to boost 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. Twenty-five crosses were made using 19 parents, 29 crosses were confirmed as true hybrid. A total of 25,137 segregating progenies were obtained from 18 crosses of F_3 generation through Field RGA (FRGA). Moreover, 746 progenies and 210 fixed lines were selected from pedigree nurseries. Thirty-four entries were selected out of 104 entries from observational yield trial (OYT) based on growth duration, yield, and homogeneity and other morpho-agronomic traits. Seven advanced lines were selected from preliminary yield trial (PYT) and secondary yield trial (SYT) for further evaluation. Two lead breeding lines were selected from regional yield trial (RYT) for further evaluation in farmers' field under different upland rice areas of Bangladesh.

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

Development of transplant Aus rice. Development of short duration (105-110 days), high yielding genotypes having tolerance to lodging and heat (high temperature) at reproductive phase, pre-harvest sprouting and good grain quality is the aim of this project. In total, 13 crosses were made and 19 crosses were confirmed as true hybrid. A total of 60,792 progenies from 19 crosses of F_2 generation, 16,658 progenies from 13 crosses of F_3 generation and 14,113 progenies from 22 crosses of F_4-F_6 generations were advanced through transplanted field RGA. Moreover, 3,922 progenies from 19 crosses of F_4 generations and 1,200 progenies from four crosses of F_5 were advanced through direct seeded field RGA. Six genotypes were selected from 27 entries in OYT and eight advanced lines were selected from 17 entries in PYT on the basis of homogeneity with respect to plant height, phenotypic acceptability at vegetative and maturity stages and physicochemical properties. From RYT, five genotypes were selected based on growth duration, PAcp, grain quality and grain yield compared to popular cultivar BR26 and BRRI dhan48. One genotype BR9011-67-4-1 was recommended as candidate variety from adaptive research trials conducted by Adaptive Research Division (ARD) at T. Aus grown areas under different agro-ecological zones to evaluate as Proposed Variety Trial (PVT).

Investigators: Mahmuda Khatun, MM Emam Ahmed, S Das, SK Debsharma and T L Aditya

Improvement of rice for shallow flooded environment. The major objectives of the this project were to develop high yielding (4.0-5.0 t ha^{-1}) 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 (11+20) crosses were made using 35 parents and 3569 F_1 seeds were produced from five crosses. Sixteen single crosses and 11 crosses were confirmed from multiple crosses. A total of 4,690 F_2 progenies, 193 F_6 progenies were advanced through FRGA. In addition, 211 progenies were also advanced through pedigree selection. Five modern deep water advanced lines having medium elongation under semi-deep flooded conditions were selected. Nine local deep water rice varieties having faster elongation under very deep flooded conditions were selected. Seed of the local cultivars were increased for genetic purity. Besides, four genotypes including a lead breeding line BR8159-20-8-5-8-2 (5.2 t ha^{-1}) showing 1.2 t ha^{-1} higher yield than the check variety BRRI dhan52 (4.4 t ha^{-1}) and BRRI dhan44 (4.4 t ha^{-1}) were selected from multi-location trials (MLT). An advanced line BR10230-15-27-7B was approved and released by the National Seed Board (NSB) as deep water rice variety BRRI dhan91 for semi-deep flooded B. Aman areas. It showed very strong stems and lodging tolerance with 185 cm plant height (medium stem and gave 1.33 t ha^{-1} higher yield than the check variety Fulkore in Broadcast Aman season 2018-19 (Table 1).

Investigators: ASM Masuduzzaman, K M Iftekharuddaula, AKM Shalahuddin, Sharmistha Ghosal and T L Aditya

Development of rainfed low land rice. Development of genotypes superior to standard varieties and adaptable to rainfed lowland environment was the aim of this project. In the reporting year 8,420 F_1 seeds were produced from 12 single crosses and five multiple crosses were made; four F_1 crosses were confirmed as true hybrid. A total of 12,931 panicles from F_2 and 8,211 from F_4 generation were harvested at the time of maturity and preserved and processed with proper labels through RGA method. From F_3 generation 930 progenies of 33 crosses, from F_4 generation 370 progenies of 18 crosses, from F_5 generation 197 progenies of 10 crosses were selected and from F_6 generation 39 progenies were bulked and selected through Pedigree method. In different yield trials, 326 genotypes were tested and 104 genotypes were selected. Two RYTs were conducted at seven regional stations of BRRI. In RYT#1, two genotypes were selected out of five and in RYT#2, two genotypes were selected out of six for ALART. The mean heritability estimates obtained from yield were 79% and 78% respectively, indicating high level of precision of these experiments. Also two PVTs were conducted at 10 different locations of Bangladesh. The proposed lines BR-RS(Raj)-PL4-B, BR-SF(Rang)-PL1-B and BR8210-10-3-1-2 produced 5.87, 5.77 and 5.65 t ha^{-1} grain yield respectively, which were significantly higher than the grain yield of check variety BRRI dhan49 (5.06 t ha^{-1}) (Table 2). In Boro 2018-19, 17 F_1 crosses were confirmed as true hybrid. Panicles of 3,318 from F_2, 9,877 from F_3 and 9,534 from F_5 generation were harvested at the time of maturity and preserved and processed with proper labels through RGA method.

Investigators: M A Kader, T K Hore, AKM Shalahuddin, Al Amin, MS Hossain, Tapan Kumar and T L Aditya

Table 1. Performance of modern deep water rice BRRI dhan91 under proposed variety trial, B. Aman 2018-19.

Designation	*Plant height (cm)	*Growth duration (day)	*Grain yield (t ha^{-1})	Grain characteristics				
				Head rice yield (%)	L/B ratio	Size and shape	Protein (%)	Amylose (%)
BRRI dhan91 (BR10230-15-27-7B)	185	154	2.37	64.8	2.6	MB	9.5	25.8
Fulkore (ck)	188	163	1.04	54.9	2.2	MB	10.1	26.3

*Mean of nine locations (Bhanga- Faridpur; Moksudpur- Gopalganj; Sadar- Manikganj; Singair- Manikganj; Ghior- Manikganj; Balikhal- Habiganj; Homna- Cumilla; Nagorpur- Tangail and BRRI farm- Gazipur.

Table 2. Performance of BR-RS (Raj)-PL4-B, BR-SF(Rang)-PL1-B, BR8210-10-3-1-2 in PVT, RLR, T. Aman 2018-19.

Designation	Plant height (cm)*	Growth duration (days)*	Grain yield (t/ha)*	Grain characteristics					
				Head rice yield (%)	L/B ratio	Size and shape	Elongation ratio	Protein (%)	Amy lose (%)
BR-RS(Raj)-PL4-B	118	134	5.87	63	2.5	MB	1.2	7.9	25.7
BR-SF(Rang)-PL1-B	127	134	5.77	65	2.5	MB	1.3	7.5	26.1
BR8210-10-3-1-2	120	125	5.65	66	2.5	MB	1.4	8.0	27.0
BRRI dhan49 (ck)	103	130	5.06	65	2.5	MB	1.3	8.5	24.7

*Mean of 10 locations (Rajshahi (Paba), Rajshahi (Chapainawabganj), Satkhira (Jashore), Satkhira, Rangpur (Dinajpur), Rangpur (Mithapukur), Kushtia, Cumilla, Bogura, Gazipur)

Development of salt tolerant rice. The general objective of this project is to develop high yielding salt tolerant rice varieties to address salinity, the major constraints for the rainfed lowland and Boro rice ecosystem in southern coastal zone of Bangladesh. In T. Aman season, 30 crosses were made using 13 parents. A total of 28 F_1s for T. Aman season were confirmed and selected. The field RGA was done at BRRI farm, Gazipur and Satkhira. Yield trials were conducted in Gazipur, Khulna and Satkhira in both T. Aman and Boro season with salinity level (EC) varied from 2 dS/m to 9 dS/m (Fig. 1). In T. Aman season 53,800 segregating progenies from 42 crosses (F_2-F_5 generation) were advanced using FRGA technique. From LST trial, 666 lines were selected from 2,882 breeding lines of 11 crosses based on strong plant type, grain type, and uniformity in heading under field condition (Fig. 2).

Seventy-five genotypes out of 120 were selected in oyt. Twenty-four genotypes out of 67 were selected from four pyt trials. Five genotypes out of 14 were selected from syt. In boro season, 32 crosses were made using 17 parents. A total of 31 f_1s were confirmed and registered into brri cross list. In boro season 86,083 segregating progenies from 60 crosses (f_2-f_5) were advanced using frga technique. From lst trial, 1,749 lines were selected on the basis of plant type, grain quality and uniformity in flowering from 6,126 breeding lines (properly labeled with qr codes) derived from 11 crosses under field condition (Fig. 3).

Thirty-seven entries (out of 170 genotypes) were selected from OYT. Forty-three entries (out of 88 genotypes) were selected from PYT#1, PYT#2, PYT#3 and PYT#4. Four entries (out of 12 genotypes) were selected from AYT. Three salinity tolerant lines (IR83484-3-B-7-1-1-1, HHZ12-SAL2-Y3-Y2 and HHZ5-DT20-DT2-DT1) were evaluated in eight locations of coastal saline areas of Bangladesh as proposed variety trial (PVT).

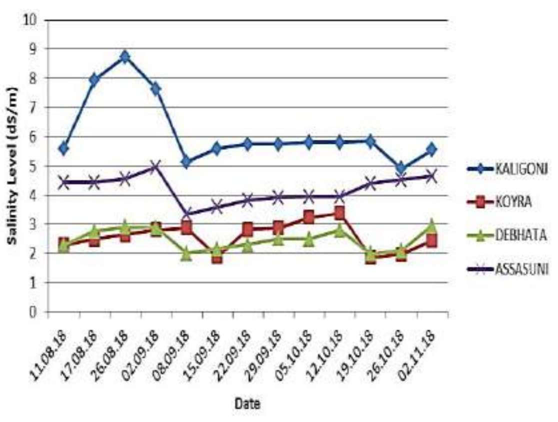


Fig. 1. Salinity level at experimental fields in coastal saline areas in T. Aman 2018-19.

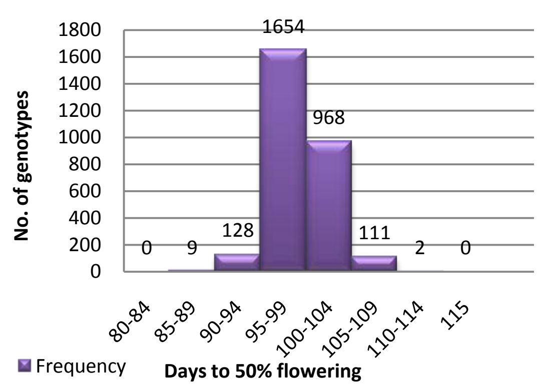


Fig. 2. Frequency distribution of the LST lines for days to 50% flowering in T. Aman 2018-19.

Fig.3. In lst trial, 6126 breeding lines were evaluated at brri farm satkhira, salinity breeding programme during boro 2018-19.

The highest level of salinity (EC) has found at Kaliganj which ranged from 6 dS/m to 16 dS/m (Fig. 4) and Figure 5 shows the responses of genotypes to high salinity stress. Two lines such as IR83484-3-B-7-1-1-1 and HHZ5-DT20-DT2-DT1 performed better compared to the two checks e.g. BRRI dhan28 (S. ck) and BRRI dhan67 (R. ck) in terms of yield and salinity tolerance. These two lines might be recommended for releasing as new salt tolerant varieties by the NSB.

Investigators: M Akhlasur Rahman, Nusrat Jahan, Md Ruhul Quddus, SK Debsharma, R Farzana Disha and M Ibrahim

Development of premium quality rice (PQR). The general objectives of this project were to develop improved aromatic and non-aromatic fine quality rice with national and international standards (Kalizira/Chinigura/Kataribhog/Radhunipagol type), anti-oxidant enriched (black and red) rice in T. Aman season and Basmati/Banglamati/Soru Balam type rice in Boro season for domestic use and export. In T. Aman, 41 crosses (21 crosses for PQR, 15 for anti-oxidant enriched rice and 5 for photosensitive fine quality rice) were made, Thirty-five crosses were confirmed and 3,850 F_2 progenies were grown from three crosses. From pedigree nurseries, 194 progenies with 42 fixed lines were selected from 230 progenies of 30 crosses in F_3-F_6 populations. A total of 88 genotypes selected out of 173 from OYT based on growth duration, yield, and homogeneity in other morpho-agronomic traits. From PYT, 25 genotypes were selected out of 74 genotypes. From SYT#1 and 2 a total of eight genotypes showing 0.7-1.3 t h^{-1} a yield advantage over check varieties

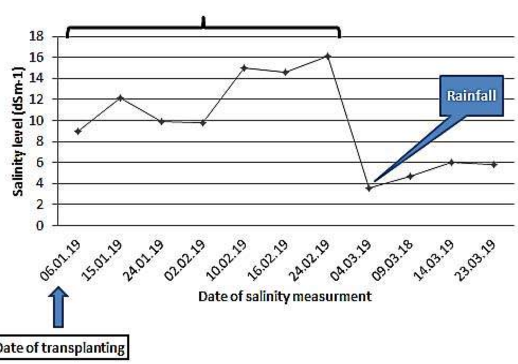


Fig. 4. Salinity level in proposed variety trial, at kaliganj, satkhira during boro 2018-19.

Fig. 5. Responses of genotypes under high salinity stress in proposed variety trial at kaliganj, satkhira, boro 2018-19.

Kalizira, Chinigura, Kataribhog, BRRI dhan34 and BRRI dhan37 were selected out of 20 genotypes. Seven genotypes showing 0.6-1.2 t ha^{-1} yield advantage over the check varieties Kalizira, Chinigura, Kataribhog, BRRI dhan34 and BRRI dhan37 were selected from 21 entries tested in RYT. In the reporting year a lead breeding line (BR8535-2-1-2) showing yield 4.63-5.56 t ha^{-1} with premium grain quality (grain size and shape similar to BRRI dhan34 and mild aroma but photoperiod insensitive) was approved and released by the NSB as BRRI dhan90. This variety produced 1.0-1.4 t ha^{-1} higher yield with around 22 days earlier growth duration than BRRI dhan34. Table 3 shows the salient feature of this variety.

In Boro season, 5,815 F_1 seeds were produced from 16 crosses. Four F_1 crosses were confirmed out of nine crosses as true hybrid. In total, 6,365 panicles from F_2 and 12,347 from F_3 generation were harvested at the time of maturity and preserved and processed with proper labels through RGA method. From F_4 generation 67 progenies of eight crosses were selected and from F_6 generation, 68 progenies were bulked through pedigree method. In DTR, 16,485 progenies and in RLR 9,534 progenies were harvested at the time of maturity and preserved and processed with proper labels through RGA method. In different yield trials, 84 genotypes were tested and 36 genotypes were selected. In RYT, two genotypes were selected out of four.

Investigators (PQR, T. Aman): T L Aditya, MR Islam and Anisar Rahman

Investigators (PQR, Boro): M A Kader, AKM Shalahuddin, Al Amin, Tapan Kumar 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^{-1}), earliness (130-135 days) and acceptable grain quality for favourable irrigated ecosystem in Bangladesh. In the reporting year, seven crosses were made. Twenty-six crosses were confirmed as true F_1. A total of 62,269 individual panicles were collected from 62,269 individual plants of 64 cross combination of F_2-F_6 generation. Out of 2,500 lines, 411 uniform lines were identified from LST based on uniformity in heading, plant height and grain type, also disease incidence was recorded after artificial inoculation. Twenty-two genotypes from PYT and 10 genotypes from AYT were selected for further evaluation. An elite advanced line BRRI dhan29-SC3-28-16-10-8-HR_1(Com) was approved and released by the NSB as a new variety, BRRI dhan88 for favourable Boro ecosystem. It showed 0.2- 0.6 t ha^{-1} higher yield with 2-3 days earlier growth duration than BRRI dhan28. Table 4 shows the performance of BRRI dhan88 in proposed variety trial. As part of nucleus seed maintenance of Boro rice varieties, 42 varieties were grown in varietal display lot and panicles and bulked seeds were collected.

Investigators: MRA Sarker, Wazifa Afrin, PS Biswas and T L Aditya

Table 3. Performance of BRRI dhan90 under proposed variety trial, T. Aman 2018-19.

Designation	Plant height* (cm)	Growth duration* (day)	Grain yield* (t ha^{-1})	Grain characteristics					
				Head rice yield (%)	L/B ratio	Size and shape	Elongation ratio	Protein (%)	Amylose (%)
BR8535-2-1-2	110	122	5.07	68.0	2.4	SB	1.5	10.3	23.2
BRRI dhan34 (ck)	120	136	3.59	69.0	2.3	SB	1.4	10.2	23.0

Mean of nine locations (Rangpur, Bogura, Rajshahi, Chapainabganj, Kushtia, Cumilla, Jashore, Satkhira and BRRI farm, Gazipur)

Table 4. Performance of BRRI dhan88 in proposed variety trial, favourable Boro rice.

Designation	Plant height (cm)	Days to maturity	Grain yield (t ha^{-1})*	Grain characteristics					
				Milling yield (%)	Head rice yield (%)	Length (mm)	L/B ratio	Size and shape	Amylose (%)
BRRI dhan29-SC3-28-16-10-8-HR1(Com) (BRRI dhan88)	96	143	7.03	71.5	66.4	6.2	3.4	LS	26.3
BRRI dhan28 (ck)	95	145	6.41	70.0	62.1	5.8	3.1	MS	27.0

*Mean of nine locations.

Development of cold tolerant rice. The major objective of the project was to develop high yielding and short duration (6.0-7.0 t ha^{-1} yield and 135-145 days growth duration for haor areas) and high yielding medium duration (6.5-7.5 t ha^{-1} yield with 145-150 days growth duration for northern regions) rice varieties tolerant to cold stress at seedling and reproductive stages. Thirteen crosses were made. Thirty-three crosses were confirmed as true F_1 through F_1 verification using QC genotyping with purity SNP panel. In total 68,531 individual plants were harvested from 83 crosses of F_2-F_6 generation by RGA system. Out of 5,370 lines, 963 uniform lines were selected from LST based on uniformity in heading, plant height and grain type, also disease incidence was recorded after artificial inoculation. Fifty-eight genotypes were selected from OYT. In PYT, 22 genotypes were selected from 70 genotypes and had yield advantage over check varieties BRRI dhan28, BRRI dhan58, BRRI dhan69 and BRRI dhan36. From AYT, three genotypes viz BR8910-B-6-3-CS1-5-CS2-P3-1-1, BR8909-B-12-2-CS1-4-CS2-P5-3-3 and BR8910-B-6-3-CS1-5-CS2-P3-1-3 were selected and had yield advantage over check varieties BRRI dhan58 and BRRI dhan69. In multi-location trials in Haor areas, two genotypes were selected based on growth duration, yield and other morpho-agronomic traits. In addition, 76 parental genotypes were maintained through QC genotyping with purity SNPs.

Investigators: PS Biswas, MRA Sarker and Wazifa Afrin

Development of zinc enriched rice. The project aims to develop high yielding rice varieties with improved nutritional quality in terms 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. In T. Aman 33 single crosses were made. A total of 44 crosses were selected and confirmed as true F_1 comparing with their parents and registered in the BR cross register. In total 23,626 progenies were advanced through field RGA. Totally, 2,775 individual progenies and 141 fixed lines were isolated from pedigree nurseries. From OYT, 40 genotypes were selected based on yield and growth duration considering significant difference in growth duration from the check variety. Forty-four genotypes from PYT-1, PYT-2 and PYT-3, seven from SYT, 11 from RYT-1, RYT-2 and RYT-3 and two genotypes from ALART were selected. The selected genotypes were better than the check varieties in terms of grain yield and other agronomic performances. One advanced breeding line (BR7528-2R-HR16-2-24-1) was evaluated at ten locations under supervision of NSB in proposed variety trial. This line showed 0.22 t ha^{-1} yields along with five days shorter growth duration than BRRI dhan39 (Table 5). Nucleus seed of BRRI dhban62 and BRRI dhan72 were produced 100 kg and 250 kg respectively. In Boro season, 50 single crosses were made. A total of 25 crosses were selected and confirmed as true F_1 comparing with their parents. A total of 10,675 progenies were advanced through field RGA. In total 3,240 individual progenies and eight fixed lines were isolated from pedigree nurseries. From OYT, 17 uniform genotypes were selected based on yield and growth duration considering significant difference in growth duration from the check variety. Three genotypes from PYT, three from SYT and two from RYT were selected. One elite breeding (BR8631-12-3-5-P2) from ALART was selected for PVT. A total of 450 kg and 960 kg nucleus seed of BRRI dhan74 and BRRI dhban84 were produced respectively.

Investigators: M A Kader, M Anisuzzaman, T K Hore, A K M Shalahuddin and Al Amin

Table 5. Performance of the proposed line (BR7528-2R-HR16-2-24-1) in PVT, ZER, T. Aman 2018-19.

Designation	Plant height (cm)*	Growth duration (days)*	Grain yield (t ha^{-1})*	Grain characteristics					
				Head rice yield (%)	L/B ratio	Size and shape	Elongation ratio	Protein (%)	Amylose (%)
BR7528-2R-HR16-2-24-1	117	113	5.00	61	3.1	LS	1.5	8.5	28.0
BRRI dhan39 (Ck)	110	118	4.78	60	3.0	LB	1.2	8.9	26.3

*Mean of 10 locations (Rajshahi, Kushtia, Bhanga, Sonagazi, Habiganj, Satkhira, Rangpur, Cumilla, Barishal, Gazipur)

Development of disease resistant rice. Development of varieties resistant to bacterial blight (BB), blast and rice tungro virus (RTV) was the main emphasis of the project. Thirteen crosses for BB and eight for blast in T. Aman and 10 crosses for BB and nine for blast were made in Boro season. Ten crosses for BB and nine for blast during T. Aman and 10 crosses for BB and nine for blast in Boro were confirmed as true F_1. In T. Aman, 22,643 progenies of 11 crosses and 15,878 progenies of eight crosses were advanced for BB and blast, respectively from F_2; 6,632 progenies of nine crosses and 3,302 progenies of six crosses were advanced for BB and blast, respectively from F_3; 14,886 progenies of 19 crosses and 4,542 progenies of eight crosses were advanced for BB and blast, respectively from F_4-F_6 generations in FRGA-Transplanted. On the other hand, 12,680 progenies of nine crosses and 312 progenies from one cross were advanced for BB and blast respectively from F_4; 1,528 progenies of eight crosses and 748 progenies of three crosses were advanced for BB and blast respectively from F_5-F_6 generations in modified FRGA.

In Boro, 10 crosses for BB and nine crosses for blast were made and 11 crosses for BB and nine crosses for blast were confirmed. A total of 11,500 F_2 progenies for BB were advanced from 11 crosses and 9,500 progenies for blast were advanced from nine crosses; 7,704 progenies for BB were advanced from 17 crosses and 6,485 progenies for blast were advanced from 11 crosses of F_3- F_4 generations and 5,842 progenies for BB were advanced from 10 crosses and 4,070 progenies for blast were advanced from 11 crosses of F_5-F_6 generations. In total 2,830 BB and 165 blast resistance lines were evaluated in LST. Forty advanced lines were selected for BB in OYT. Six entries from PYT for BB resistance were selected and three entries were selected for BB resistance in RYT. One genotype BR9838-19-4-3-1-1 was recommended as candidate variety from adaptive research trials conducted by ARD at Boro areas under different agro-ecological zones to evaluate as PVT.

Investigators: Mahmuda Khatun, MM Emam Ahmed, S Das, SK Debsharma and T L Aditya

Development of insect resistant rice. The main thrust of the project was to develop varieties resistant to gall midge (GM), brown plant hopper (BPH) and white backed plant hopper (WBPH). The experiments were conducted in both T. Aman and Boro season. In T. Aman season, 20 crosses were made using 16 parents. Sixteen crosses were confirmed as true hybrid. A total of 41,817 segregating progenies from 52 crosses were advanced using FRGA technique. Twenty-three out of 60 lines were selected from OYT. Fifteen out of 36 lines were selected from IRBPHN. Eleven lines from two PYT's were selected. Ten out of 20 lines from SYT were selected. Two promising lines were evaluated in ALART and one line (BR8693-8-4-2-1) was recommended for PVT. In Boro season, 20 crosses were made and 22 crosses were confirmed as true hybrid. A total of 74,368 segregating progenies from 78 crosses were advanced using FRGA technique. In LST, 356 lines were selected from 3,062 breeding lines of eight crosses with strong plant type, grain quality and uniformity in heading in the field condition. Eleven out of 41 lines were selected from OYT. Four out of 20 lines from SYT were selected. One advanced line (BR8340-5-6-1) was recommended as candidate variety from ALART for conducting PVT.

Investigators: M Akhlasur Rahman, Nusrat Jahan, M Ruhul Quddus and Md Ruhul Amin Sarker

Development of submergence and water stagnation tolerant rice varieties. The project aims to develop high yielding rice varieties tolerant to submergence (flash flooding) and medium stagnant water (MSW) stresses. In total, 5,680 F_1 seeds were obtained from single cross and 235 F_1 seeds were obtained from multiple cross. Twenty-three single and 14 multiple F_1s crosses were selected and confirmed. Panicles of 12,467 from F_2, 12,595 from F_5, 3,830 from F_6 individuals were harvested at the time of maturity and preserved and processed with proper labels. From LST population, 12,860 lines were genotyped with trait markers using custom SNP panel and finally 1,321 lines were selected. In yield trial, 351 genotypes were tested out of which 58 genotypes were selected. In PVS, IR13F441 showed the highest survival (67%) with a pooled grain yield of 5.1 t ha^{-1} under rainfed condition. However, BR9175-9-2-1-12-5 and BR9175-9-1-3-31-3 got the highest preference score in PVS function in flood prone farmers field of Domdoma and Dorshona respectively because of their higher yield performance as there was no flood this year. The pooled heritability obtained from grain yield of PVS trial conducted under flooding condition was 94%, indicating acceptable level of precision in this experiment.

Investigators: K M Iftekharuddaula, A K M Shalahuddin, Sharmitha Ghosal, Yakub Khan and T L Aditya

Development of drought tolerant rice. The project aims to develop high yielding rice varieties tolerant to drought stresses at the reproductive stage in the rainfed lowland rice ecosystem in Bangladesh**.** In T. Aman 2018-19 season, 3,990 F_1 seeds were obtained from seven crosses. Nine F_1 crosses were confirmed out of 11 crosses as true hybrid. A total of 18,795 panicles from F_2 and 6,763 from F_4 generation were harvested at the time of maturity and preserved and processed with proper labels through RGA method following SSD. Besides, from F_3 generation 380 progenies of 28 crosses, from F_4 generation 235 progenies of 16 crosses, from F_5 generation 230 progenies of 17 crosses were selected and from F_6 generation 54 progenies were bulked and selected following pedigree method. In different yield trials, 99 genotypes were tested and 22 genotypes were selected on the basis of grain yield and phenotypic acceptance. In Boro 2018-19, 10 F_1 crosses were confirmed as true hybrid. Single panicles of 4,263 individual plants from F_2, 6,636 from F_3 and 5,586 from F_5 generation were harvested at the time of maturity and preserved and processed with proper labels through RGA method.

Investigatorss: M A Kader, T K Hore, AKM Shalahuddin, Al Amin, MS Hossain, Tapan Kumar 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 under transplanted alternate wetting and drying (AWD) and aerobic condition. A total of eight crosses were made using six parents. Following field RGA technique, 2000 individuals of F_6 generation were harvested. From yield trial conducted under AWD condition, three genotypes from PYT and four genotypes from AYT were selected. However none of the genotypes gave higher yield than the check varieties BRRI dhan28, BRRI dhan29 and BRRI dhan58. Only based on the similar yield performance and phenotypic acceptance the genotypes were selected for further evaluation.

Investigators: K M Iftekharuddaula, A K M Shalahuddin, Sharmitha Ghosal, Yakub Khan and T L Aditya

Development of green super rice (GSR). The project aims at developing of less input but high yield potential genotypes with tolerance to different stresses. In T. Aman season, 16 genotypes from SYT and two genotypes from PVS were selected for further evaluation. In Boro Season, 12 genotypes out of 31 were selected in OYT; 24 genotypes out of 54 were selected from PYT and 10 genotypes out of 22 were selected from SYT. In AYT, two advanced lines were selected. Two genotypes were evaluated by NSB team in eight locations of saline prone areas.

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

Development of provitamin A, high iron and zinc enriched rice. The main objective of the project is to develop high yielding rice varieties with enhanced provitamin A, high iron and zinc content in polished rice grain. In T. Aman, 47 F_1s were confirmed from three backcrosses. Mature F_1 seeds were harvested, sun dried and stored separately in paper bags with proper labeling. In Boro season, 164 individual progenies comprising three backcrosses from BC_3F_2 generation were selected. High iron and zinc rice event IRS495-274 introgressed lines showed acceptable performance in contained trial and seven promising entries were selected for next trial based on their grain yield and other parameters. 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 of eight locations (Gazipur, Rajshahi, Cumilla, Barishal, Habiganj, Satkhira, Rangpur and Sonagazi) under government approval. For evaluating potential unintended effects of the genetic modification, data from GR2E introgression line in BRRI dhan29 was pooled for across-sites and single-site statistical analyses. In the across-sites analysis, the statistically significant differences between GR2E and near-isogenic control BRRI dhan29 in measured agronomic parameters were in days to maturity, plant height, panicle number per plant, flag leaf length, number of unfilled spikelet per plant and grain length, where the differences were very marginal, but were still within the range of values recorded for the control entry.

Investigators: M A Kader, T K Hore, A K M Shalahuddin and Al Amin

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 total, 63 germplasm from 14 INGER nursery sets were selected to use in different breeding programmes for direct use in the breeding pipeline.

National Coordinator: TL Aditya

Key Cooperator: KM Iftekharuddaula

Biotechnology Division

SUMMARY

Twenty-one experiments were conducted under eight projects during the reporting period. A total of 12 double haploid plants were regenerated from hybrid anther of different crosses. A total of 89 homozygous lines were evaluated in different yield trials including OT, PYT, RYT and ALART. Among them 39 promising lines were selected based on phenotypic appearance, growth duration and yield performance for further evaluation. During Aus and T. Aman 2018, a total of 542 and 66 and 48 EMS treated somaclonal plants (M_1SC_3) were selected from BRRI dhan48, BR11 and Tilbajal respectively. On the other hand during Boro 2018-19, a total of 32, 10, 240 and eight somaclones were selected from BRRI dhan28, BRRI dhan29, BRRI dhan86 and BRRI dhan92 respectively. In total, 81 plants were selected from 39 somaclonal lines of BRRI dhan48. During Boro 2018-19, 201 plants were selected and 31 lines were bulked from 322 pedigree lines for further evaluation. Nine plants were regenerated through embryo rescue technique from three wide crosses. A total of 144 BC_1F_1 seeds were harvested from embryo rescued plants of three different wide crosses for further backcrossing. In total 34 pedigree lines of different generations were selected from four different wide crosses, BRRI dhan87/ *O. glaberrima* (IRGC105190), BRRI dhan48/*O. glaberrima* (IRGC105190), BRRI dhan28/*O. glaberrima* (IRGC05190) and BRRI dhan28/*O. nivara* (IRGC103821) for further evaluation. Three advanced materials from yield enhancement QTL were evaluated in nine regional stations during T. Aman 2018 and from them two lines were selected. In Boro 2018-19, one advanced line BR(Bio)9787-BC2-63-2-2 developed from yield enhancement QTL was evaluated as PVT. The proposed line was found better than the check in relation to yield, lodging resistance, growth duration and protein content. Bacterial blight (BB) gene pyramided three BRRI dhan29 rice lines having two BB resistant genes (*Xa4* and *Xa21*) were evaluated as ALART in Boro 2018-19 and among them one line was selected for PVT. On the other hand in Boro 2018-19, BB gene pyramided five BRRI dhan28 rice lines having three BB resistant genes (*Xa4*, *xa13* and *Xa21*) were evaluated as RYT and among them three lines were selected depending on yield performance, duration and BB resistance. For the identification of taller seedling QTL, genotyping was done using seven polymorphic primers with 185 F_2 populations of BR11/Shadamota (acc.no.1576). From F_2 mapping population nine lines (F_3) were selected for further evaluation. Aroma detection was carried out with 41 F_2 progenies of BRRI dhan28 and Kalizira cross by panel test and genotyping to differentiate aromatic and non-aromatic progenies. Aroma detection was carried out with 41 F_2 progenies of BRRI dhan28 and Kalizira cross by panel test and genotyping to differentiate aromatic and non-aromatic progenies. Forty-one selected F_2 progenies were screened against functional marker of fragrance gene *BADH2*. Among them nine were identified as aromatic and 32 were non-aromatic. Same result was found when used KOH for aroma testing. For gene cloning study, cDNA was synthesized from RNA of treated *P. coarctata* and amplified with vacuolar ATPase (PVA) primer. After confirmation, PCR product was cloned into TOPO TA cloning vector and confirmed by PCR. PVA construct was prepared using Gateway cloning technique followed by transformation into *Agrobacterium* LBA4404. BRRI dhan29 was transformed with salt tolerant genes (*GlyI and GlyII)* and five putative T_1 transgenic plants were confirmed by both *GlyI* and *GlyII* gene specific primer. Salt tolerant *AeMDHAR* (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 *AeMDHAR* gene into them. Five putative BC_1F_1 transgenic plants were confirmed by gene specific primer.

Pea DNA helicase (PDH) containing selected nine (9) transgenic lines from different background were evaluated separately under salt stress at reproductive stage. But yield reduction was significantly higher in all transgenic lines than the tolerant check.

DEVELOPMENT OF DOUBLE HAPLOID RICE THROUGH ANTHER CULTURE

Low glycemic index (GI) rice variety

A total of 29,201 hybrid anthers were plated in N6 media. In total, 105 calli were obtained. No green plants were regenerated from those calli but 127 albino plants were obtained. A total of 28 homozygous lines were bulked for OT.

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

Salt tolerant rice variety

A total of 13,148 hybrid anthers from nine crosses were plated in M10 and N6 media. In total 32 calli were obtained. No green plants were regenerated. Fifteen crosses were made for further anther culture for salt tolerant rice development. A total of 709 F_1 seeds were harvested from 15 crosses for future anther culture programme.

Investigators: Nilufar Yasmin Shaikh, Shahanaz Sultana, and Md Enamul Hoque

Premium quality rice variety

A total of 25,657 hybrid anthers were plated in N6 and M10 media. In total, 181 calli were obtained. One hundred and fifteen albino plants were obtained but no green plants were regenerated. In T. Aman 2018, a total of 280 F_1 seeds were harvested from eight crosses for future anther culture programme.

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

High yielding Aus rice variety

A total of 177 F_1 seeds were harvested from five crosses for further anther culture.

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

Antioxidant enriched black rice variety

A total of 30,569 anthers were plated on to N6 media. From them 1,181 calli were obtained. A total of 12 green plants were regenerated.

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 2018, a total of 542 and 66 and 48 EMS treated somaclonal plants (M_1SC_3) were selected from BRRI dhan48, BR11 and, Tilbajal respectively. On the other hand, during Boro 2018-19, a total of 32, 10, 240 and eight somaclones were selected from BRRI dhan28, BRRI dhan29, BRRI dhan86 and BRRI dhan92 respectively.

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

Somaclone of Aus variety

A total of 39 somaclonal lines (SC_3) of BRRI dhan48 were evaluated during Aus 2018. From them, 81 plants were selected. Eighteen fixed somaclonal lines were evaluated as OT during Aus season 2018. From them nine lines were selected for PYT.

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

Somaclone of BRRI dhan47

During Boro 2018-19, five SC_4 somaclone lines developed from BRRI dhan47 were evaluated as PYT (Fig. 1). Among them three lines were selected. Moreover, ten SC_4 somaclone lines developed from BRRI dhan47 were grown as OT in Boro 2018-19. Among them, three lines were selected.

Investigators: Nilufar Yasmin Shaikh, Shahanaz Sultana and Md Enamul Hoque

Fig. 1. Field view of somaclones of BRRI dhan47 in PYT during Boro 2018-19.

DEVELOPMENT OF RICE VARIETY THROUGH WIDE HYBRIDIZATION

Wide hybridization followed by embryo rescue

In total nine plants were regenerated through embryo rescue technique from three wide crosses (Table 1, Fig. 2). A total of 144 BC_1F_1 seeds were harvested from embryo rescued plants of three different wide crosses for further backcrossing. In total, 34 pedigree lines of different generations were selected from four different wide crosses BRRI dhan87/ *O. glaberrima* (IRGC105190), BRRI dhan48/ *O. glaberrima* (IRGC105190), BRRI dhan28/ *O. glaberrima* (IRGC105190) and BRRI dhan28/ *O. nivara* (IRGC103821) (Fig. 3).

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

Table 1. List of embryo rescued plants after wide hybridization.

Wide cross	No. of embryo rescued plants
BRRI dhan92/ *O. glaberrima* (IRGC105190)	3
BRRI dhan89/ *O. glaberrima* (IRGC105190)	-
BRRI dhan87/ *O. glaberrima* (IRGC105190)	3
BRRI dhan48/ *O. glaberrima* (IRGC105190)	-
BRRI dhan28/ *O. glaberrima* (IRGC105190)	3
BRRI dhan86/ *O. glaberrima* (IRGC105190)	-
Total	9

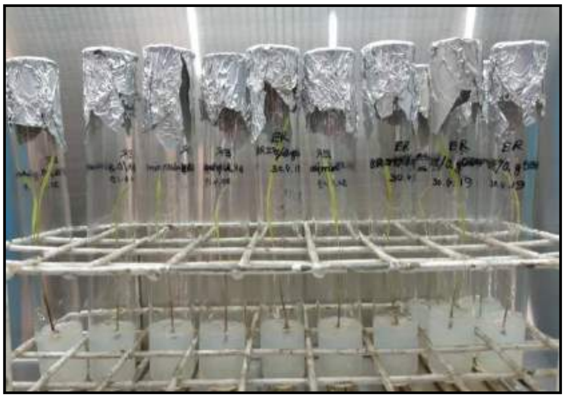


Fig. 2. Embryo rescued plantlets in rooting media from wide hybridization.

BRRI dhan48/*O glaberrima* (105190) BRRI dhan48

Fig. 3. Panicle of embryo rescued F_1 plant from wide hybridization.

FIELD EVALUATION OF TISSUE CULTURE DERIVED LINES

Progeny selection

During Boro 2018-19, a total of 201 plants were selected and 31 lines were bulked from 322 pedigree lines for further evaluation.

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

Observational trial (OT)

During Boro 2018-19, 23 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, seven lines were selected depending on the duration and comparable yield with checks for further evaluation.

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

Preliminary yield trial (PYT)

During T. Aman 2018, five doubled haploid rice lines were evaluated as PYT with standard checks. From them three lines were selected. During Boro 2018-19, six doubled haploid lines were evaluated in one PYT with standard checks. Among them four lines were selected depending on the duration and comparable yield with checks for further evaluation.

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

Advanced line adaptive research trial (ALART)

In T. Aman 2018, two advanced and two doubled haploid rice line were evaluated as ALART with standard checks by ARD. Two lines were selected for further evaluation.

Investigators: ARD scientist and Md Enamul Hoque.

Identification of yield enhancement QTLs

Three advanced materials from yield enhancement QTL were evaluated at nine regional stations of BRRI during T. Aman 2018 as RYT and two lines were selected out of them (Table 2). On the other hand, a line BR (Bio) 9787-BC2-63-2-2 developed from yield enhancement QTL was evaluated along with a check BRRI dhan28 at 10 locations of Bangladesh, during Boro 2018-19 as PVT. The proposed line was found better than the check in relation to yield, lodging resistance, and growth duration and protein content.

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

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

Two advanced pedigree lines from identification of salt QTL were evaluated at nine regional stations during T. Aman 2018 as RYT-1, but none was selected. On the other hand three advanced pedigree lines from identification of salt QTL were evaluated at nine regional stations in boro 2018-19 and among them two lines were selected (Table 3; Fig. 4). During Boro 2018-19, two advanced lines developed from identification of salt QTL were evaluated with the standard check variety in 10 locations of Bangladesh as ALART, but none was selected.

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

Table 2. Agronomic characteristics of three lines developed from QTL mapping population of BRRI dhan29*^{3}/ *O. rufipogon* (IRGC 103404) cross during T. Aman 2018 (RYT).

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1}) Location									
			Bar	Cum*	Hab	Kus	Raj	Rang	Sat	Son	Gaz	Avg.
BR (Bio) 9786-BC2-161-1-2	110	118	5.99	3.18	5.98	3.01	6.44	5.61	7.35	5.88	5.98	5.78**
BR (Bio) 9786-BC2-65-1-1	116	121	5.87	1.63	6.16	3.13	6.24	4.60	7.16	5.95	6.16	5.66
BR (Bio) 9786-BC2-80-1-1	114	121	5.99	2.32	6.24	3.34	6.26	4.91	7.04	5.74	6.24	5.72**
BRRI dhan71 (ck.)	116	115	4.79	3.31	4.05	4.35	5.32	4.84	6.59	5.53	4.05	4.94

*= Damaged by rat. **= selected.

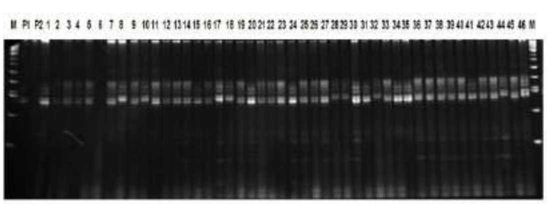
Table 3. Agronomic characteristics of three lines developed from QTL mapping population of BRRI dhan29/IR4630-22-2-5-1-3 cross during Boro 2018-19 (RYT).

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})								Avg.
			Bha	Cum	Ran	Sat	Kus	Raj	Bor	Gaz	
BR (Bio) 9777-116-12-2-4	105	155	7.18	7.39	5.79	5.41	7.45	6.80	7.77	7.86	7.18*
RB (Bio) 9777-116-12-2-5	106	155	7.3	7.42	6.20	5.28	7.16	6.26	8.06	8.20	7.23*
BR (Bio) 9787-BC2-35-4-2	95	152	6.38	6.79	5.86	5.44	6.77	5.49	7.39	7.83	6.64
BRRI dhan58 (ck)	96	153	7.04	6.93	6.73	5.39	7.62	6.96	7.56	7.68	7.22

* = Selected

Fig. 4. RYT field view during Boro 2018-19.

Identification of QTLs for taller seedling height
QTL mapping population was developed by crossing between BR11/Shadamota (acc.no.1576). Parental polymorphism survey was carried out and 125 SSR markers were identified as polymorphic. DNA was extracted from leaf sample of F_2 population consisting with 185 individual. Genotyping was done using seven polymorphic primers with 185 individuals (Fig. 5). From mapping population, nine lines (F_3) were selected for further evaluation during T. Aman 2019.
Investigators: Nilufar Yasmin Shaikh, S M Hisham Al-Rabbi and Md Enamul Hoque



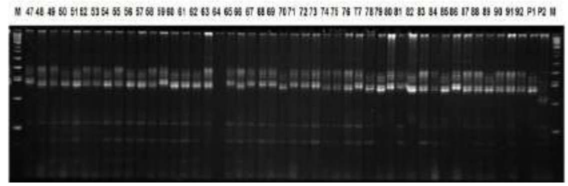
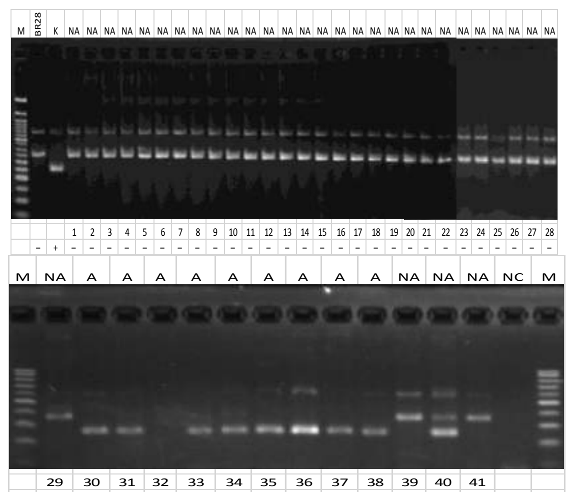


Fig. 5. Gel view of genotyping using polymorphic primer RM3867 in taller seedling height QTL identification.

Validation of a simple functional marker for fragrance in non-Basmati fragrant rice varieties
Aroma detection was carried out with 41 F_2 progenies of BRRI dhan28 and Kalizira cross by panel test and genotyping to differentiate aromatic and non-aromatic progenies. Forty-one selected F_2 progenies were screened against functional marker of fragrance gene *BADH2*. Among them nine were identified as aromatic and 32 were non-aromatic (Fig. 6). Same result was found when used KOH for aroma testing.
Investigators: Jannatul Ferdous, S M Hisham Al-Rabbi and Md Enamul Hoque



M= Molecular marker, BR28= BRRI dhan28, K= Kalizira, NA= Non-aromatic A= Aromatic, + = Aromatic, - = Non-aromatic
Fig. 6. Validation of functional marker for fragrance gene (BADH2).

GENE PYRAMIDING

Gene pyramiding for resistance to bacterial blight in rice
Bacterial blight (BB) gene pyramided three BRRI dhan29 rice lines having two BB resistant genes

(*Xa4* and *Xa21*) were evaluated as ALART at 10 locations in Boro 2018-19 with standard checks by Adaptive Research Division, BRRI. Among them one line was selected for PVT. On the other hand in Boro 2018-19, BB gene pyramided five BRRI dhan28 rice lines having three BB resistant genes (*Xa4*, *xa13* and *Xa21*) were evaluated with standard checks in a RYT (Tables 4 and 5; Fig. 7). Among them two lines were selected depending on yield performance, growth duration and disease score.

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

Table 4. Agronomic characteristics of bacterial blight (BB) gene pyramided BRRI dhan28 lines having three BB resistant (*Xa4, Xa13, Xa21*) in Boro 2018-19 (RYT).

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})								
			Bah	Cum	Ran	Sat	Kus	Raj	Bor	Gaz	
BR (Bio)11447-1-28-4-6	92	150	6.76	6.26	7.51	4.47	6.33	4.51	6.69	7.28*	6.48
BR (Bio)11447-1-28-12-3	91	151	6.87	6.47	7.23	4.55	6.24	5.34	7.27	7.10	6.65*
BR (Bio)11447-1-28-14-1	102	152	6.96	6.30	6.52	.	6.16	4.25	7.47	7.15	6.40
BR (Bio)11447-1-28-14-3	96	151	7.292	6.42	8.06	.	6.74	5.20	7.35	7.41*	6.92*
BR (Bio)11447-3-10-7-1	96	148	6.97	6.34	7.44	3.26	6.19	5.67	6.75	7.20*	6.65*
BRRI dhan28 (Std. ck)	94	148	7.21	5.89	7.50	5.75	6.70	5.47	7.18	6.64	6.66
IRBB60 (Res. ck)	79	158	7.53	5.99	6.08	4.36	6.48	3.48	6.46	6.37	6.06

* = Selected

Table 5. Disease reaction and BB score of bacterial blight gene pyramided BRRI dhan28 lines having three BB resistant (*Xa4, Xa13, Xa21*) in Boro 2018-19 (RYT).

Designation	Avg. area damage (%)	BB score	Remark
BR (Bio)11447-1-28-4-6	5.01	3	R
BR (Bio)11447-1-28-12-3	7.96	3	R
BR (Bio)11447-1-28-14-1	6.49	3	R
BR (Bio)11447-1-28-14-3	7.95	3	R
BR (Bio)11447-3-10-7-1	3.35	3	R
BRRI dhan28 (Std. ck)	82.91	9	S
IRBB60 (Res. ck)	2.51	3	R

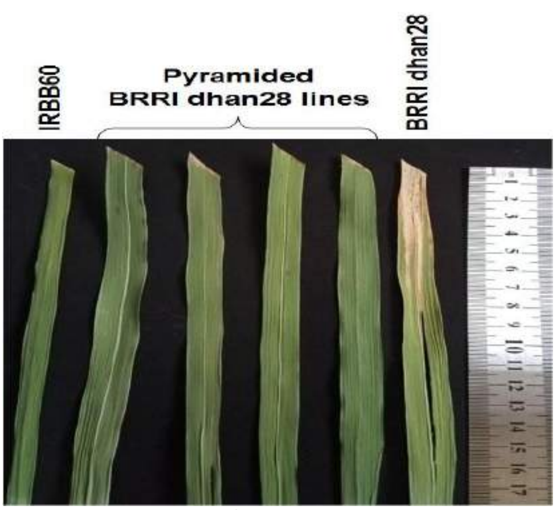


Fig. 7. Disease reaction of BRRI dhan28 BB pyramided lines after 21 days of bacterial inoculation with B x O9.

GENE CLONING

Isolation and cloning of salt and drought tolerant gene

For gene cloning study, cDNA was synthesized from RNA of treated *P. coarctata* and amplified with vacuolar ATPase (PVA) primer. After confirmation, PCR product was cloned into TOPO TA cloning vector and confirmed by PCR. PVA construct was prepared using Gateway cloning technique followed by transformation into *Agrobacterium LBA4404* (Fig. 8).

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

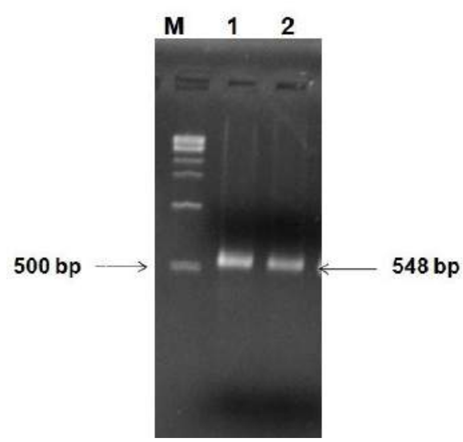


Fig. 8. Transformation of PVA into *Agrobacterium LBA4404*.

Development of salt tolerant transgenic rice

BRRI dhan29 was transformed with salt tolerant genes (*GlyI and GlyII)* and five plants were confirmed by both *GlyI* and *GlyII* gene specific primer. T_1 putative transformants were also confirmed by gene specific primer and sequencing.

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

Introgression of salt tolerant mangrove gene

Salt tolerant *AeMDHAR* (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 *AeMDHAR* gene into them. After F_1 confirmation backcrosses were made and five BC_1F_1 plants were confirmed by gene specific primer (Fig. 9).

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

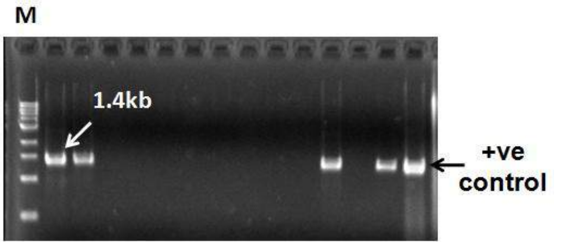


Fig. 9. BC_1F_1 plants were confirmed by gene specific primer of AeMDHAR.

Reproductive stage evaluation of PDH45 gene containing transgenic rice lines under salt stress

Based on the performance at seedling stage selected nine (9) transgenic lines e.g. PDH_BR47-2, PDH_BR47-3, PDH_BR47-1, PDH_BR29-2, PDH_BR29-4, PDH_BR36-2, PDH_BR36-3 PDH_BR28-1 and PDH_BR28-3 from different background were evaluated separately under salt stress at reproductive stage with their respective parents, tolerant and susceptible check. In this study, yield reduction was found significantly higher in all transgenic lines than the tolerant check.

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Genetic Resources and Seed Division

SUMMARY

In total, 119 rice germplasm of which four in Aus, 100 *Jhum* rice from hilly areas, 14 in T. Aman and one in Boro seasons were collected from different districts of Bangladesh during 2018-19. Fifty-five germplasm accessions in T. Aman and 48 in Boro seasons were characterized against 51 morpho-agronomic traits. Besides, characterization of 70 local germplasm for boosting yield through trait discovery in changing climatic conditions were completed under KGF project and six superior germplasm were selected due to their better performance. Molecular characterization of 94 red and black Aus rice germplasm using 61 SSR markers along with 48 T. Aman germplasm using 54 SSR markers were performed. The highest PIC values were found in RM289 (0.71) out of 61 and RM 207 (0.76) out of 54 SSR markers and confirmed them as the best markers for the studied 94 and 48 germplasm respectively.

Rejuvenation of 1,977 accessions were completed of which 465 in T. Aus 2018, 1,096 in T. Aman 2018 and 416 in Boro 2018-19. A total of 1,951 accessions of which 465 in Aus 2018, 1076 in T. Aman 2018 and 410 acc. in Boro 2018-19 seasons were processed and stored in short-term storage. Similarly, 70 and 78 accessions in Aus, 212 and 306 accessions in T. Aman and 33 and 62 accessions in Boro 2018-19 were stored in medium and long-term storages respectively during the reporting year. Apart from this, 342 new germplasm were registered as new accessions (from accession number 8237 to 8578) in BRRI Genebank. Besides, 2,268 samples of rice germplasm and BRRI developed varieties were supplied to different users. Moreover, 1000 accessions were entered into the database with collected available information during the reporting year.

Ninety-nine BRRI developed and recommended rice varieties were maintained along with nucleus seed. Besides, nucleus seed stocks of 67 varieties were produced for the source of breeder seed. In total, 226.86 tons of breeder seed with tag of which 154.39 tons from 24 varieties in Boro and 72.47 tons from 43 varieties in T. Aman seasons were produced during 2018-19. Among the total production, 210.16 tons were produced by GOB fund and 16.70 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, 183.89 tons of breeder seed of which 113.22 tons from 23 varieties in Boro, 9.27 tons from 15 varieties in Aus and 61.40 tons from 33 varieties in T. Aman were distributed among 822 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. One collection mission was made during the reporting year and 119 rice germplasm of which four in Aus, 100 *Jhum* rice, 14 in T. Aman and one in Boro seasons were collected from different districts of Bangladesh including hilly areas.

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 20 × 20 cm spacing between rows and plants respectively. Fertilizers were applied @ 60:20:40 kg NPK/ha in T. Aus and T. Aman and @ 80:20:40 kg NPK/ha in Boro seasons.

A total of 1,977 germplasm of which 465 accessions in T. Aus 2018, 1,096 accessions in T. Aman 2018 and 416 accessions in Boro 2018-19 were rejuvenated in field for getting fresh seed and on average 500 g of seeds per accession were produced.

Morphological characterization of germplasm. Two experiments were conducted to characterize rice germplasm through 51 agro-morphological traits (20 quantitative and 31 qualitative characters) using the Rice Germplasm Descriptors and Evaluation Form, GRSD, BRRI. The experiments were conducted in BRRI 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 103 germplasm (accessions as well as new collections) of which 55 in T. Aman and 48 in Boro were used for characterization. Fertilizers were applied @ 60:20:40 kg NPK/ha in T. Aman and @ 80:20:40 kg NPK/ha in Boro seasons.

In T. Aman 2018, 55 germplasm were characterized. Among them 18 had short (<120 days), 27 had medium (120-130) and 10 had long (>130) growth duration (Table 1). Thirteen germplasm were found with short (<110 cm), 14 moderate (110-130) and the rest (28) with long (>130) plant height. Thirty-eight were found with medium (20-25 cm), 14 with long (26-30 cm) and three had short (<20) panicle length. Thirty genotypes were found in total tiller number with the range of 10-15 and 25 were found with <10 cm. For 1000-grain weight (TGW), two germplasm had very low (≤15 g), 14 with low (16-19), 23 had medium (20-23), 13 with high (24-27) and three had very high (>27) TGW. Thirty germplasm had moderate (5-10 g/hill) and the rest 25 possessed higher (>10) yield per hill.

The shortest growth duration (109 days) was observed in Khato babu dhan (NC) and the longest (135 days) in Charulota (NC), Dudhlaki (NC) and Digha (3) (Acc. 489).The shortest plant height (73.2 cm) was observed in Dudulota (NC) and the longest (190.6 cm) in Digha (2) (Acc. 128). The lowest number of effective tillers (6) was observed in Sona Digha (Acc. 122) and Swarna (Acc. 5974), while the highest (13) was in Digha (3) (Acc. 489). Digha (3) (Acc. 489) had the highest (28.25 g) and Lal swarna (Acc. 6669) had the lowest (15.25 g) TGW. The highest yield per hill (19.61 g) was observed in Digha (3) (Acc. 489) and the lowest (5.42) in Bhawal Digha (Acc. 106).

In Boro 2018-19, 48 germplasm were characterized. Among them 11 had medium (135-150 days) and 37 had long (>150) growth duration (Table 2). Thirty germplasm were found with short (<110 cm), 14 moderate (110-130) and the rest (4) with long (>130) plant height. Eleven germplasm were found with short (≤20 cm), 34 with medium (21-25), two with long (26-30) and one had very long (>30) panicle length. Thirty-three germplasm possessed intermediate (6-10), 14 had high (>10) and the rest 1 had the lowest (<6) number of effective tiller. Considering decorticated grain length-breadth ratio, 35 germplasm were medium slender (2.1-3.0) and 13 were bold (1.1-2.0) types grain. For TGW, 12 germplasm had low (16-19 g), 21 had medium (20-23), 12 had high (24-27) and three had very high (>27) TGW. One germplasm possessed low (<5 g/hill), four had moderate (5-10) and 43 had higher (>10) yield.

The shortest growth duration (139 days) was observed in Boro Dhan (Acc. 4970) and the longest (172) in Kali Boro (Acc.7657). The shortest plant height (59.4 cm) was observed in Topa boro (Acc. 5041) and the longest (137) in Pokkali-28609 (Acc. 6842). The highest number of effective tillers (14) was observed in Unknown germplasm (Acc. 7293) and the lowest (5) in Unknown (Acc. 6905). Ata Sail (Acc. 7298) had the lowest (16.7 g) and Pokkali (Acc. 6842) had the highest (29.9) TGW. The highest yield per hill (22.31 g) was observed in BR6108-R1-8 (Acc. 4672) and the lowest (4.99) in Boro (Acc. 4970). In conclusion, the variety having higher yield would be utilized in a crossing programme, if other characters satisfy the breeder's objectives.

Characterization of germplasm for boosting yield through trait discovery in changing climatic conditions. Seventy local germplasm were selected for their specific characteristics like disease and insect resistance, abiotic stress like drought/salinity/submergence tolerance, higher number of spikelet per panicle, culm strength, TGW, lodging tolerance etc and grown in T. Aman 2018. Characterization of rice germplasm accessions were completed with 51 morpho-agronomic traits (both quantitative and qualitative characters) using the Rice Germplasm Descriptors and Evaluation Form, GRSD, BRRI.

After detailed analysis of the collected data, six germplasm viz Badol, Beni Gocha, IR-71347-3B-16-2-1-2B, Laldoga, Sorsoria and Noakhali were selected due to their better performance (Table 3). Most of the studied germplasm were deep water rice. One of the selected IR line showed higher grain length like 10.69 mm and L/B ratio was more than 4.0 accordingly, with shorter culm length (99.4 cm). Dry grain weight of the selected germplasm showed the difference from the local germplasm and the maximum was 34.48 g from Sorsoria, also had higher culm diameter (6.48 mm). All of the germplasm were medium to long durated considering days to maturity (142 days maximum). Seedling height was ranging from 37.8 to 63.6 cm. The filled grain number per panicle was higher in all the selected germplasm (maximum 136 in Badol) with minimum unfilled grain. Phenotypic acceptances during both vegetative and reproductive stage of all of the selected germplasm had the scores within the range of 5-6. Table 3 presents the maximum, minimum and mean value of the studied parameter for 70 germplasm. However, these superior six germplasm against different traits need to be confirmed by another year characterization by Plant Physiology and Plant Breeding Division.

Molecular characterization of T. Aman rice germplasm using SSR markers. Forty-eight germplasm were studied in the Molecular Laboratory of Genetic Resources and Seed Division of BRRI during T. Aman 2018 for developing DNA profiles under PBRG-NATP-2 project. DNA was extracted from young leaves following the quick DNA extraction protocol by Ferdous *et al.* (2012). PCR analysis was performed in 10 µl reaction sample containing 3 µl of DNA template, 4.5 µl of Go Taq G2 Green Master Mix (Promega), 1.5 µl of Nuclease-Free Water, 0.5 µl each of 10 µM forward and reverse primers using a GeneAtlas G (Astec, Japan) 96-well thermal cycler. The mixture was overlaid with 10 µl of mineral oil to prevent evaporation. After initial denaturation for five minutes at 94°C, each cycle comprised 30 sec denaturation at 95°C, 30 sec annealing at 55°C, and 25 sec extension with a final extension for 5 min at 72°C at the end of 32 cycles. The PCR products were then mixed with bromophenol blue gel loading dye and were analyzed by electrophoresis on 8% polyacrylamide gel using mini vertical polyacrylamide gels for high throughput manual genotyping (CBS Scientific Co. Inc., CA, USA). Then, 2.5 µl of amplification products were resolved by running gel in 0.5X TBE buffer for 1.5-2.5 hrs depending upon the allele size at around 100 volts and 500 mA current. The gels were then stained in 5 µl SYBR Safe DNA gel stain (10,000X concentration in DMSO, USA) with 200 ml 0.5X TBE buffer for 15 min and exposed to UV light using a molecular imager gel documentation unit (XR System, Uvitec Cambridge, France) for visualization. Fifty-four well distributed SSRs (simple sequence repeats) were used for diversity analysis.

A total of 190 alleles were detected at 54 SSR markers across 48 T. Aman rice germplasm. The highest amplicon size was produced by RM472 (281 bp) and the lowest by RM413 (67). The number of alleles per locus ranged from two alleles to seven alleles, with an average of 3.56 alleles across the 54 loci. The PIC values ranged from 0.04 (RM455) to 0.76 (RM207) with an average of 0.38. Lower PIC value indicates that the genotypes under study are closely related, while the higher value of PIC indicates higher diversity of materials, which is better for development of new varieties. Primer RM 207 had the highest PIC value (0.76) and it detected the highest level of polymorphism. Therefore, it confirmed that RM207 was the best marker for characterizing the studied T. Aman rice germplasm. The frequency of the most common allele at each locus ranged from 27.08% to 97.92%. On average, 69.09% of the 48 T. Aman rice germplasm shared a common major allele at any given locus. Figure 1 shows the DNA profiles of 48 T. Aman rice germplasm with RM253 SSR marker. The genetic distance-based results seen in the UPGMA clustering system revealed that the 48 T. Aman rice germplasm were grouped into four major clusters using Mega software (Fig. 2). The highest numbers of germplasm (35) were found in cluster I followed by cluster II (10), IV (2) and the lowest in cluster III (1).

Table 1. Some important features of characterized germplasm in T. Aman 2018.

Growth duration (days)		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		No. of tiller		Filled grain/panicle		1000-grain weight (g)		Yield/hill (g)	
Range	**No. of entries**	**Range**	**No of entries**	**Range**	**No. of entries**	**Range**	**No. of entries**	**Range**	**No. of entries**	**Range**	**No of entries**	**Range**	**No of entries**	**Range**	**No. of entries**
<120	18	<100	39	<110	13	<20	3	<10	25	<100	15	≤15	2	<5	0
120-130	27	110-125	16	110-130	14	20-25	38	10-15	30	100-150	29	16-19	14	5-10	30
>130	10	>125	0	>130	28	26-30	14	>15	0	>150	11	20-23	23	>10	25
						>30	0					24-27	13		
												>27	3		
Shortest (109)	Khato babu dhan (NC)	Shortest (79)	Khato babu dhan (NC)	Shortest (73.2)	Dudulota (NC)	Shortest (12.4)	Dudulota (NC)	Lowest (6)	Sona digha (Acc.122), Swarna (Acc. 5974)	Lowest (52)	Boro digha (Acc. 5042)	Lowest (15.25)	Lal swarna (Acc. 6669)	Lowest (5.42)	Bhawal digha (Acc. 106)
Longest (135)	Charulota (NC), Dudhlaki (NC), Digha(3) (Acc. 489)	Longest (108)	Charulota (NC), Dudhlaki (NC), Lal mohon (NC)	Longest (190.6)	Digha (2) (Acc. 128)	Longest (29.6)	Manik digha (Acc. 105), Boro digha (Acc. 5042)	Highest (13)	Digha (3) (Acc. 489)	Highest (186)	Sada swarna (NC)	Highest (28.25)	Digha (3) (Acc. 489)	Highest (19.61)	Digha (3) (Acc.489)
Mean	123.53	94.29		134.29		23.22		9.42		122.25		21.47		10.85	
S. Dev.	7.35	8.05		28.62		3.03		1.69		33.34		3.77		4.21	
CV	5.95	8.54		21.31		13.07		17.89		27.27		17.55		38.82	
LSD	1.94	2.13		7.56		0.80		0.45		8.81		1.00		1.11	

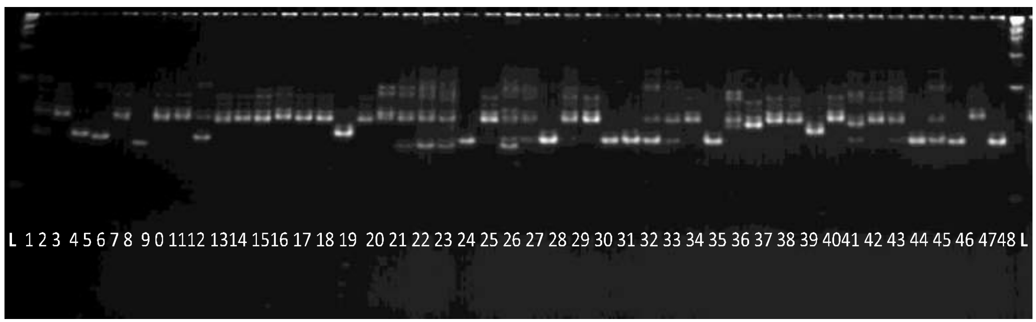
Table 2. Some important features of characterized germplasm in Boro 2018-19.

Growth duration (days)		Plant height (cm)		Panicle length (cm)		No. of tiller		No. of effective tiller		Grain LB ratio		1000-grain weight (g)		Yield/hill (g)	
Range	**No. of entries**	**Range**	**No. of entries**	**Range**	**No. of entries**	**Range**	**No. of entries**	**Range**	**No of entries**	**Range**	**No of, entries**	**Range**	**No of entries**	**Range**	**No. of ntries**
<135	0	<110	30	≤20	11	<10	16	<6	1	<1.1	0	≤15	0	<5	1
135-150	11	110-130	14	21-25	34	11-15	31	6-10	33	1.1-2.0	13	16-19	12	5-10	4
>150	37	>130	4	26-30	2	>15	1	>10	14	2.1-3.0	35	20-23	21	>10	43
				>30	1					>3.0	0	24-27	12		
												>27	3		
Shortest (139)	Boro Dhan (Acc. 4970)	Shortest (59.4)	Topa boro (Acc. 5041)	Shortest (17.4)	Topa boro (Acc.4983)	Lowest (6)	Unknown-469340 (Acc.6905)	Lowest (5)	Unknown-469340 (Acc.6905)	Lowest (1.59)	Bithri (Acc.4760)	Lowest (16.7)	Ata Sail (Acc.7298)	Lowest (4.99)	Boro Dhan (Acc. 4970)
Longest (772)	Kali Boro (Acc.7657)	Longest (137)	Pokkali-28609 (Acc.6842)	Longest (26.60)	Unknown-469428 (Acc. 6933)	Highest (16)	Unknown (Acc. 7293)	Highest (14)	Unknown (Acc. 7293)	Highest (2.87)	Tepu (Acc.7382)	Highest (29.9)	Pokkali-28609 (Acc. 6842)	Highest (22.31)	BR6108-R1-8 (Acc.4672)
Mean	155.88	104.58		22.21		11.18		9.35		2.16		21.92		12.25	
S. Dev.	8.18	17.67		2.73		2.47		2.19		0.31		3.61		3.98	
CV	5.25	16.90		12.27		22.07		23.39		14.61		16.47		30.95	
LSD	2.32	5.00		0.77		0.70		0.62		0.09		1.02		1.06	

Table 3. Performance of six selected T. Aman rice germplasm from 70 Genebank accessions.

Acc. No.	Acc. Name	SH (cm)	LL (cm)	LW (mm)	CD (mm)	CL (cm)	ETN/ hill	DTM	PL (cm)	FG/ panicle	UFG/ panicle	TGW (g)	Fresh Biomass (g, 5 hill)	Fresh Grain Wt (g, 5hill)	Dry Biomass (g, 5Hill)	Dry Grain Wt (g, 5Hill)	GL (mm)	GB (mm)	L/B ratio	Dehulled GL (mm)	Dehulled GB (mm)
6045	Badol	51.4	78.8	13.8	4.01	155.2	8.4	141	23.8	134.6	21.6	27.4	179.87	38.19	45.78	29.32	9.02	2.99	3.02	5.87	2.4
6046	Beni Gocha	50.4	51.2	13.2	5.74	146.6	7.8	141	29.2	119.0	22.2	30.0	179.12	38.63	50.85	28.74	8.31	3.31	2.51	6.02	2.66
6150	*IR line	37.8	68.8	11.6	5.75	99.4	8.8	142	26.2	81.0	11.0	31.6	117.08	26.87	42.31	19.34	10.69	2.5	4.28	7.6	2.05
6370	Laldoga	50.4	34.0	10.6	4.44	136.8	11.8	124	22.2	78.8	7.0	25.7	101.89	29.61	30.42	21.35	8.78	3.08	2.85	5.79	2.6
6376	Sorsoria	47.8	68.0	9.0	6.48	146	9.6	131	26.0	68.8	27.8	23.6	107.16	41.63	52.43	34.48	8.2	3.16	2.59	5.72	2.69
6379	Noakhali	63.6	60.2	10.0	6.98	153.2	8.2	141	27.6	98.8	48.6	23.4	103.95	32.11	52.9	25.53	7.32	3.31	2.21	5.23	2.89
Maximum (70 Acc.)		63.6	78.8	18.8	7.65	175.6	12.4	142	30.2	153.6	48.6	38.0	275.5	41.89	64.7	34.48	10.6	3.45	4.48	7.6	2.90
Minimun (70 Acc.)		37.8	6.1	9.0	4.01	74.0	5.2	111	17.4	14.7	5.2	22.0	12.0	10.33	21.3	8.79	6.9	2.26	2.21	4.8	2.05
Mean (70 Acc.)		49.64	63.3	12.3	5.77	135.8	8.64	134.2	25.0	97.24	18.8	27.5	136.7	25.6	42.8	18.22	8.5	2.93	2.95	6.06	2.5
LSD		2.91	8.3	1.2	1.1	7.23	1.57		2.12				20.9		8.6	5.3					

Legend: SH= Seedling height, LL=Leaf length, LW=Leaf width, CD=Culm diameter, CL=Culm length, ETN=Effective tiller number, DTM=Days to maturity, PL=Panicle length, FG=Filled grain, UFG=Un-filled grain, TGW=Thousand grain weight, Wt=Weight, GL=Grain length, GB=Grain Breadth and *IR line=IR -71347 -3B-16 -2 -1 -2B.



Legend: 1. Badkalamkati, 2. Baisbis, 3. Bhasha manik, 4. Bansfol, 5. Blue stik, 6. Chinri gushi,7. Chitraj, 8. Daudkhani, 9. Dhola amon, 10. Dudhlaki, 11. Indra sail, 12. Jesso balam, 13. Jhinga sail, 14. Kumari, 15. Nagra, 16. Rupsail, 17. Bashpul, 18. Apchaya, 19. Dhal katia, 20. Boron, 21. Dhaldata, 22. Sechi amon, 23. Laxmidigha, 24. Dal katra, 25. Chota bhawalia, 26. Bhora bhawlia, 27. Digha, 28. Manik digha, 29. Bhawal motuk, 30. Jatra motuk, 31. Bora digha, 32. Rangi khama, 33. Dudh bhawalia, 34. Goirol, 35. Bhawalia amon, 36. Hash fol, 37. Rajmondal, 38. Gonakray, 39. Kala mona, 40. Belon dhan, 41. Shor soria, 42. Gorcha, 43. Luta, 44. Sonadigha, 45. Gabura, 46. Khaiya motor, 47. Sona digha (Acc. 126), 48. Raj bhawalia.

Fig. 1. DNA profiles of 48 T. Aman rice with RM253 SSR marker.

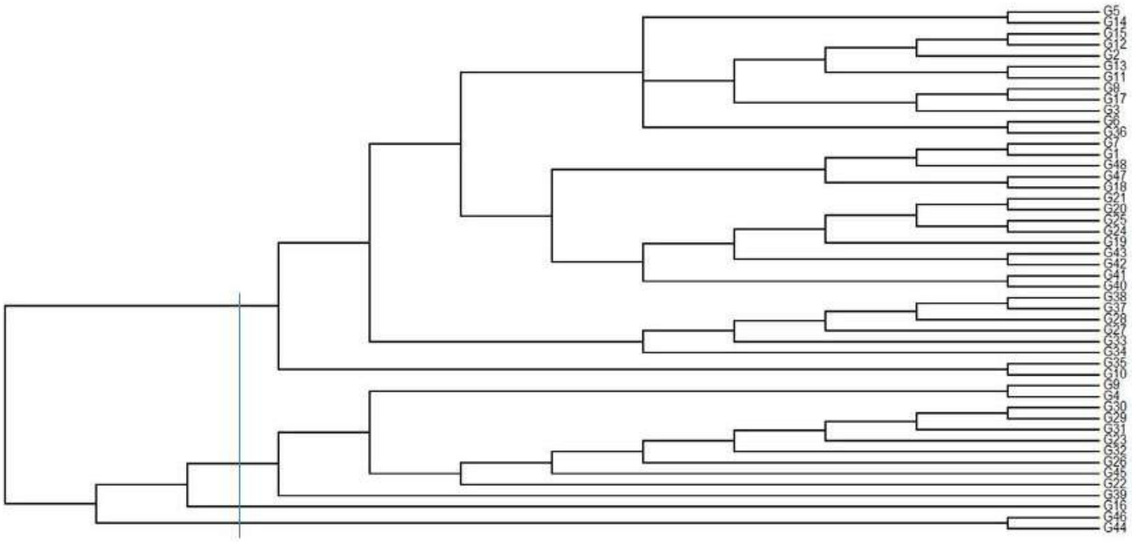


Fig. 2. Dendogram showing distribution 48 T. Aman germplasm using 54 SSR markers.

Germplasm processing, registration and storage. In total 2,712 germplasm were processed to conserve with respective accession number in different storages of Genebank during 2018-19. The germplasm were cleaned and dried with a seed moisture content of less than 9%.

In details, 1,951 accessions of which 465 in Aus 2018, 1,076 in T. Aman 2018 and 410 acc. in Boro 2018-19 seasons were processed and stored in short-term storage. Similarly, 70 and 78 accessions in Aus 2018, 212 and 306 accessions in T. Aman 2018 and 33 and 62 in Boro 2018-19 seasons were stored in medium and long-term storages, respectively during the reporting year. On the other hand, 342 germplasm were registered in accession book as new accession (from acc. 8237 to 8578).

Viability testing, periodic evaluation and routine monitoring of stored germplasm. One hundred accessions in Aus, 85 in T. Aman and 92 in Boro seasons were checked randomly for viability (germination %) test in short-term storage during 2018-19. 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 of 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 277 stored germplasm, 109 had viability between 80-90% and 147 had above 90%. The germplasm accessions stored during 2018-19 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 2018 and March 2019 were 70-99% and 72-100% respectively, which indicate the viability condition of stored germplasm in medium and long term storages.

Germplasm distribution/exchange. A total of 2,268 samples were supplied to different users in the reporting year. Among the samples, 1,441 germplasm accessions were supplied for research purpose and 827 samples of BRRI developed rice varieties were supplied to the researchers, Department of Agricultural Extension (DAE) personnel and university students for research, demonstration as well as other purposes.

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

SEED PRODUCTION AND VARIETY MAINTENANCE

Variety maintenance and nucleus seed production. Ninety-nine BRRI developed and recommended rice varieties including 14 local improved varieties (LIV's) were maintained using panicle to row method, implementing time isolation and performing thorough roguing (Table 4). After harvest, both intact panicles and nucleus seed of each variety were stored (20°C with 40% RH) for variety maintenance and distribution to researchers, DAE personnel and students respectively.

Nucleus seed stock production. Sixty-seven BRRI developed rice varieties of which 43 in T. Aman and 24 in Boro were grown in panicle to row method to produce nucleus seed stocks for breeder seed production. The objective for nucleus seed production was to maintain genetic purity and homogeneity of morphological characteristics of a variety and subsequently breeder seed production. 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 both intact panicles for BRRI Gazipur and nucleus seed stocks for BRRI regional stations were stored in controlled temperature (20°C with 40% RH).

Breeder seed production and distribution. GRS Division, Farm Management Division and eight regional stations of BRRI were engaged in breeder seed (BS) production as per national demand during 2018-19. 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 226.86 tons of breeder seed with tags of which 154.39 tons from 24 varieties in Boro and 72.47 tons from 43 varieties in T. Aman seasons were produced (Tables 5 and 6). Among the total production, 210.16 tons were produced by GOB fund and 16.70 tons were produced by project fund viz. HarvestPlus, Transforming Rice Breeding (TRB) and Stress-Tolerant Rice for Africa and South Asia (STRASA) (Table 7). On the other hand, 183.89 tons of breeder seed of which 113.22 tons from 23 varieties in Boro, 9.27 tons from 15 varieties in Aus and 61.40 tons from 33 varieties in T. Aman were distributed among the 'Rice Seed Network' partners (822) during 2018-19 (Tables 8, 9 and 10).

Table 4. List of BRRI developed and recommended rice varieties maintained during 2018-19.

Season	Type	Number	Variety
T. Aman	MV	48	BR4, BR5, BR10, BR11, BR21, BR22, BR23, BR24, BR25, BRRI dhan27, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan40, BRRI dhan41, BRRI dhan42, BRRI dhan43, BRRI dhan44, BRRI dhan46, BRRI dhan48, BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan76, BRRI dhan77, BRRI dhan78, BRRI dhan79, BRRI dhan80, BRRI dhan82, BRRI dhan83, BRRI dhan85, BRRI dhan87
	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
Total		99	

Table 5. Production (in kg) of breeder seed (with tag) of Boro varieties during 2018-19.

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 Barishal	BRRI RS Satkhira	Total
BR3	270										270
BR14	650										650
BR16	1140										1140
BR26	1060				5020				6000		12080
BRRI dhan28	80	3600		8120	6040	10450	7160	3640	6760	8760	54610
BRRI dhan29	650				4560	5220	4640	5150	5800		26020
BRRI dhan36	120										120
BRRI dhan45	50										50
BRRI dhan47	500								1020		1520
BRRI dhan50	310									6600	6910
BRRI dhan55	270										270
BRRI dhan58			4400		5640	9500					19540
BRRI dhan59	420										420
BRRI dhan60	540										540
BRRI dhan61	280										280
BRRI dhan63	2670			2300				1320			6290
BRRI dhan64	270										270
BRRI dhan67	850								2990	1150	4990
BRRI dhan68	500	700									1200
BRRI dhan69						2750					2750
BRRI dhan74	4760					4750			2470		11980
BRRI dhan81	620					1420					2040
BRRI dhan84	120										120
BRRI dhan86	330										330
Total	16460	4300	4400	10420	21260	34090	11800	10110	25040	16510	1,54,390

Table 6. Production (in kg) of breeder seed (with tag) of T. Aman varieties during 2018-19.

Variety	Production (kg)								
	GRS Division	Farm Division	BRRI RS Rangpur	BRRI RS Rajshahi	BRRI RS Cumilla	BRRI RS Sonagazi	BRRI RS Barishal	BRRI RS Satkhira	Total
BR10	80							1440	1520
BR11	360			2760		4300			7420
BR21	170								170
BR22	230				3200		740		4170
BR23	130						3710		3840
BR24	60								60
BR25	20								20
BRRI dhan27	130								130
BRRI dhan30	190							830	1020

Table 6. Continued.

Variety	Production (kg)								
	GRS Division	Farm Division	BRRI RS Rangpur	BRRI RS Rajshahi	BRRI RS Cumilla	BRRI RS Sonagazi	BRRI RS Barishal	BRRI RS Satkhira	Total
BRRI dhan31	20								20
BRRI dhan32	140				1080				1220
BRRI dhan33	290			1220					1510
BRRI dhan34	100					2120	2950		5170
BRRI dhan37	20								20
BRRI dhan38	10								10
BRRI dhan39	190	3240							3430
BRRI dhan40	40								40
BRRI dhan41	70					1330			1400
BRRI dhan42	130								130
BRRI dhan43	330								330
BRRI dhan44	60								60
BRRI dhan46	200								200
BRRI dhan48	1400			3240	1500				6140
BRRI dhan49	400	1960			7300		3200	3560	16420
BRRI dhan51	1000								1000
BRRI dhan52	290		2480				3120		5890
BRRI dhan53	20								20
BRRI dhan54	30								30
BRRI dhan56	380			330					710
BRRI dhan62	500				2320				2820
BRRI dhan66	480								480
BRRI dhan71	280		890	440					1610
BRRI dhan72	700								700
BRRI dhan73	50								50
BRRI dhan75	600						210		810
BRRI dhan76	80						530		610
BRRI dhan77	120						590		710
BRRI dhan80	270					1300			1570
BRRI dhan82	390								390
BRRI dhan83	240								240
BRRI dhan85	170								170
BRRI dhan87	100								100
Nizersail	110								110
Sub total	10580	5200	3370	7990	15400	9050	15050	5830	72,470

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

Variety	Project and quantity (in kg)			Total
	HarvestPlus	TRB	STRASA	
BRRI dhan51		120		120
BRRI dhan60		270		270
BRRI dhan62	2820			2820
BRRI dhan63		2260		2260
BRRI dhan67			850	850
BRRI dhan71			140	140
BRRI dhan72	700			700
BRRI dhan74	8050	1210		9260
BRRI dhan75		100		100
BRRI dhan80		180		180
Total	11570	4140	990	16,700

Monitoring seed production plots and farms. Breeder seed production plots of BRRI regional stations (RSs) viz Rangpur, Rajshahi, Habiganj, Cumilla, Bhanga, Barishal, Sonagazi and Satkhira along with foundation seed production farms of BADC in Madhupur, Tangail; Datta Nagar; Jhenaidah; Paikgacha, Khulna; Trishal, Mymensingh; Dinajpur; Madhupur, Tangail; Uzirpur Organic Bohumukhi Shomobay Somity, Narail and Al Ikra Beez Vander, Chuadanga 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. Isolation distance was properly maintained. Foundation seed (FS) producers were advised to discard three meters boundari 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.

EXPLORATORY AND GENETIC STUDIES

Identification and selection of sticky rice from *Jhum* rice germplasm. Fifty-nine *Jhum* rice germplasm were characterized to study the selection criteria during Aus 2018 and the selected lines would be purified afterward. The germplasm were grown in T. Aus 2018 with three replications and single seedling per hill with a spacing of 20 × 20 cm^2 between rows and plants. Fertilizers were applied @ 30:20:40 kg NPK/ha. Maximum growth duration among the studied lines was found 131 days (Lal company-Acc. 7743), while the minimum was 89 (Gunda-Acc. 7835, Misha koia-Acc. 7836, Bardia-Acc.7837). Maximum yield/hill at 14% moisture content was 36 g (Bekui-Acc. 7840). The tested 19 out of 59 germplasm had medium amylose content with a range of 20-25%, where Bardia (Acc. 7837) had the lowest. This study need to continue to find out more low amylose content Aus/*Jhum* rice germplasm. Table 8 presents the maximum, minimum and mean value of the studied parameter for 59 germplasm.

Characterization of red and black rice germplasm using SSR markers. Ninety-four red and black Aus rice germplasm were studied using 61 well distributed SSR markers during Aus 2018. DNA extracted, PCR products, temperature profiles, gel documentation and data analysis were performed as same as described earlier in molecular characterization of T. Aman rice germplasm using SSR markers under rice Germplasm Conservation and Management section.

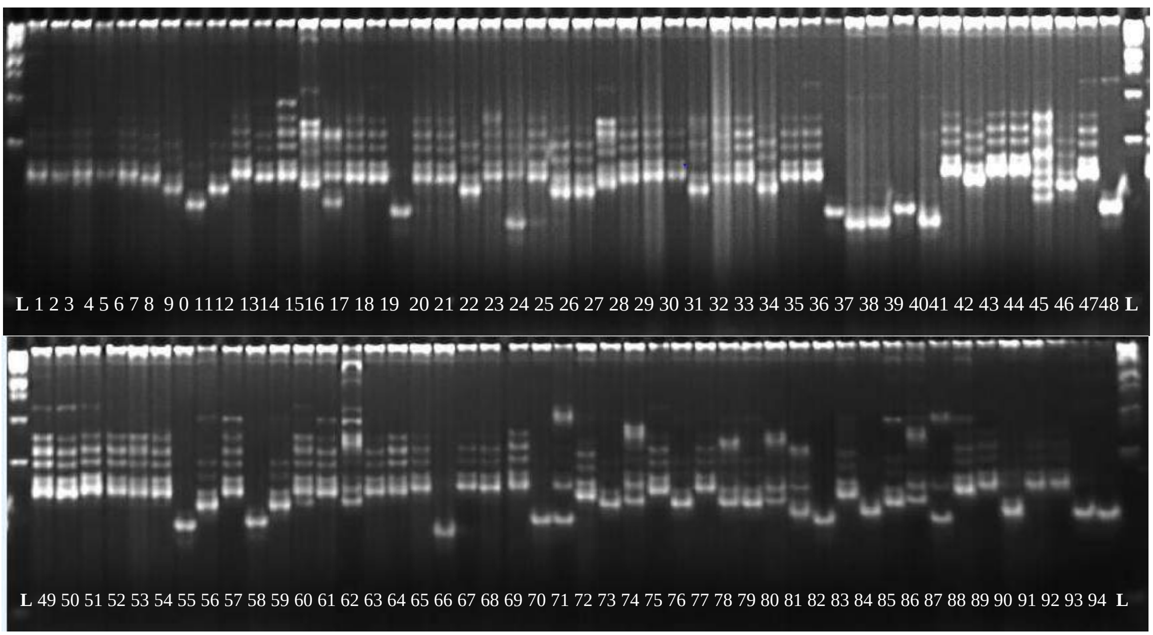
All the markers showed polymorphism and 236 alleles were detected. The average number of alleles per locus was 3.87, ranging from 2 (RM 124, RM 133, RM 212, RM 338, RM 452, RM 455, RM 484, RM38, RM 277, RM 321, RM 536)

Table 8. Mean performance of fifty-nine *Jhum* germplasm for various yield contributing traits.

Subject	Seedling height (cm)	No. of total tiller	No. of effective tiller	Panicle length (cm)	Plant height (cm)	Growth duration (days)	Filled grain /panicle	Un-filled grain/panicle	Thousand grain Weight (g)	Yield/ Hill (g)
Max	34	17	11	31	150	131	182	83	33	36
Min	12	4	4	8	75	89	67	8	13	6
Mean	22.3	8	8	25.0	114.9	103	111	34	21.0	18.4
STD	4.12	2.36	1.76	4.06	18.21	14.07	26.12	13.79	3.91	7.86
CV	18.49	28.21	23.30	16.23	15.85	13.70	23.49	40.82	18.58	42.72
LSD	1.04	0.60	0.44	1.03	4.61	3.56	6.61	3.49	0.99	1.99
SE	0.53	0.31	0.23	0.52	2.35	1.82	3.37	1.78	0.51	1.01

to 10 (RM303). The gene diversity ranged from 0.06 to 0.75, with an average of 0.45. The highest amplicon size was produced by RM472 (301 bp) and the lowest by RM413 (67). The polymorphism information content (PIC) for the SSR loci ranged from 0.06 (RM338) to 0.71 (RM289). Primer RM289 had the highest PIC value (0.71) and was supposed to be the best marker for characterizing the 94 Aus rice germplasm. The frequency of the most common allele at each locus ranged from 37.23% (RM303) to 96.74% (RM338). On average, 68.34% of the 94 Aus rice germplasm shared a common major allele at any given locus. Figure 3 presents the DNA profiles of 94 Aus germplasm with SSR marker RM209. The genetic distance-based results seen in the unrooted neighbour-joining tree revealed that the studied germplasm were grouped into three major clusters using Mega software (Fig. 4). The highest numbers of germplasm (32) were found in cluster I and cluster III and the lowest in cluster II (30).

Screening of rice germplasm for the early-morning flowering trait to escape heat stress in rice. Forty-eight germplasm were observed against the early-morning flowering (EMF) trait to escape heat stress in rice during T. Aman 2018. The flowering patterns of rice germplasm were investigated in the field using conventional rice cultivation methods. The EMF trait was evaluated using the visual observation only on sunny days. Opened spikelets were marked every morning from 7.00 am to 9.00 am. In thorough observation, no landraces were found with early morning flowering (before 9.00 am) trait.



Legend: 1. Goria (Acc. 4741), 2. Boloiparashi, 3. Nokhidungra, 4. Solai, 5. Nordi, 6. Kalosate, 7. Bahoi, 8. Challisha, 9. Kala Bora, 10. Boira, 11. Korchamuri, 12. Gumvir, 13. Amei, 14. Kamarang, 15. Musur, 16. Koisramuri, 17. Ogoan, 18. Auskhuni, 19. Aus Khorni, 20. Akuee, 21. Aus Balam, 22. Aus Khusni, 23. Kobila Aus, 24. Kalo Buri, 25. Ratol, 26. Kalo Soti, 27. Cn (Indian), 28. Balam, 29. Lota Bhog, 30. Aus Boro, 31. Nuncha, 32. Kala Bori, 33. Bir Pala -1, 34. Bir Pala -2, 35. Pol Bira, 36. Manik Muri (Acc. 4972), 37. Aus Dhan (4973), 38. Boroi Dhan, 39. Manik Muri (5019), 40. Aus Dhan (5020), 41. Soru Saita, 42. Khora Jamrl, 43. Pathar Kuchi, 44. Bhoira Aus, 45. Vadai, 46. Nengri, 47. Kerondol, 48. Kali Aitta, 49. Kalo Kochi, 50. Aus Dhan (6617), 51. Kala Boyei -1, 52. Katki Dhan, 53. Kala Boyei -2, 54. Company, 55. Klingraochitoi, 56. Tokday, 57. Raingkoi, 58. Binni Dhan, 59. Cray, 60. Kala Binni (7258), 61. Kutkutta Binni, 62. Badia, 63. Horin Binni, 64. Laxmi Digha, 65. Mosair Aus, 66. Aus Dhan (7302), 67. Lal Aus, 68. Kalo Aus, 69. Sada Aus, 70. Gota Mala, 71. Katihatia, 72. Nali, 73. Army Dhan, 74. Kangandhi, 75. Patteki Dhan, 76. Lamnakhoiya, 77. Kaikui Dhan, 78. Mang Thang, 79. Roingui, 80. Lal Dhan, 81. Jibini, 82. Khato Mala, 83. Chuli Dhan, 84. May May Binni, 85. Kangbu, 86. Kilong, 87. Badi Kaborok, 88. Galong, 89. Moisor, 90. Baisbis, 91. Sarong, 92. Goria (4741), 93. Kala Binni (NC), 94. Sada Binni.

Fig. 3. DNA profiles of 94 Aus rice germplasm using RM209 SSR marker.

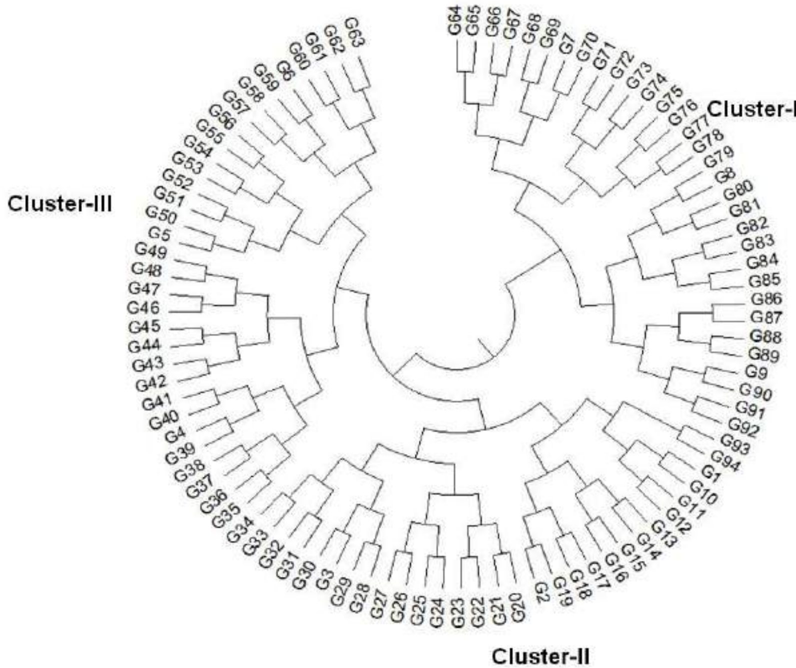


Fig. 4. An unrooted neighbour-joining tree showing the genetic relationships among 94 red and black Aus rice germplasm using 61 SSR markers.

Preliminary yield trial (PYT) of Jirasail genotype. Four popular Jirasail germplasm of which three HRC (Path) Jirasail genotypes collected from Rajshahi, Bogura and Jashore districts and one Jirasail genotype collected from BADC, Madhupur along with BRRI dhan81 as standard check were evaluated at BRRI Gazipur as PYT during T. Aman 2018. The highest grain yield (30 g/hill) was observed in HRC (Path) Jirasail, Bogura followed by HRC (Path) Jirasail, Rajshahi (21) and the lowest (19) in HRC (Path) Jirasail, Jashore and Jirasail, Madhupur (BADC) genotypes respectively.

PYT of aromatic rice germplasm. Eleven aromatic rice germplasm viz Chinigura, Ranisalute, Jirakatari, Radhunipagal, Dudsail, Tulsimala, Kataribhog, Sakkorkhora, Chinisail, Begunbichi, Chiniatop along with standard check BRRI dhan34 were evaluated at BRRI Gazipur for PYT during T. Aman 2018. The germplasm were grown in 10 m^2 plot with three replications and single seedling per hill with a spacing of 20 × 20 cm^2 between rows and plants. Maximum yield/hill (at 14% moisture content) was found in Ranisalute variety (35 g), while the minimum yield/hill was found in Tulsimala and Begunbitchi (17) respectively. Table 9 presents the detailed yield performance of the germplasm for the studied parameter.

PYT of popular rice germplasm of southern region. Seven accessions of popular rice germplasm from southern region, in which two from Balam (Acc. 1011, 516), three from Jesso-Balam TAPL (Acc. 2473, 2464, 2472), one each from Sadamota (Acc. 7888) and Lalmota (Acc. 7889) along with BRRI dhan44, BRRI dhan49 and BRRI dhan57 as standard checks were grown during T. Aman 2018 for PYT. The higher grain yields per hill were observed in Acc. 1011 (22.5 g) of Balam, Acc. 2473 (27.9) of Jesso-Balam TAPL and Acc. 7889 (36.2) of Lalmota genotype. Besides, the highest panicle lengths were found in Acc. 516 (26.8 cm) among the Balam and Acc. 7888 (28.6) of Sadamota types. The highest numbers of filled grains were observed in Acc. 516 (178) among the Balam and Acc. 7889 (97) of Lalmota germplasm. The highest LB ratio were found in Acc. 1011 (3.6) but the lowest dehulled grain breadth was found in Acc. 516 (1.6). Finally, Acc. 516 as fine grain from Balam and Acc. 2464 and 2472 from Jesso-Balam TAPL and Acc. 7888 of Sadamota for higher grain yields were selected along with BRRI dhan70 and BRRI dhan80 as standard checks for the next T. Aman 2019 season for confirmation.

Morphological diversity of similar named Jirasail rice germplasm of Bangladesh. Eleven accessions viz Jira Sail (Acc. 7591), Jira Shail (5061), Jirasail (6694), Jirasail (6718), Jirasail (Indian) (8056), Jira Bhog (Bolder) (4828), Jira Bhog (Finer) (4831), Jira Buti (1984), Jira Dhan (5313), Jira Katari (5045), Gira Katari (5975) and four new collections (NC) *viz* Jira, Jirasail, Jirasail germplasm from BRRI Genebank were grown during Boro 2018-19 for studying their morphological diversity. The highest number of effective tiller per hill (14) were observed in Acc. 7591 (Jira Sail) and NC (Jirasail) and the lowest (10) in Acc. 6718, 4828, 5313 and NC (Jirasail). Jira Shail (Acc. 5061) had the longest plant (134 cm), while the shortest (84.4) was observed in NC (Jira). The highest panicle length (25.8 cm) was observed in Acc. 5061 (Jira Shail). The longest growth duration (157) was observed in Acc. 4831 (Finer Jira Bhog) and the shortest (141) also in NC (Jira). Jira Shail (Acc. 5061) had the highest number of filled grains per panicle (187). The highest TWG (21.5 g) was observed in Acc. 6694 (Jirasail) and the lowest (10) in Acc. 1984 (Jira Buti). Besides, the longest dehulled grain (7.4 mm) and the highest LB ration (4) was found in NC (Jirasail). Finally, the highest grain yield (41.8 g/hill) was observed in Acc. 7591 (Jira Sail). No duplicate germplasm was found.

SEED TECHNOLOGY PACKAGES

Publication on seed production technology packages. Two leaflets titled as ‘Identification and roguing of Off-type’ (2000 copies) for Rice Seed Network partners and ‘BRRI Genebank-A very short introduction’ (4000 copies) for BRRI Genebank visitors were published on March 2019 under the supervision of Publications and Public Relations Division of BRRI.

Table 9. Performance of 11 aromatic rice germplasm for various yield contributing traits.

Name	Total tiller	Effective tiller	Panicle length (cm)	Plant height (cm)	Growth duration (day)	Filled grain /panicle	Un-filled grain /panicle	Thousand grain weight (g)	Yield/ hill (gm)
Chinigura	14	12	23	116	122	196	20	10	32
Ranisalute	16	14	27	130	130	132	12	26	35
Jirakatari	9	8	24	123	121	164	16	11	23
Radunipagal	15	13	22	100	119	182	23	12	23
Dudsail	10	9	25	119	124	182	20	14	29
Tulsimala	10	8	25	128	120	193	23	11	17
Kataribhog	10	9	22	132	124	127	15	14	21
Sakkorkhana	11	9	25	117	124	184	25	13	23
Chinisail	10	9	22	105	121	161	22	12	32
Begunbichi	12	10	23	113	123	171	16	11	17
Chiniatop	16	13	28	99	124	120	19	11	21
BRRI dhan34	12	11	26	104	124	203	25	10	18
Max	16	14	28	132	130	203	25	26	35
Min	9	8	22	99	119	120	12	10	17
Mean	12	10	24	115	123	168	20	13	24
STD	2.58	2.02	2.06	11.73	2.90	28.05	4.20	4.48	6.30
CV	21.52	19.22	8.45	10.16	2.36	16.70	21.37	34.68	25.90
LSD	1.46	1.14	1.16	6.64	1.64	15.87	2.38	2.54	3.57

Grain Quality and Nutrition Division

SUMMARY

A total of 133 breeding lines were analyzed and some of the promising lines were identified for higher milling and head rice recovery, size and shape, amylose and protein contents, elongation ratio and acceptable other physicochemical properties.

Among the eating quality and cooking properties of local rice cultivars, excellent taste depends on higher protein and stickiness whereas very good test depends on higher amylose and fluffiness. Though Ranisalute and Rataboro are sticky and soft the result demonstrated it as excellent in taste.

Heavy metals such as As, Pb, Cd, Cr, Ni, bacteriological assay such as bacterial load (cfu/g), fungal assay such as yeast and molds load (cfu/g) and fungal toxins specially aflatoxins (B1, B2, Gl and G2) were investigated for RB, RBO and DORB samples. RB and DORB samples were found positive for bacteria, yeast and mold population, and aflatoxin B1 for fresh (0), 7, 14 and 21 days after storage at ambient temperature. RB and DORB samples for 28 days after storage found lower load in bacteria, yeast and mold load but completely negative for aflatoxin B1. We have examined all the above mentioned quality parameters for RBO and found negative for bacteria, yeast and mold load and even aflatoxin B1. In addition, no trace heavy metals was present in either crude or refined RBO samples. Since acute toxicity experiment on animal health, toxins and heavy metal toxicity in RBO samples found negative, so refined RBO is safe and will bring benefit to health for Bangladeshi population.

It was observed that 25% replacement of BRRI recommended fertilizer dose with SBE does not compromise yield component at all. This replacement percentage of BRRI recommended dose can further be extended up to 50% at best in extended multilocation field trials in Bangladesh. Since SBE is very cheap (only Tk 1-2 per kg SBE) and available in refined edible oil mills in Bangladesh, so it could possibly save significant amount of currency in return and lower agricultural cost indeed.

Puffed, popped and flattened rice were produced from 10 BRRI varieties to evaluate the quality products. Comparing few parameters (fully puffed rice, length and breadth increase percentage) with BR16 (Std), it is ascertained from the results that BRRI dhan72 is better in producing whole puffed rice followed by BRRI dhan70. Considering physical parameters, BRRI dhan70 and BRRI dhan71 show excellent performance for whole, partial broken, broken and unpopped rice. Among the tested varieties, in terms of weight of whole, partial broken and broken flattened rice as well as percentage of length increased, BRRI dhan74 performed better than BR16.

GRAIN QUALITY CHARACTER

Determination of physicochemical and cooking properties of breeding lines

After yield, grain quality of rice is important parameters for researchers and consumers. Consumer acceptance of rice depends on its physicochemical quality of rice. Physical parameters were measured by milling outrun, head rice yield and size and shape. Cooking quality was determined by cooking time, elongation ratio and volume expansion ratio. Chemical parameters were determined by amylose content, protein content and alkali spreading value. New HYR varieties that have better benefits than the existing ones will be more accepted if their characteristics are in accordance with consumers' preferences (Zen 2007). High quality rice, uniform shape, whiteness and translucency are major factors defining market value of rice (Fitzgerald *et al.* 2008). Rice is a very rich source of carbohydrate followed by protein.

A total of 133 samples were provided from different BRRI divisions and outside of BRRI to find out the desirable characteristics. In Bangladesh, consumers prefer long slender type translucent grains as premium quality rice with higher price. But medium bold type grains are most suitable for milling. Out of 108 samples, 92 had more than 70% milling outtern and 72 had more than 60% head rice recovery. Out of 116 samples, 79 had long grain, 37 had medium grain but there is no short grain. Among these samples 85 had more than 3.0 L/B ratio, whereas 31 had between the range of (2.0-3.0) L/B ratio. Out of 97 samples, there is no samples more than 30.0 g 1000 grain wt (TGW), 87 had between the range of (20.0-30.0g) TGW and 10 had TGW less than 10 g (Table 1).

Table 1. Physical properties of rice samples.

Range	Sample no.
Milling outturn (%) (total sample no. 108)	
>70.0	92
68.0-70.0	14
<68.0	2
Head rice recovery (%) (total sample no. 108)	
>60.0	72
50.0-60.0	25
<50.0	11
Length (mm) (total sample no. 116)	
Long	79
Medium	37
Short	-
L/B ratio (total sample no. 116)	
3.0>	85
2.0-3.0	31
<2.0	-
1000-grain wt (g) (total sample no. 97)	
>30.0	-
20.0-30.0	87
<20.0	10

Amylose is the most important trait for eating quality, which indicates the texture of cooked rice and also volume expansion. Out of 133 samples, 91 had more than 25.0% amylose, 40 had between the range of (20.0-25.0%) amylose and only two had less than 20% amylose. Nutritional quality is measured by protein content. Out of 116 samples, 28 had more than 9.0% protein, 80 had between the range of (7.0-9.0%) protein and only eight had less than 7.0% protein. Less than 7% protein content in brown rice, which is not normally recommended for variety release. Grain with high gelatinization temperature is not desirable. Out of 116 samples, 114 had more than 15 minutes cooking time and only two had less than 15 minutes cooking time. Among these samples, 36 had more than 1.5 elongation ratio (ER), 55 had between the range of (1.4-1.5) ER and 25 had less than 1.4 ER. More than 1.5 elongation ratio is desirable. High volume expansion of cooking is still considered to be a good quality for the working class people who do not care whether the expansion is lengthwise or crosswise. Among these samples, 101 had more than 4.0 volume expansion ratio and 15 had less than 4.0 volume expansion ratio (Table 2).

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

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

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

Grain quality is an important component for consumer's preference and profitability. For the transforming rice breeding project on rice grain quality screening, a total of 1,524 samples (preliminary yield trial 218, observational trial 152 and line stage trial 1,154) were received, processed and evaluated. Milling is one of the parameters determining milled rice yield per unit paddy weight. Among 370 advanced lines 182 had high (>70%) and 121 lines had intermediate (68.0-70.0%) milling yield. On the contrary, 155 lines had more than 57% head rice yield. Chalkiness in grain is not a positive quality factor for the unparboiled rice consumers. Around 118 lines had translucent grains. Grain length and length-breadth ratio determines the grain size and shape. Five hundred twenty-five lines had long (>6.0mm), 995 had medium (5.0-6.0 mm) and only four had short (< 5.0 mm) grains. Two hundred ninety lines had long slender grain (Table 4).

Table 2. Chemical and cooking properties of rice samples.

Range	Sample no.
Amylose content (%) (total sample no. 133)	
>25.0	91
20.0-25.0	40
<20.0	2
Protein content (%) (total sample no. 116)	
>9.0	28
7.0-9.0	80
<7.0	8
Cooking time (mim.) (total sample no. 116)	
>15.0	114
<15.0	2
Elongation ratio (total sample no. 116)	
>1.5	36
1.4-1.5	55
<1.4	25
Volume expansion ratio (total sample no. 116)	
>4.0	101
<4.0	15

Table 3. Physicochemical properties promising samples.

Ac. no.	Genotype	Milling outturn (%)	Head rice recovery (%)	Alkali spreading value	Amylose content (%)	Protein content (%)	Elongation ratio	Size and shape	100-grain wt (g)
14804	T10= T10=BR (path) 12452-BC3-8-13	72	65	5.3	27.3	8.7	1.7	MB	25.1
14324	BRC297-15-1-1-1	72	62	4.4	26.2	8.6	1.5	LB	22.6
14119	BR(Bio) 10368-AC2-1-1	70	60	4.5	25.0	9.1	1.6	LS	21.6
14127	BR(Bio) 10368-AC24-2-3	72	68	5.0	26.0	8.9	1.6	LS	27.8
14130	BR(Bio) 9777-116-12-2-2	72	68	4.8	25.1	9.3	1.5	MS	23.1
13980	BR9674-5-6-2-1-7-22	71	68	7.0	28.1	7.6	1.6	MB	21.0
13981	BR9966-12-5-6-3-2	73	70	7.0	28.9	8.0	1.5	MB	23.7
14139	IR4630	70	66	5.9	27.9	9.4	1.5	MB	23.3
13995	IR99285-1-1-1-P1	70	63	4.3	25.8	7.6	1.4	LS	21.8
14050	BR8938-30-2-4-2-1	70	62	4.5	25.4	8.2	1.4	LS	24.6
14053	BR8904-28-1-2-2-2	72	64	4.6	27.6	8.3	1.5	LB	24.1
-	Krishibid basmoti chal	71	50	4.7	28.4	8.1	1.6	LS	-

Amylose content determines the quality of cooked rice. Out of 1201 lines, 551 had high (>25%), 643 had intermediate (20-25%) and seven had low (<20%) amylose content. Low amylose rice is not acceptable to our people. Protein content measures the nutritional value of rice. Out of 192 lines, 82 had high (9.0%) protein content and 110 had intermediate protein content (7.0-9.0%). Generally a variety that has less than 7% protein content in brown rice is not recommended for release. Alkali spreading value has inverse relationship with gelatinization temperature. Among the lines, 150 had intermediate and 37 had high gelatinization temperature (Table 5).

High volume expansion of rice is a positive quality factor for low-income group of people. Only one line had high (>4.0) and six had intermediate (3.5-4.0) volume expansion ratio. Elongation ratio is the important quality indicator. The grain that elongates more in length looks finer. On the contrary, the grain that expands more in girth looks coarse. Among 188 lines 16 had high (1.5), 175 had intermediate (1.3-1.5) and seven had low (<1.3) elongation ratio (Table 5).

This study identified some of the promising lines for high milling and acceptable other physicochemical properties (Table 6).

PI: MAS **CI:** SSD

Table 4. Physical properties of TRB rice lines.

Range	Entry no.
Milling Outturn (%) (total sample no. 370)	
>70.0	182
68.0-70.0	121
<68.0	67
Head rice recovery (%) (total sample no. 370)	
>60.0	205
50.0-60.0	165
<50.0	-
Length (mm) (total sample no. 1524)	
Long	525
Medium	995
Short	4
L/B ratio (total sample no. 1524)	
3.0>	290
2.0-3.0	1204
<2.0	30

Table 5. Chemical and cooking properties of TRB rice lines.

Range	Entry no.
Amylose content (%) (total sample no. 1201)	
>25.0	551
20.0-25.0	643
<20.0	7
Protein content (%) (total sample no. 188)	
>9.0	82
7.0-9.0	106
<7.0	-
Cooking time (mim.) (total sample no. 188)	
>15.0	184
<15.0	4
Elongation ratio (total sample no. 188)	
>1.5	16
1.4-1.5	165
<1.4	7
Volume expansion ratio (total sample no. 188)	
>4.0	1
<4.0	187

Table 6. Physicochemical properties of promising transforming breeding lines.

Genotype	Head rice (%)	Size and shape	Amylose content (%)
BR8448-14-2-1-1-1-25	57.1	LB	25.6
IR92466-SUB-SUB-59-1-B	53.3	LS	25.5
IR13F458	57.5	LB	26.1
IR13F45	60.3	LB	25.7
IR13F548	65.2	MB	25.6
BR9649-9-2-1	63.9	LB	27.1
IR65482-4-136-2-2	57.3	LS	26.2
BR9006-54-1-3-2	62.1	SR	27.2
BR8781-16-1-3-2-P2	59.1	MB	27.2
IR16F1153	60.2	LS	25.8
BR9159-10-2-1-2-5-1-B1	60.4	MB	25.7
BR9175-9-2-1-12-5	53.6	MB	25.8
BR9175-9-1-3-20-3	48.8	MB	25.1
IR13F458-5	50.9	MB	25.1
IR13F458	53.9	MB	25.9

NUTRITIONAL QUALITY ASSESSMENT OF RICE

Components of rice in relation to the palatability

Rice is the most commonly grown cereal crops throughout the world. Sreepada and Vijayalaxmi, (2013) reported that rice is the staple food and around 3.5 billion people are consuming the rice. As a result, people of different countries prefer different types of rice due to their palatability of cooked rice. Palatability of cooked rice is a complex phenomenon, which can justify delectableness, deliciousness, lusciousness, sweetness, tastiness, scrumptiousness and yumminess etc. In general, consumers purchase rice grain from the different thinking like palatability, brand name and location specific but most of the consumers' desire palatability of cooked rice. Palatability, nutritional qualities and physicochemical properties of rice varieties vary not only with the genotypes but also with the agro-ecological zones, cultural practices (Bhattacharya, 1976 and Siscar-Lee *et al.*, 1990), processing technique, storage condition and consumer preference.

The eating quality of rice, known as rice palatability, is a very important factor that determines the commercial value of rice. Similarly, texture of rice such as hardness, fluffiness, softness and stickiness are the most important indicators for determining the palatability of cooked rice. Previously, eating quality of rice is directly related to the physicochemical properties eg. gelatinization temperature, water absorption, protein and amylose content. Now-a-days, water absorption, volume expansion, hardness, softness, fluffiness, stickiness, whiteness and glossiness of cooked rice are affected by amylose content. In general, cooked rice with low amylose content is soft and sticky, while rice with high amylose content is relatively hard and fluffy. However, many cultivars with similar high amylose contents exhibit different textural properties. For instance, either hard or soft with fluffy texture of indica cooked rice are generally preferred in Bangladesh, India, Pakistan and Indonesia etc., while moderately elasticity, soft and sticky texture of japonica cooked rice are normally chosen in Japan and Korea etc.

To characterize and compare the composition of rice endosperm components of these cultivars and varieties as well as establish correlation between the components and textural properties of rice due to identify the parameters of rice grain that are responsible for palatability. A total of 17 local cultivars and BRRI varieties were taken for identifying the palatability of cooked rice with different parameters.

Assessment of the quality of cooked rice is reported to be more precisely measured by a combination of physicochemical and sensory properties. Among the eating quality and cooking properties of local rice cultivars, Ranisalute and Rataboro have shown intermediate amylose content (22.3% and 20.6%), higher protein content (9.0% and 10.0%) and <14% moisture content. Cultivars, Gangia and Nizersail have shown higher amylose content (25.9% and 25.8%), intermediate protein (8.4% and 8.3%) and <14% moisture contents. The highest elongation (1.8) was found in Rataboro, whereas the lowest elongation (1.3) was found in Sadaberoin. All the local cultivars have shown intermediate gelatinization temperature except Gangia and Sadaberoin. Volume expansion of all local cultivars varied from 3.6 to 4.3 (Table 7). Among the eating quality and cooking properties of HYVs, eight BRRI varieties have shown higher amylose content but rest of the varieties have shown intermediate amylose content; eight BRRI varieties have shown the intermediate protein content but rest of the varieties have shown lower protein content as well as all BRRI varieties have shown <14% moisture content. Less than 14% moisture

Table 7. Eating quality and cooking properties of local rice cultivars.

Cultivar	ASV	Amylose content (%)	Protein content (%)	Moisture content (%)	Cooking time (min.)	ER	IR
Gangia	6.6	25.9	8.4	13.6	16:30	1.5	4.1
Nizersail	5.7	25.8	8.3	13.1	17:30	1.5	3.6
Rataboro	4.1	20.6	10.0	12.6	16:0	1.8	3.6
Ranisalute	5.9	22.3	9.0	12.5	15:30	1.4	3.7
Sadaberoin	6.5	7.8	9.4	13.6	15:0	1.3	3.7
Tapiboro	4.3	27.0	8.8	13.5	22:0	1.6	4.3

content is recommended for best rice grain quality. The highest elongation (1.5) was found in BRRI dhan26, whereas the lowest elongation (1.3) was found in BRRI dhan62. Alkali spreading value of all the BRRI varieties varied from 3.0 to 7.0. Similarly, volume expansion of BRRI varieties varied from 3.7 to 4.5 (Table 8). The parameters including alkali spreading value, amylase content, protein content and elongation ratio along with palatability parameters such as excellent test, V. good test, good test and tasteless were considered to identify the best quality rice cultivars and variety. Considering the local varieties, Ranisalute showed the highest score (57%) followed by Rataboro (37%) for excellent taste. Similarly, considering the HYV varieties, BRRI dhan49 showed the highest score (37%) for excellent taste followed by BRRI dhan50 and BRRI dhan73 (26% each). On the other hand, Gangia as local variety showed the highest score (53%) for very good taste as well as BRRI dhan30 and BRRI dhan67 (58% each) as HYV fell under very good taste category (Fig. 1). Pearson correlation matrix for relationship had among the eating quality, cooking and milling properties as well as taste and texture parameters of all local cultivars and BRRI varieties (Table 9). In this case, excellent taste of rice was significant and positively correlated with protein content ($r=0.558$, $p<0.05$) as well as stickiness of rice was highly significant and positively correlated with protein content ($r=0.768$, $p<0.01$). On the other hand, v. good taste and fluffiness of rice were significant and positively correlated with amylose content ($r=0.573$ and 0.532, $p<0.05$). Hardness of rice was highly significant and positively correlated with milled rice breadth ($r=0.798$, $p<0.01$) as well as fluffiness of rice was significant and positively correlated with L/B ratio of milled rice ($r=0.558$, $p<0.05$).

Excellent taste depends on higher protein and stickiness whereas very good taste depends on higher amylose and fluffiness among the local cultivars. Though Ranisalute and Rataboro are sticky and soft the result demonstrated it as excellent in taste.

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

Table 8. Eating quality and cooking properties of HYVs.

Cultivar	ASV	Amylose content (%)	Protein content (%)	Moisture content (%)	Cooking time (min.)	ER	IR
BR10	5.3	26.5	8.1	13.0	17:0	1.4	4.3
BRRI dhan26	3.7	22.2	8.5	13.6	17:30	1.5	4.3
BRRI dhan28	5.7	27.4	8.6	13.3	15:0	1.4	4.5
BRRI dhan30	4.0	27.0	8.8	12.9	18:30	1.5	4.5
BRRI dhan47	7.0	26.9	6.7	13.0	16:30	1.4	4.3
BRRI dhan49	5.3	25.2	8.8	12.6	17:0	1.5	4.5
BRRI dhan50	5.2	26.8	8.0	13.5	16:30	1.4	4.0
BRRI dhan62	3.0	19.0	7.8	13.2	19:30	1.3	4.5
BRRI dhan67	5.0	25.3	8.8	12.5	18:30	1.4	4.2
BRRI dhan69	3.0	22.0	7.9	12.9	19:0	1.4	3.9
BRRI dhan73	5.9	27.1	8.6	13.3	17:30	1.4	3.7

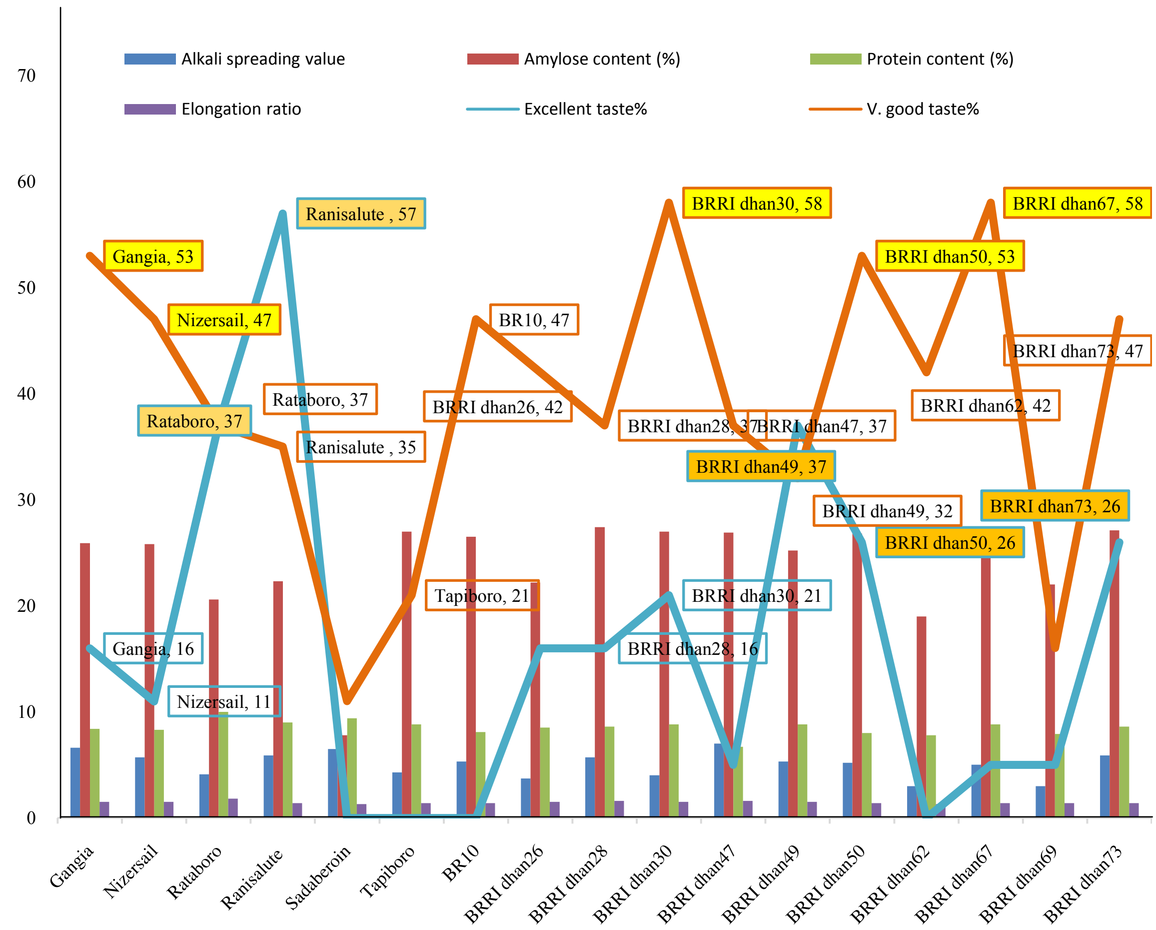


Fig. 1. Taste depends on eating quality and cooking properties.

Table 9. Correlation among eating quality, cooking and milling properties and taste and texture parameters.

	Correlation								
Parameter	ASV	Amylose %	Protein %	ER	IR	CT (min)	Milled rice L (mm)	Milled rice B (mm)	L/B ratio
Excellent taste	-.127	-.046	.558*	.393	-.025	-.268	-.199	-.379	.207
Very good taste	.093	.573*	-.124	.128	.225	-.361	.161	-.254	.288
Good taste	.197	.266	-.309	-.100	.213	.312	-.256	.509*	-.504*
Tasteless	-.202	-.858**	.123	-.467	-.330	.347	.206	-.058	.117
Hard	.051	.046	-.463	.239	-.391	.270	-.645*	.798**	-.797**
Soft	-.212	-.244	.453	-.118	-.238	.359	-.034	.254	-.223
Fluffy	.234	.532*	-.271	-.123	.246	-.176	.131	-.673**	.569*
Sticky	.132	-.649*	.768**	-.009	-.653*	.060	.024	.247	-.192

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

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

Detection and quantification of heavy metals and toxins in rice bran, rice bran oil and deoiled rice bran

Rice bran (RB) is a byproduct of rice milling industry which converts into DORB when its oil content extracted in oil industry. Its composition varies according to the type of milling but it contains 15-25% oil, 11-17% protein, 6-14% fibre, 10-15% moisture and 8-17% ash (Sharif *et al.*, 2014; Haque and Shozib, 2018). It is an abundant source of antioxidant compounds such as tocopherols, Y-oryzanol and other phenolics (Aguilar-Garcia *et al.*, 2007), which helps in health benefits including lowering blood cholesterol, decreasing platelet aggregation and anti-inflammation (Lai *et al.*, 2009). It is a good source of lysine and methionine (Dale, 1997). As such RB is considered a suitable feed ingredient for livestock and fisheries. During oil extraction chemical and heat treatments applied to RB. It seems reasonable to conclude that, those treatments may change the quality of the nutrients presence in the bran that need further investigations. On the other hand, some nutrient profile would proportionately be higher in the DORB than RB due to oil extraction from RB (Houston, 1972; Warren and Farrell, 1990). Other benefits include less susceptibility of DORB to the rancidity. Some researchers found that the nutritional value of DORB is equal to the value of RB in broiler diets when diets are adjusted for metabolizable energy by adding oil (Farrell, 1994). Islam *et al.*, (2018) conducted a study on the performance of broiler feed on iso-caloric and iso-nitrogenous diets containing either RB or DORB and assessed the economics of broiler diet.

Heavy metal pollution of soil affects the nature of the environment leading to serious consequences. Heavy metals group includes Ag, Ba, Cd, Co, Cr, Mn, Hg, Mo, Ni, Pb, Cu, Sn and Zn and some metalloids such as As, Sb, Bi and Se. Arsenic, for example, is often considered as a heavy metal due to the similarity of its chemical properties and behavior with the other heavy metals. Heavy metals accumulation in soil and in the environment in general, may be related to the phenomenon of bioaccumulation ability of living organisms that is heavy metal may be increased in human organism due to industrial activities and the food chain. The main sources ofheavy metal pollution in soil are irrigation, especially with sewage; solid-waste disposal, for example, sludge and compost refuse; the use of pesticides and fertilizers; and atmospheric deposition (Fabjola *et al.*, 2015).

Rice is the second largest in quantity staple food and internationally traded cereal. Aflatoxin is produced in areas where climatic conditions are favourable to fungal growth. The production of aflatoxin affects plant growth and rice yield.

Elangovan *et al.*, (1999) surveyed on the prevalence of aflatoxin B1 (AFB) in rice bran and collected 142 samples from 55 rice mills in coastal and interior districts of Tamil Nadu, Andhra Pradesh and Karnataka. It was reported that 62% of the samples contained AFB and the levels far exceeded the permissible limit of 50 ppb. Among them 60% of the positive samples having 50-500 ppb and 30% up to 2000 ppb. The mycoflora of bran included over 20 osmophilic species, of which Aspergillus flavus link showed the highest frequency (75%) as well as abundance (37.6%). The high frequency and high levels of AFB showed no correlation with moisture content of the samples, climatic variations, or with the unparboiled or parboiled status of the rough rice but with the maintenance of sanitation in the rice mills, which was, therefore, suspected to be a major source of contamination of bran with aflatoxigenic fungi.

Heavy metal pollution of soil affects the nature of the environment leading to serious consequences. Heavy metals group includes Ag, Ba, Cd, Co, Cr, Mn, Hg, Mo, Ni, Pb, Cu, Sn and Zn and some metalloids such as As, Sb, Bi and Se. Arsenic, for example, is often considered as a heavy metal due to the similarity of its chemical properties and behaviour with the other heavy metals. Heavy metals accumulation in soil and in the environment in general, may be related to the phenomenon of bioaccumulation ability of living organisms that is heavy metal may be increased in

human organism due to industrial activities and the food chain. The main sources ofheavy metal pollution in soil are irrigation, especially with sewage; solid-waste disposal, for example, sludge and compost refuse; the use of pesticides and fertilizers; and atmospheric deposition (Fabjola *et al.*, 2015).

Study on heavy metals and toxins in rice bran related industrial products. A total of 33 commercial mills including nine auto rice mills, 12 RBO and 12 feed industries were visited to get rice bran related information from industries. In this regard, RBO mills including KBC Agro Products Private Limited (Savar, Dhaka), Ali Natural Oil Mills and Agro Industries Limited (Sonotia Bazar, Jamalpur), AM Bran Oil Company Ltd (Ghatail, Tangail), Rashid Oil Mills Limited (Ishwardi, Pabna), Majumder groups of industries (Chanka, Sherpur, Bogura), Jamuna Agro products Ltd (Godagari, Rajshahi) and Tamim Agro Industries Ltd (Bogura) etc; feed mills including Krishibid Feed Limited (Bhaluka, Mymensigh), Saudi Bangla Fish Feed Ltd (Bhaluka, Mymensigh), Provita Feed Ltd (Bhaluka, Mymensigh), Nourish Poultry and Hatchery Ltd. (Bhaluka, Mymensigh), Chhuya Agro Products Ltd. (Kapasia, Gazipur) and Aristocrat Agro Ltd (Bogura) etc as well as auto rice mills including Haji Auto Rice Mill (Shombugong, Mymensingh), Yamin Auto Rice Mill (Shombugong, Mymensingh), Ma Auto Rice Mill (Kashigong, Mymensingh), Akashi Auto Rice Mill (Shombugong, Mymensingh), Krishani Auto Rice Mill (Dhamrai, Dhaka) and Mordern Auto Rice Mill (Sherpur) etc were visited. We have analyzed RB, RBO and DORB samples for heavy metal detection such as As, Cd, Pb, Cr and Ni and found negative results for these repeated samples (three replications). According to BCSIR, the detection limit of As, Cd, Pb, Cr and Ni are 5.0 ppb, 0.05 ppm, 0.5 ppm, 0.2 ppm and 0.5 ppm respectively. In both crude and refined RBO samples were free from bacterial and fungal growth specially aflatoxin B1 (Table 10). We also analyzed RB and DORB samples from freshly harvested (0) to 28 days of storage samples at ambient temperature with a period of seven days interval. We took only freshly extracted and purified samples regarding crude and refined RBO samples. The detection limit of heavy metals such as As, Cd, Pb, Cr and Ni in crude and refined RBO was similar with RB and DORB (Table 10). Irrespective of storage duration bacterial colonies were found ranging from 1×10^4 to 2.75×10^4cfu/g and 1.16×10^4 to 5.9×10^4cfu/g in RB and DORB respectively. In case of RB, the highest number of colony (2.75×10^4cfu/g) was found at seven days of storage followed by 14 days (1.85×10^4cfu/g) and 21 days (1.68×10^4cfu/g). The lowest number of colony ($1x10^4$cfu/g) was recorded at 0 day of storage. In case of DORB, the highest number of colony ($5.9x10^4$cfu/g) was recorded at 14 days of storage which was followed by 21 days (1.72×10^4cfu/g), 0 day (1.16×10^4 cfu/g) and 28 days (0.93×10^4cfu/g) (Table 11). The lowest number was at 28 days (0.93×10^4cfu/g). In both types of rice bran like RB and DORB, yeast and molds (cfu/g) were positive for all samples and those ranges from 50 to 12500 cfu/g and 36 to 14700 cfu/g for RB and DORB respectively (Table 11). These RB and DORB samples were also tested for toxicity test on experimental rat model and found negative in toxicity but toxins such as aflatoxin B1 was found positive for all RB and DORB samples ranges from 9.79 to 40.21 ppb and 9.43 to 57.74 ppb respectively except 28 days of storage samples (Below detectable limit). RB samples of 14 and 21 days ofstorage had showed higher load of aflatoxin B1 of 40.21 and 33.24 ppb respectively, which are over MRL (maximum residual limit of >20.0 ppb). On the other hand, DORB samples of 7, 14 and 21 days of storage had showed higher load of aflatoxin B1 of 40.98, 57.74 and 38.11 ppb respectively (Table 11). Gourama and Bullerman (1995) verified a positive correlation between fungal growth and aflatoxin Bl production in rice stored under controlled conditions. Our data revealed similar result.

PI: MAH, CI: NF, SA (Path), HBS and MAS

Table 10. Detection of heavy metals and toxins in RB, DORB and RBO samples.

Parameter	As (ppb)	Cd (ppm)	Pb (ppm)	Cr (ppm)	Ni (ppm)	TVC (cfu/g)	Yeasts and Molds (cfu/g)	Microbiological effect	Toxicity	Aflatoxins (ppb)
RB-Fresh	<5.0	<0.05	<0.5	0.03	<0.5	10000	50	AQ	No	9.79
DORB-Fresh	<5.0	0.071	<0.5	<0.2	<0.5	11600	300	NAQ	No	9.43
RBO crude	<5.0	<0.05	<0.5	0.03	<0.5	Nil	Nil	AQ	No	Nil
RBO refined	<5.0	<0.05	<0.5	<0.2	<0.5	Nil	Nil	AQ	No	Nil

Note: RB= Rice bran, DORB= De-oiled rice bran, cfu = colony forming unit.

Table 11. Detection of heavy metals and toxins in RB and DORB samples at different durations (0-28 days).

Parameter	TVC (cfu/g)	Yeasts and molds (cfu/g)	Microbiological effect	Toxicity	Aflatoxins MRL 20 ppb
RB-Fresh	10000	50	AQ	No	9.79
RB-7 days	27500	12500	NAQ	No	12.15
RB-14 days	18500	1600	AQ	No	40.21
RB-21days	16800	923	AQ	No	33.24
RB-28 days	920	85	AQ	No	ND
DORB-Fresh	11600	300	NAQ	No	9.43
DORB-7 days	59000	14700	NAQ	No	40.98
DORB-14 days	17200	2000	AQ	No	57.74
DORB-21 days	9350	892	AQ	No	38.11
DORB-28 days	11.40	36	AQ	No	ND

Note: MRL: Maximum Residual Limit, AQ: Accepted Quality, NAQ: Not Accepted Quality

Effect of spent bleaching earth on sustainable rice production

Activated bleaching earth is white filter clay, which is known as activated clay. It has strong decoloring ability. So, bleaching earth is used in refining process for degumming and bleaching in industry of rice bran oil extracted from rice bran as well as all edible vegetable oils extracted from plant sources. Spent bleaching earth (SBE) is an ash colour waste product of activated bleaching earth which is generated after using edible oil in industry. As a result, generated huge amount of SBE is deposited as garbage and some of this SBE is being used in brick field as fuel in Bangladesh. Cheong *et al.*, 2013 reported a novel approach of using SBE in agricultureas an alternative method for improved biogas production efficiency. SBE is being sold out at Tk 1 to 2 per kg at RBO mill gate at present in Bangladesh. We have noticed regarding RBO industrial waste such as SBE which might have potential to use as alternate fueling as well as fertilizer in Bangladesh. We demonstrated field experiment data on theeffect of SBE as an organic fertilizer on BRRI dhan81 in Boro season for feasibility study.

Field experiment was conducted with six treatments of BRRI dhan81 in Boro season 2018-19 at BRRI HQ farm, Gazipur. Every plot size was (5 × 2) $10m^2$. Here, T_1 was control (no fertilizer), T_2 was 100% BRRI recommended dose (Fertilizers @ 160: 20: 30: 10: 2 kg N: P: K: S: Zn), T_3 was 100% SBE with no BRRI recommended dose, T_4 was

75% SBE with 25% BRRI recommended dose, T_5 was 50% SBE with 50% BRRI recommended dose and T_6 was 25% SBE with 75% BRRI recommended dose. Yield contributing characters were analyzed by BRRI recommended technique. Milling, physical, chemical and cooking properties were analyzed using Grain Quality and Nutrition laboratory technique. Statistical analysis was done by Statistix10 and IBM SPSS Statistics 23.

In this study, six treatments (T_1, T_2, T_3, T_4, T_5 and T_6) of BRRI dhan81 were conducted in Boro season. Here, T_1 was used as control; T_2 was BRRI recommended dose as well as T_3, T_4, T_5 and T_6 were different percent of SBE with BRRI recommended dose. Table 12 shows the composition of SBE. It contains 50.36% ash, 6.58% carbon along with 36% volatile matter. Therefore, SBE is a good source of organic matter.

Table 13 shows the findings of the percentage of SBE of those treatments among yield and yield contributing characters which were very close to BRRI recommended dose (BRD). Result shows that plant height of T_2 was similar to plant height of T_6, whereas plant height of T_2 was dissimilar to T_3, T_4 and T_5. Tiller number of T_2 was similar to tiller number of T_6 and almost similar to T_5, whereas tiller number of T_2 was dissimilar to T_3 and T_4. Panicle number of T_2 was similar to panicle number of T_6 and almost similar to T_5, whereas tiller number of T_2 was dissimilar to T_3 and T_4. Grain yield of T_2 was dissimilar to grain yield of T_1, T_3, T_4 and T_5 whereas T_2 was similar to T_6. Straw yield of T_2 was dissimilar to T_1, T_3, T_4 and T_5 whereas T_2 was similar to T_6. The 1000 grain weight (TGW) of T_2 was similar to T_4 as well as almost similar to T1, T_3, T_5 and T_6. In this Table, T_3 was similar to T_1 of all parameters except grain yield.

Table 14 shows the findings of the percentage of SBE of those treatments among milling and physical properties, which were very close to BRD. Result shows that milling outturn of T_2 was similar to milling outturn of T_4 and T_5, whereas milling outturn of T_2 was almost similar to T_6. Head rice recovery of T_2 was almost similar to head rice recovery of T_4, T_5 and T_6. T_3 of milling outturn was almost similar to T_1 as well as T_3 of head rice recovery was similar to T_1. In this Table, paddy length, paddy breadth, milled rice length, milled rice breadth, L/B ratio, size and shape, appearance and chalkiness have shown similar result.

Table 15 shows the findings of the percentage of spent bleaching earth of those treatments among chemical and cooking properties, which were very close BRD. Result shows that all treatments (T_1, T_2, T_3, T_4, T_5 and T_6) of alkali spreading value (ASV), amylose content, elongation ratio (ER) and imbibition ratio (IR) were similar. Protein content of T_2 was similar to protein content of T_3, T_5 and T_6, whereas protein content of T_2 was dissimilar to T_4. Moisture content of T_2 was almost similar to moisture content of T_4, T_5 and T_6, whereas moisture content of T_2 was dissimilar to T_3. Cooking time of T_2 was similar to cooking time of T_1, T_5 and T_6 as well as almost similar to T_3 and T_4. In this Table, T_3 was similar to T_1 of ASV, amylose content, ER and IR as well as T_3 was almost similar to T_1 of protein content, moisture content and cooking time.

Pearson correlations coefficients for relationships had among the different parameters of BRRI dhan81 based on the composition of SBE and BRRI recommended dose (Table 16). Yield of SBE and yield of BRD were significant and positively correlated with panicle number of SBE and panicle number of BRD ($r=0.668$ and $r=0.997$, $p<0.05$). The TGW of SBE was highly significant and positively correlated with panicle number of SBE ($r=0.716$, $p<0.01$) as well as it was positively correlated with yield of SBE whereas TGW of BRD was negatively correlated with panicle number of BRD and yield of BRD. Milling outturn of SBE was positively correlated with panicle number and yield of SBE as well as it was significant and positively correlated with TGW of SBE ($r=0.704$, $p<0.05$) whereas milling outturn of BRD was positively correlated with panicle number, yield and TGW of BRD. Head rice recovery of SBE was significant and panicle number of BRD ($r=0.668$ and $1r=0.997$, $p<0.05$). TGW of SBE was highly significant and positively correlated with panicle number of SBE ($r=0.716$, $p<0.01$) as well as it was

Table 12. Properties of spent bleaching earth (SBE).

Item	Unit	SBE
As	ppb	0.89
Al	ppm	11650
Cd	ppm	BDL
Pb	ppm	BDL
Cr	ppm	10.28
Si	ppm	BDL
Ni	ppm	BDL
Ash	%	50.36
Moisture	%	4.7
Volatile matter	%	36
Carbon	%	6.58
Functional group	-	C-H, C=O, -C-H, C-O,C-Cl
Calorie	kcal/kg	3411

Note: ppm= Parts per million, ppb= Parts per billion, BDL= Below detectable limit.

positively correlated with yield of SBE whereas TGW of BRD was negatively correlated with panicle number of BRD and yield of BRD. Milling outturn of SBE was positively correlated with panicle number and yield of SBE as well as it was significant and positively correlated with TGW of SBE (t=0.704, p<0.05) whereas milling outturn of BRD was positively correlated with panicle number, yield and TGW of BRD. Head rice recovery of SBE was significant and positively correlated with panicle number, yield and TGW of SBE (r=0.608, r=0.664 and r=0.643, p<0.05) as well as it was highly significant and positively correlated with milling outturn of SBE (r=0.834, p<0.01). Head rice recovery of BRD was positively correlated with panicle number, yield and milling outturn of BRD but it was negatively correlated with TGW of BRD. Amylose content of SBE was positively correlated with panicle number, TGW and head rice recovery of SBE but negatively correlated with yield and milling outturn of SBE. Amylose content of BRD was significant and positively correlated with TGW (r=1.000, p<0.05) as well as it was only positively correlated with milling outturn of BRD but negatively correlated with panicle number, yield and head rice recovery of BRD. Protein content of SBE was highly significant and positively correlated with milling outturn of SBE (r=0.775, p<0.01), significant and positively correlated with head rice recovery of SBE (r=0.632, p<0.05) as well as it was positively correlated with panicle number, yield, TGW and amylose content of SBE. Protein content of BRD was highly significant and positively correlated with milling outturn of BRD (r=0.1.000, p<0.01) as well as it was positively correlated with panicle number, yield, TGW and amylose content of BRD. But protein content of BRD had no relation with head rice recovery of BRD. ER of SBE was positively correlated with head rice recovery, amylose content and protein content of SBE but negatively correlated with panicle number, yield, TGW and milling outturn of SBE. ER of BRD (r=1.000 and r=1.000, p<0.1) was positively correlated with milling outturn andprotein content of BRD but negatively correlated with panicle number, yield, head rice recovery.

PI: MAH, **CI:** NF, SH (Soil Sc), HBS and MAS

Table 13. Effect of SBE on yield and yield contributing characters of BRRI dhan81, Boro 2018-19, BRRI, Gazipur.

Treatment	Plant height (cm)	Tiller No.	Panicle No.	Grain yield, dry (t ha^{-1})	Straw yield, dry (t ha^{-1})	1000 grain wt (g) (TGW)
T_1	29.33^{D}	144^{C}	135^{C}	2.41^{E}	2.26^{D}	22.6^{B}
T_2	37.68^{A}	256^{A}	246^{A}	6.66^{A}	5.39^{A}	23.0^{AB}
T_3	28.57^{D}	165^{C}	153^{C}	3.88^{D}	2.47^{D}	22.6^{B}
T_4	31.97^{C}	198^{BC}	186^{B}	4.65^{C}	3.95^{C}	23.1^{AB}
T_5	34.75^{B}	240^{AB}	225^{AB}	5.49^{B}	4.72^{B}	23.3^{A}
T_6	36.52^{A}	250^{A}	241^{A}	6.27^{A}	5.27^{A}	23.2^{A}
Mean±SE	33.14±0.76	208.94±16.40	197.61±14.89	4.89±0.21	4.01±0.15	22.95±0.21
CV (%)	3	10	9	5	5	1

Table 14. Effect of SBE on milling and physical properties of BRRI dhan81, Boro 2018-19, BRRI, Gazipur.

Treatment	Milling outturn (%)	Head rice recovery (%)	Paddy length (mm)	Paddy breadth (mm)	Milled rice length (mm)	Milled rice breadth (mm)	L/B ratio	Size and shape	Appear ance	Chalkin ess
T_1	70.7^{C}	50.3^{C}	10.0^{A}	2.1^{A}	6.8^{A}	1.8^{A}	3.8^{A}	LS	V.good	Tr/Wc_9
T_2	72.7^{AB}	55.3^{A}	10.2^{A}	2.1^{A}	6.8^{A}	1.8^{A}	3.8^{A}	LS	V.good	Tr/Wc_9
T_3	71.7^{BC}	52.0^{C}	10.0^{A}	2.2^{A}	6.8^{A}	1.8^{A}	3.8^{A}	LS	V.good	Tr / Wc_9
T_4	72.0^{AB}	53.7^{BC}	10.1^{A}	2.1^{A}	6.7^{A}	1.8^{A}	3.7^{A}	LS	V.good	Tr / Wc_9
T_5	72.3^{AB}	57.3^{AB}	10.3^{A}	2.1^{A}	6.8^{A}	1.8^{A}	3.8^{A}	LS	V.good	Tr / Wc_9
T_6	73.0^{A}	57.3^{AB}	10.3^{A}	2.1^{A}	6.7^{A}	1.8^{A}	3.7^{A}	LS	V.good	Tr / Wc_9
Mean ± SE	72.06±0.51	54.94±1.95	10.1±0.1	2.12±0.1	6.77±0.1	1.81±0.03	3.74±0.1	-	-	-
CV (%)	1	4	1	3	2	2	2	-	-	-

Note: LS= Long slender, Tr= Translucent, Wc= White centre.

Table 15. Effect of SBE on chemical and cooking properties of BRRI dhan81, Boro 2018-19, BRRI, Gazipur.

Treatment	ASV	Amylose (%)	Protein (%)	Moisture (%)	Cooking time (min)	ER	IR
T_1	5.0^{A}	25.4^{A}	8.8^{B}	12.8^{C}	16.2^{AB}	1.5^{A}	4.4^{A}
T_2	5.3^{A}	25.8^{A}	9.7^{A}	13.3^{A}	16.4^{AB}	1.4^{A}	4.3^{A}
T_3	5.0^{A}	25.9^{A}	9.0^{AB}	13.0^{BC}	17.1^{A}	1.4^{A}	4.3^{A}
T_4	5.2^{A}	26.3^{A}	8.7^{B}	13.2^{AB}	15.5^{B}	1.5^{A}	4.4^{A}
T_5	5.3^{A}	26.2^{A}	9.1^{AB}	13.1^{AB}	16.8^{AB}	1.5^{A}	4.4^{A}
T_6	5.1^{A}	26.1^{A}	9.3^{AB}	13.2^{AB}	16.2^{AB}	1.4^{A}	4.3^{A}
Mean ± SE	5.15±0.27	25.94±0.69	9.10±0.37	13.11±0.12	16.37±0.61	1.44±0.064	4.35±0.09
CV (%)	7	3	5	1	5	5	3

Note: ASV= Alkali spreading value, ER= Elongation ratio, IR= Imbibition ratio, TGW=1000 grain weight (g), BRD= BRRI recommended dose, SBE= Spent bleaching earth.

Table 16. Pearson correlations coefficients among the parameters of BRRI dhan81.

		Correlations							
Treatment	Parameter	Panicle no.	Yield t/ha	TGW (g)	Milling outturn %	Head rice recovery %	Amylose (%)	Protein (%)	ER
SBE	Yield (t/ha)	.668*							
BRD		.997*							
SBE	TGW (g)	.716**	.390						
BRD		-.564	-.500						
SBE	Milling outturn (%)	.571	.499	.704*					
BRD		.705	.756	.189					
SBE	Head rice recovery (%)	.608*	.664*	.643*	.834**				
BRD		.710	.655	-.982	.000				
SBE	Amylose (%)	.068	-.328	.323	-.066	.040			
BRD		-.540	-.475	1.000*	.217	-.976			
SBE	Protein (%)	.218	.027	.530	.775**	.632*	.222		
BRD		.705	.756	.189	1.000**	.000	.217		
SBE	Elongation ratio (ER)	-.342	-.188	-.164	-.190	.055	.199	.004	
BRD		-.705	-.756	-.189	-1.000**	.000	-.217	-1.000**	
SBE	Imbibition ratio (IR)	-.028	.232	.049	.091	.099	-.568	-.096	.451
BRD		-.564	-.500	1.000**	.189	-.982	1.000*	.189	-.189

**. Correlation is significant at the 0.01% level (2-tailed).*. Correlation is significant at the 0.05 % level (2-tailed). TGW=1000 grainwt (g), SBE=Spent bleaching earth, BRD=BRRI recommended dose

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

Physical properties viz length, breadth, thickness, increased length and breadth, volume of rice product such as puffed, popped and flattened rice were determined. This study aims to screen out the BRRI released varieties that are suitable for popular snack food products: puffed, popped and flattened rice for instances. It is ascertained from the results that BRRI dhan72 is better in producing whole puffed rice (167.3 g) followed by BRRI dhan70 (130.9 g). However, BRRI dhan70 yielded better results: puffed rice length=13.7 mm, increased percentage of puffed rice length=105.33%, and volume=625 ml followed BRRI dhan72, (puffed rice length=13.5 mm, increased percentage of length=106.33%, volume=490 ml) and BRRI dhan75 (length =12.7 mm, increased percentage of length=93.67 mm, volume=560 ml) (Table 17). Results of correlation matrix for relationships indicated that puffed rice length is highly significant and positively correlated with volume (r=0.811, $p<0.01$), while there is negative correlation between puffed rice breadth and volume (r=-0.153). On the other hand, the increased percentage of both puffed rice length and breadth are highly significant and positively correlated with volume of 50g puffed rice (r=0.827 and 0.882, $p<0.01$) (Table 20).

In case of popped rice, BRRI dhan70 and BRRI dhan71 show excellent performance considering whole, partial broken, broken and unpopped rice. On the other hand, in terms of increased popped rice length, breadth and volume of 50g, BRRI dhan70 (1016.7 ml) performed better than BRRI dhan71 (833.3 ml). However, BRRI dhan78 showed the highest potential in increasing length after being popped (Table 18). Results of correlation matrix for relationships ascertained that popped rice length is highly significant and positively correlated with volume (r=0.929, $p<0.01$) as well as there is only positive correlation between popped rice breadth and volume (r=0.387). In contrary, the increased percentage of popped rice breadth is highly significant and positively correlated with volume of 50g popped rice (r=0.950, $p<0.01$) as well as there is only positive correlation between popped rice length and volume (r=0.537) (Table 21).

Similarly, physical properties such as whole, partial and broken flattened rice were considered. It revealed from the results that in terms of weight of whole, partial broken and broken flattened rice as well as percentage of length increased, BRRI dhan74 showed the best performance. On the other hand, the results demonstrated that BRRI dhan75 showed higher potential in producing flattened rice considering thickness of flattened rice and volume of 50 g sample, which is better than the standard as of BR16 considered for this study (Table 19). Results of correlation matrix for relationships displayed that flattened rice length is highly significant and positively correlated with volume (r=0.803, $p<0.01$) as well as there is only positive correlation between flattened rice breadth and volume (r=0.398). Similarly, the increased percentage of flattened rice length is highly significant and positively correlated with volume of 50g flattened rice (r=0.859, $p<0.01$) as well as there is significant and positive correlation between flattened rice breadth and volume (r=0.736, $p<0.05$) (Table 22).

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

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

Variety	Fully puffed wt. (g)	Partially puffed wt (g)	Puffed rice L (mm)	Puffed rice B (mm)	Increased puffed rice L (%)	Increased puffed rice B (%)	1000 puffed rice wt (g)	Volume of 50 g puffed rice (ml)
BR16	103.7^{C}	93.5^{E}	12.3^{B}	3.87^{D}	86.0^{F}	66.33^{F}	19.83^{A}	485.0^{D}
BRRI dhan70	130.9^{B}	58.53^{F}	13.7^{A}	3.7^{E}	105.33^{AB}	97.33^{A}	13.67^{E}	625.0^{A}
BRRI dhan71	92.1^{D}	107.77^{D}	12.3^{B}	4.53^{B}	98.33^{C}	93.0^{AB}	17.27^{B}	530.0^{C}
BRRI dhan72	167.3^{A}	31.8^{G}	13.5^{A}	4.73^{A}	106.33^{A}	90.33^{BC}	19.53^{A}	490.0^{D}
BRRI dhan74	2.9^{H}	197.07^{A}	10.67^{C}	3.87^{D}	66.0^{G}	47.33^{H}	20.27^{A}	348.0^{F}
BRRI dhan75	92.1^{D}	107.67^{D}	12.17^{B}	3.83^{D}	93.67^{D}	85.0^{D}	14.6^{D}	560.0^{B}
BRRI dhan76	21.6F^{G}	178.27^{B}	9.63^{F}	4.23^{C}	68.67^{G}	50.67^{H}	17.47^{B}	350.3^{F}
BRRI dhan77	21.1^{G}	178.6^{B}	10.23^{D}	4.57^{B}	85.33^{F}	59.0^{G}	17.57^{B}	396.0^{E}
BRRI dhan78	70.2^{E}	127.43^{C}	10.77^{C}	4.8^{A}	103.0^{B}	87.0^{CD}	17.13^{B}	521.7^{C}
BRRI dhan79	28.5^{F}	171.43^{B}	9.93^{E}	4.2^{C}	90.0^{E}	76.0^{E}	15.93^{C}	391.7^{E}
Mean±SD	73.03±53.925	125.21±55.537	11.52±1.466	4.233±0.406	90.267±14.227	75.20±18.23	17.327±2.178	469.77±94.184
SE	3.491	4.161	0.10	0.1	1.5	2.3	0.412	9.5
CV%	6	4	1	2	2	4	3	2

Table 18. Physical properties of popped rice of BRRI modern varieties.

Variety	Fully popped rice wt (g)	Partially popped rice wt (g)	Broken popped rice wt (g)	Unpopped paddy wt (g)	Hull wt (g)	Popped rice L (mm)	Popped rice B (mm)	Increased popped rice L (%)	Increased popped rice B (%)	1000 popped rice wt (g)	Volume of 50 g popped rice (ml)
BR16	46.47^{CD}	18.4^{BCD}	2.17^{A}	16.17^{CD}	16.73^{A}	12.0^{C}	5.07^{D}	69.67^{F}	107.0^{CD}	21.5^{B}	678.0^{DEF}
BRRI dhan70	60.47^{A}	7.33^{G}	1.47^{BC}	15.67^{CD}	14.87^{AB}	14.17^{A}	5.1^{D}	90.0^{CD}	158.33^{A}	14.57^{F}	1016.7^{A}
BRRI dhan71	55.43^{AB}	13.37^{EF}	1.17^{BCDE}	13.27^{D}	16.67^{A}	13.6^{B}	5.43^{AB}	107.33^{AB}	114.0^{C}	17.83^{D}	833.3^{BC}
BRRI dhan72	17.23^{F}	14.83^{DEF}	0.93^{CDE}	60.47^{A}	6.47^{D}	11.5^{D}	4.47^{F}	57.67^{G}	76.67^{EF}	21.67^{B}	566.7^{GH}
BRRI dhan73	51.9^{BC}	12.7^{F}	1.33^{BCD}	21.03^{BCD}	12.87^{BC}	13.27^{B}	5.2^{CD}	107.33^{AB}	129.33^{B}	16.53^{E}	771.7^{CD}
BRRI dhan74	40.4^{DE}	18.97^{BC}	1.76^{AB}	26.87^{B}	11.93^{C}	11.93^{C}	4.77^{E}	78.0^{EF}	72.667^{F}	23.53^{A}	518.7^{GH}
BRRI dhan75	40.3^{DE}	20.67^{ABC}	1.76^{AB}	25.3^{BC}	11.93^{C}	13.37^{B}	5.33^{ABC}	105.67^{B}	135.67^{B}	17.93^{D}	933.3^{AB}
BRRI dhan76	18.8^{F}	16.9^{CDE}	0.6^{EF}	56.8^{A}	6.8^{D}	10.77^{E}	5.3^{BC}	78.0^{EF}	79.33^{EF}	21.53^{B}	497.3^{H}
BRRI dhan77	23.7^{F}	14.57^{DEF}	0.83^{CDE}	52.03^{A}	8.67^{D}	10.97^{E}	5.33^{ABC}	83.33^{DE}	82.67^{E}	20.2^{C}	589.0^{FGH}
BRRI dhan78	44.9^{CDE}	21.27^{AB}	0.73^{DE}	19.1^{BCD}	13.73^{BC}	12.2^{C}	5.5^{A}	117.33^{A}	105.33^{D}	18.47^{D}	715.7^{DE}
BRRI dhan79	38.33^{E}	23.97^{A}	0.0^{F}	23.33^{BCD}	14.07^{BC}	11.43^{D}	4.57^{F}	98.33^{BC}	71.33^{F}	18.0^{D}	610.3^{EFG}
Mean±SD	39.81±14.49	16.63±4.69	1.133±0.60	29.96±17.57	12.25±3.59	12.29±1.14	5.10±0.35	90.24±18.58	102.94±29.25	19.25±2.66	702.79±170.41
SE	3.7	1.9	0.3	4.9	1.2	0.2	0.1	5.4	4.0	0.4	52.6
CV%	11	14	35	20	12	2	2	7	5	2	9

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

Variety	Fully flattened rice wt (g)	Partial flattened rice wt (g)	Broken flattened rice wt (g)	Brown rice L (mm)	Brown rice B (mm)	Thickness of flattened rice (mm)	Flattened rice L (mm)	Flattened rice B (mm)	Increased flattened rice L (%)	Increased flattened rice B (%)	1000 flattened rice wt (g)	Volume of 50g flattened rice (ml)
BR16	113.7^{G}	3.6^{E}	129.7^{A}	7.07^{B}	2.43^{C}	0.56^{D}	14.4^{A}	4.57^{C}	103.7^{A}	88.0^{A}	19.2^{C}	183.3^{A}
BRRI dhan70	147.67^{F}	41.4^{A}	56.1^{DE}	7.47^{A}	1.97^{E}	0.88^{A}	9.23^{F}	2.63^{H}	23.7^{F}	34.7^{D}	15.27^{F}	78.3^{G}
BRRI dhan71	185.3^{CD}	12^{D}	50.8^{E}	6.57^{C}	2.53^{C}	0.62^{CD}	11.57^{C}	4.2^{D}	76.0^{C}	64.3^{C}	$18.6C^{D}$	118.3^{D}
BRRI dhan72	206.7^{B}	2.3^{E}	38.6^{F}	7.27^{AB}	2.53^{C}	0.92^{A}	10.13^{D}	3.37^{G}	38.7^{E}	33.0^{D}	20.3^{B}	90.0^{F}
BRRI dhan74	217.6^{A}	2.2^{E}	28.6^{G}	6.7^{C}	2.77^{B}	0.65^{C}	13.33^{B}	4.53^{C}	99.3^{A}	64.0^{C}	23.3^{A}	131.7^{C}
BRRI dhan75	170.7^{E}	2.3^{E}	74.4^{B}	6.47^{C}	2.3^{D}	0.44^{E}	13.27^{B}	3.93^{E}	104.3^{A}	73.3^{BC}	14.5^{G}	188.3^{A}
BRRI dhan76	179.3^{D}	5.1^{E}	62.4^{CD}	6.07^{D}	2.93^{A}	0.58^{D}	11.33^{C}	5.37^{A}	87.0^{B}	82.7^{AB}	20.2^{B}	126.7^{C}
BRRI dhan77	155.2^{F}	26^{B}	66^{C}	6.0^{D}	2.93^{A}	0.81^{B}	10.33^{D}	5.33^{A}	73.3^{C}	81.3^{AB}	19.9^{B}	103.3^{E}
BRRI dhan78	188.2^{C}	3.4^{E}	56.3^{DE}	5.6^{E}	2.7^{B}	0.88^{A}	9.733^{E}	4.83^{B}	73.7^{C}	81.3^{AB}	17.7^{E}	148.3^{B}
BRRI dhan79	213.9^{AB}	16.6^{C}	18.6^{H}	5.77^{DE}	2.67^{B}	0.9^{A}	8.967^{F}	3.7^{F}	55.0^{D}	39.0^{D}	$18D^{E}$	90.0^{F}
Mean±SD	177.81±32.43	11.5±13.15	58.15±30.45	6.50±0.64	2.58±0.30	0.73±0.27	11.23±1.89	4.25±0.87	73.47±27.39	64.17±21.24	18.70±6.04	125.83±38.21
SE	4.02	2.14	3.45	0.16	0.06	0.03	0.17	1.00	4.68	4.68	0.34	3.07
CV%	3	23	7	3	3	5	2	3	8	9	2	3

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

	Correlation					
Parameter	MRL (mm)	MRB (mm)	PuRL (mm)	PuRB (mm)	InPuRL (%)	InPuRB (%)
MRB (mm)	-.641					
PuRL (mm)	.789**	-.769*				
PuRB(mm)	-.548	.620	-.204			
InPuRL (%)	.092	-.520	.683*	.308		
InPuRB (%)	.179	-.668*	.716*	.146	.954**	
Volume (ml)	.424	-.854**	.811**	-.153	.827**	.882**

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

Table 21. Correlation among the physical properties of popped rice of BRRI modern varieties.

	Correlation					
Parameter	BRL (mm)	BRB (mm)	PoRL (mm)	PoRB (mm)	InPoRL (%)	InPoRB (%)
BRB (mm)	-.668*					
PoRL (mm)	.426	-.853**				
PoRB (mm)	-.352	-.011	.308			
InPoRL (%)	-.550	-.164	.518	.591		
InPoRB (%)	.383	-.871**	.906**	.472	.463	
Volume (ml)	.336	-.853**	.929**	.387	.537	.950**

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

Table 22. Correlation among the physical properties of flattened rice of BRRI modern varieties.

	Correlation					
Parametr	BRL (mm)	BRB (mm)	FRL (mm)	FRB (mm)	InFRL (%)	InFRB (%)
BRB (mm)	-.716*					
FRL (mm)	.257	-.034				
FRB (mm)	-.637*	.812**	.316			
InFRL (%)	-.293	.356	.847**	.672*		
InFRB (%)	-.437	.422	.567	.864**	.815**	
Volume (ml)	-.115	-.041	.803**	.398	.859**	.736*

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

Note: MRL, Milled rice length; MRB, Milled rice breadth; PuRL, Puffed rice length; PuRB, Puffed rice breadth; InPuRL, Increased puffed rice length based on milled rice; InPuRB, Increased puffed rice breadth based on milled rice; BRL, Brown rice length; BRB, Brown rice breadth; PoRL Popped rice length; PoRB, Popped rice breadth; InPoRL, Increased popped rice length based on brown rice; InPoRB, Increased popped rice breadth based on brown rice; FRL, Flattened rice length; FRB, Flattened rice breadth; InFRL, Increased flattened rice length based on brown rice; InFRB, Increased flattened rice breadth based on brown rice.

Hybrid Rice Division

SUMMARY

In T. Aman season 2018, a total of 153 test crosses and 248 (A × R) crosses were made from source nursery. Forty-eighty test crosses (F_1s) were evaluated for their pollen fertility status of which two 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 cytoplasmic male sterile (CMS) lines in the next season. Five entries were found completely sterile and their corresponding male parents were regarded as suspected maintainer lines. Two backcross generations were advanced as new CMS lines. Other backcross generations except one BC_2 and 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.

Sixty test crosses and 370 (A × R) crosses were made using nine CMS lines in Boro season 2018-19. One hundred ninety-two test crosses (F_1s) were evaluated for their pollen fertility status. Among them two entries showed complete sterility and immediately backcrossed with their corresponding male parents for conversion. On the other hand, four entries have been selected for their high yielding ability compared to the 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. Ninety-one CMS lines along with their respective maintainer lines were maintained by hand crossing in CMS maintenance and evaluation nursery for their genetic purity.

In T. Aman, out of 215 test hybrids under observational trials, eight hybrid combinations were selected based on yield, duration and grain type and produced more than 13-42% yield advantage over the check variety BRRI hybrid dhan4, 3-29% over BRRI hybrid dhan6 and 6-44% over BRRI dhan49 but growth duration was 2 to 4 weeks earlier than six varieties and almost similar to the check variety BRRI dhan49. In Boro, out of 417 test hybrids 16 hybrid combinations were selected based on yield, duration and grain type and showed 3-20% yield advantage over BRRI hybrid dhan3 with growth duration similar to BRRI dhan28 but one to two weeks earlier than BRRI dhan29, 4-20% over BRRI hybrid dhan5 with similar growth duration to BRRI dhan28, 24 to 43% over BRRI dhan28 and 18 to 36% over BRRI dhan29. Under multilocation trials, three hybrids out of nine produced 12-19% yield advantage over BRRI hybrid dhan4 and BRRI hybrid dhan6. In Boro, 39 hybrids were evaluated along with two hybrid and two inbred checks and all the selected hybrids showed yield advantage ranging from 28-59% over BRRI dhan28 and 6-32% 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 2018 and Boro 2018-19, which included 19 and 58 hybrids along with two inbred check variety. Results were compiled by SCA.

Work is in progress for the development of disease resistant parental lines of hybrid rice. We are trying to develop bacterial blight resistant maintainer and restorer lines of BRRI released hybrids through MAS. It is now in BC_3 and BC_4 stage.

Seed yield of 476 kg/plot (1.4 t ha^{-1}), 364 kg/plot (1.3 t ha^{-1}), 180 kg/plot (1.5 t ha^{-1}), 192 kg/plot (1.2 t ha^{-1}), 456 kg/plot (1.2 t ha^{-1}) and 105 kg/plot (1.0 t ha^{-1}) were obtained from BRRI10A, BRRI11A, IR58025A, BRRI7A, IR79156A and IR75608A respectively in T. Aman 2018. On the other hand, in Boro 2018-19, CMS seed yield of 63 kg (2.3 t ha^{-1}), 222 kg (2.1 t ha^{-1}), 351 kg (2.2 t ha^{-1}) and 230 kg (1.8 t ha^{-1}) were obtained from BRRI10A, IR58025A, BRRI7A and IR79156A respectively. A total of 230 kg (1.3 t ha^{-1}) and 130 kg (1.3 t ha^{-1}) hybrid seeds were produced from BRRI hybrid dhan5 (BRRI7A/BRRI31R) and BRRI hybrid dhan7 (IR75608A/BRRI31R) respectively during T. Aman 2018. In Boro 2018-19, a total of 177 kg (2.4 t ha^{-1}) hybrid seeds from BRRI hybrid dhan2, 760 kg (2.5 t ha^{-1}) from BRRI hybrid dhan3, 389 kg (2.0 t ha^{-1}) from BRRI hybrid dhan4, 750 kg (2.1 t ha^{-1}) from BRRI hybrid dhan5 and 528 kg (1.9 t ha^{-1}) from BRRI hybrid dhan6 were obtained. We received 17 high amylose hybrids and some parental lines from hybrid rice

development consortium (HRDC) during late Boro 2018-19. Among 17 high amylose hybrids three hybrids performed well in late sowing conditions and we are evaluating it again in on-going T. Aman 2019 season. A total of 81000 kg F_1 seeds were produced during Boro 2018-19 with the technical assistance of BRRI under BADC, 19 seed companies and regional stations of BRRI. In the reporting year, Hybrid Rice Division supplied 10585 kg of parental lines and F_1 seeds to 87 farmers, 19 seed companies, BRRI scientists and staffs**.**

DEVELOPMENT OF PARENTAL MATERIALS

Source nursery

One hundred fifty-three test crosses and 248 (A × R) crosses were made using nine CMS lines during T. Aman 2018. Sixty test crosses and 370 (A × R) crosses were made using nine CMS lines during Boro 2018-19.

Test cross nursery

In Aman 2018, out of 48 testcrosses (F_1s) of two entries have been found heterotic over the check varieties expressing 21-30% yield advantage over the check BRRI hybrid dhan4 with similar growth duration, 10-18% over BRRI hybrid dhan6 and 32-41% over BRRI dhan49 and five entries were found completely sterile. Pollen parents heterotic combinations were regarded as suspected restorers and pollen parents of completely sterile combinations were regarded as suspected maintainer lines.

In Boro 2018-19, out of 192 test crosses (F_1s), two tested entries showed complete sterility and immediately back crossed with their corresponding male parents for conversion. On the other hand, four entries have been selected for their high yielding ability compared to the check variety.

Back cross nursery

In T. Aman 2018, two BC_6 generations were stable in terms of pollen sterility and other desired agronomic traits and hence shifted to CMS maintenance and evaluation nursery as new CMS lines (Table 1). Other generations were advanced for next generation except for one BC_2 and two BC_1 generations. It was discarded due to fluctuation in pollen fertility.

In Boro 2018-19, four BC_6 generations were advanced as new CMS lines and shifted to CMS nursery. Other entries were advanced for next generations.

CMS maintenance and evaluation nursery

Sixty-five CMS lines were maintained by hand crossing for seed increase and genetic purity in T. Aman 2018 and in Boro 2018-19, a total of 91 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. Matured BC_4F_1 seeds were also collected and preserved. On the other hand, DNA extraction was done of each combinations an molecular work is going on. In T. Aman 2018, 50 restorer and 55 maintainer lines were screened for bacterial blight resistant genes against 10 different isolates. In Boro 2018-19, out of six testcrosses one entry (IR79156A/HRBB1) was found completely sterile against bacterial blight and immediately back crossed for conversion and no entry was found heterotic over the check variety.

Table 1. List of back cross entries shifted to CMS nursery as a new CMS lines during Boro 2018-19.

BC gen	Designation	Sterility status	DFF	D50% F	DTM	Grain type	Base color	Remark
BC6	BRRI33A/EL-199	CS	119	122	146	MS	Green	Advanced as New CMS lines
BC6	BRRI28A/EL-28	CS	106	110	132	S	Purple	Advanced as New CMS lines
BC6	BRRI28A/EL26	CS	96	100	122	M	Purple	Advanced as New CMS lines
BC6	BRRI13A/EL75	CS	117	120	144	MS	Green	Advanced as New CMS lines

DS: P_1 =2 Dec 2018; P_2/F_1=5 Dec 2018; P_3 =8 Dec 2018; DT: 10 Jan 2019; CS = completely sterile; S = sterile; DFF=Days to first flowering; D50% F= Days to 50% flowering; DTM= Days to maturity; S= Slender; MS= Medium slender; MB= Medium bold.

EVALUATION OF PARENTAL LINES AND HYBRIDS

In T. Aman 2018, out of 215 hybrids eight hybrid combinations were selected based on yield, duration and grain type. The selected hybrid combinations expressed 13-42% yield advantage over BRRI hybrid dhan4, 3-29% over BRRI hybrid dhan6 and 6-44% over standard inbred check 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 multilocation yield trials (MLT). Upon satisfactory yield advantage over the check variety it is subjected to registration under national hybrid rice yield trial (NHRYT) for releasing as new hybrid BRRI rice. Out of 417 test hybrids 16 hybrid combinations were selected based on yield, duration and grain type and showed 3-20% yield advantage over BRRI hybrid dhan3 with growth duration similar to BRRI dhan28 but one to two weeks earlier than BRRI dhan29 and 4-20% yield advantage over BRRI hybrid dhan5 (Table 3).

Preliminary yield trials of promising hybrids

Under preliminary yield trials three hybrids out of ten gave more 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 2018 (Table 4) and in Boro 2018-19, out of 39 hybrids were selected based on yield, grain type and growth duration. All the selected hybrids showed yield advantage ranging from 28-59% over BRRI dhan28 and 6-32% over BRRI dhan29. Three hybrid combinations had out yielded BRRI hybrid dhan3 and BRRI hybrid dhan5 by more than one tons (Table 5).

Table 2. List of experimental hybrids found heterotic over check variety in T. Aman 2018.

Test hybrid	PHT (cm)	DTM	SF (%)	Yield (t ha^{-1})	GT	% yield advantage over checks		
						Ck-1	Ck-2	Ck-3
BRRI7A/BU507R	124	125	90.1	7.2	MB	20.0	9.0	22.0
BRRI35A/CQR	125	135	92.8	8.0	MB	33.3	21.2	35.5
BRRI7A/LPH47R	110	103	91.5	7.0	MS	16.6	6.0	6.0
BRRI13A/BU507R	134	118	88.2	7.4	MS	23.3	12.1	25.4
BRRI35A/WinR (New)	111	136	79.2	8.2	MS	36.6	24.2	38.9
IR79156A/S-1203R	130	118	87.6	8.5	MS	41.6	28.7	44.0
BRRI7A/R line 7	120	112	90.9	7.2	LS	20.0	9.0	22.0
IR79156A/straw col R	140	114	81.7	6.8	LS	13.3	3.0	15.2
BRRI hybrid dhan4	112	120	80.1	6.0	MS			
BRRI hybrid dhan6	106	122	82.2	6.6	LB			
BRRI dhan49	101	138	79.7	5.9	MB			
Mean	119	121	82.2	7.1				
CV%	10.3	8.9	5.9	11.7				
LSD (0.05)	9.5	8.2	3.8	0.64				

DS: 08 Jul 2018; DT: 28 Jul 2018. Legend: DTM =Days to maturity; SF (%) = Spikelet fertility; GT= Grain type; MB= Medium bold; MS= Medium slender; LS= Long slender; LB= Long bold.

Table 3. List of the hybrid combinations found heterotic from observational nursery in Boro 2018-19.

Entry	Cross combination	E/T	PHT (cm)	PL (cm)	SF%	DTM	GT	Yield (t ha^{-1})	Yield advantage over checks			
									Ck1	Ck2	Ck3	Ck4
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
OT248	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
OT312	IR79156A/CHH32R	11.0	103	25.2	89.1	141	MS	9.13	7.03	7.7	28.2	21.7
OT353	IR79156A/LPH47R	9.8	108	25.4	85.8	144	LS	8.81	3.3	3.9	23.7	17.5
OT391	IR79156A/Basmati L	10.6	112	25.8	87.4	143	S	8.93	4.7	5.3	25.4	19.06
OT412	IR79156A/BasmatiL-14	9.6	104	25.6	87.6	143	S	9.05	6.1	6.7	27.1	20.7
Ck1	BRRI hybrid dhan3	9.0	105	25.0	90.6	144	MB	8.53				
Ck2	BRRI hybrid dhan5	10.2	110	25.0	86.7	143	LB	8.48				
Ck3	BRRI dhan28	9.4	112	21.8	81.9	138	MS	7.12				
Ck4	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 2018; DT: 8 Jan 2019. PHT (cm) = Plant height; E/T = Number 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.

Table 4. Results of preliminary yield trials in T. Aman 2018.

Sl. no.	Designation	PHT (cm)	E/T	SF%	GT	DTM	Yield (t ha^{-1})	Yield advantage over cks (%)		
								Ck-1	Ck-2	Ck-3
2	IR79156A/CHA15R	112	10	78	MS	109	6.75	42.8	24.4	14.7
3	BRRI13A/EL108R	114	11	76	MS	110	6.43	36.0	18.4	9.2
5	BRRI48A/EL262R	112	10	79	M	110	6.21	31.5	14.5	5.6
Ck-1	BRRI dhan49	129	11	80	M	133	4.73			
Ck-2	BRRI hybrid dhan4	113	12	79	S	117	5.43			
Ck-3	BRRI hybrid dhan6	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 2018; DT: 03 Aug 2018; 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 2018-19.

SL	Test hybrid	PH	DTM	SF (%)	YLD (t/h)	GT	Yield advantage over checks (%)			
							Ck1	Ck2	Ck3	Ck4
1	BRRI13A/EL254R	105.3	143	84.5	9.87	MS	21.4	20.4	57.2	30.7
2	BRRI7A/EL255R	104.0	144	85.6	9.83	MS	20.9	19.9	56.5	30.2
3	BRRI7A/EL262R	108.0	147	82.0	9.97	MB	22.6	21.6	58.8	32.1
4	BRRI13A/EL262R	110.0	148	79.2	9.17	MB	12.8	11.8	46.0	21.5
5	BRRI35A/EL262R	113.0	149	83.2	9.30	MB	14.4	13.4	48.1	23.2
6	BRRI35A/CHA15R	111.7	150	80.1	8.83	LS	8.6	7.7	40.6	16.9
7	IR79156A/CHA15R	106.3	139	78.7	8.53	LS	4.9	4.0	35.8	13.0
8	IR79156A/Win1R	108.0	151	77.0	8.23	LS	1.2	0.4	31.1	9.0
9	BRRI7A/Basmati L, Ind	114.3	142	79.7	8.03	LS	-	-	27.9	6.4
Ck1	BRRI hybrid dhan3	107.0	148	78.4	8.13	LB				
Ck2	BRRI hybrid dhan5	106.3	149	80.8	8.20	LB				
Ck3	BRRI dhan28	104.0	137	69.5	6.28	MS				
Ck4	BRRI dhan29	107.7	158	73.0	7.55	MS				
	Heritability	0.60	0.9	0.85	0.75					
	$LSD_{(0.05)}$	5.7	4.1	4.71	1.5					

DS: 8 Dec 2018; DT: 8 Jan 2019. Unit plot size: 30 $m^{2;}$ PH=Plant height (cm); DTM=Days to maturity; SF (%)=Spikelet fertility; GT=Grain type.

Multilocation yield trials of promising hybrids

In T. Aman 2018, out of nine hybrids, three combinations showed 12-19% yield advantage over BRRI hybrid dhan4 and BRRI hybrid dhan6 with similar growth duration. Yield advantage was reduced due to rat damage in Barishal (Table 6).

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

In T. Aman 2018, 84 F_4 from 18 crosses and 161 F_5 generations from 36 crosses were advanced for next generations and in Boro 2018-19, 79 progenies of F_5 and 155 progenies of F_6 generations derived from 18 and 36 (B×B) crosses were advanced for next generation. In T. Aman 2018, 55 F_5 and 41 F_4 generations of (R×R) crosses were advanced for next generations. In Boro 2018-19, 55 F_6 and 41F_5 generations of (R×R) crosses were advanced for next generations.

Evaluation of Fatema dhan

Ten lines of Fatema dhan were evaluated in T. Aman 2018. All the tested lines had low tillering ability, panicle exertion rate was very low, flower bloomed inside the leaf sheath, with long awn, still segregating, highly infected by sheath rot diseases and some had large panicle with more spikelets and strong stem. At maturity, single panicle were harvested from each plant for next season use. In Boro 2018-19, selected 20 lines based on red stigma, white stigma, awn less and awn present.

SEED PRODUCTION OF PARENTAL LINES AND HYBRIDS

CMS line multiplication of released hybrids

Seed yield of 476 kg/plot (1.4 t ha^{-1}), 364 kg/plot (1.3 t ha^{-1}), 180 kg/plot (1.5 t ha^{-1}), 192 kg/plot (1.2 t ha^{-1}), 180 kg/plot (1.5 t ha^{-1}), 456 kg/plot (1.2 t ha^{-1}) and 105 kg/plot (1.0 t ha^{-1}) were obtained from BRRI10A, BRRI11A, IR58025A, BRRI7A, IR79156A and IR75608A respectively in T. Aman season 2018 (Table 7). On the other hand, in Boro 2018-19, seed yield of 276 kg (2.3 t ha^{-1}), 425 kg (2.1 t ha^{-1}), 222 kg (2.1 t ha^{-1}), 351 kg (2.2 t ha^{-1}) and 230 kg (1.8 t ha^{-1}) were obtained from BRRI10A, BRRI11A, IR58025A, BRRI7A and IR79156A respectively (Table 8).

Table 6. Results of multilocation yield trials during T. Aman 2018.

En	Hybrid	PH	DTM	Yield				Yield advantage over ck (%)
				Gaz	*Bari	Ran	Mean	
1	BRR35A/EL108R	99.3	117	6.7	1.3	5.14	4.4	-
2	BRRI48A/EL108R	104.6	117	6.7	2.4	4.4	4.5	-
3	IR79156A/EL108R	108.0	128	7.3	4.4	5.34	5.7	16
4	BRR35A/EL253R	105.6	121	6.4	3.7	5.61	5.2	7
5	BRRI48A/EL253R	104.3	119	6.6	3.6	4.9	5.0	3
6	IR79156A/EL253R	113.9	120	6.8	5.0	5.67	5.8	19
7	BRR35A/ EL254R	103.3	119	6.3	1.7	5.37	4.5	-
8	BRRI48A/ EL254R	105.0	119	6.4	1.4	5.02	4.3	-
9	IR79156A/EL254R	115.0	123	7.2	3.5	5.85	5.5	12
10	BHD4 (ck-1)	108.2	121	6.2	4.0	4.64	4.9	
11	BHD6 (ck-2)	111.5	122	6.3	2.5	5.83	4.9	
Mean		107	120	7.0	3.0	5.0	5.0	
CV (%)		4.4	3	5.6	41.0	9.1	10.9	
LSD (0.05%)		3.6	2	0.3	1.0	0.4	0.4	

DS: 11 Jul 2018; DT: 29 Jul 2018; * Rat damage; Unit plot size: 30 m^2.

Table 7. CMS lines multiplication of BRRI10A, BRRI11A, IR58025A, BRRI7A, IR79156A and IR75608A in T. Aman 2018.

Combination	Plant height (cm)		50% flowering date		PER (%)	OCR (%)	Yield	
	A line	B line	A line	B line			Kg/plot	(t ha^{-1})
BRRI10A/B	81	85	73	71	74	42	476	1.4
BRRI11A/B	78	81	72	71	71	41	364	1.3
IR58025A/B	104	105	93	94	75	49	180	1.5
BRRI7A/B	93	96	84	86	70	42	192	1.2
IR79156A/B	86	91	89	86	72	37	456	1.2
IR75608A/B	86	91	89	86	72	37	105	1.0

DS: B_1=08 Jun 2018; A/B_2=11 Jun 2018; B_3=13 Jun 2018; DT: A/B= 04 Jul 2018. DS: B_1=09 Jun 2018, A/B_2=12 Jun 2018, B_3=14 Jun 2018; DT: A/B=07 Jul 2018. DS: B_1= 09 Jun 2018, A/B_2=12 Jun 2018, B_3=14 Jun 2018; DT: A/B=13 Jul 2018. DS: B_1=12 Jun 2018, A/B_2=15 Jun 2018, B_3=18 Jun 2018; DT: A/B=15 Jul 2018. DS: B_1=12 Jun 2018, A/B_2=15 Jun 2018, B_3=18 Jun 2018; DT: A/B=15 Jul 2018. DS: B_1=15 Jun 2018, A/B_2=18 Jun 2018, B_3=21 Jun 2018; DT: A/B=18 Jul 2018. PER=Panicle exertion rate, OCR= Out crossing rate.

F_1 Hybrid seed production of BRRI hybrid dhan5 and BRRI hybrid dhan7 (Up-coming Aus) in T. Aman 2018 and BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5, BRRI hybrid dhan6 and BRRI hybrid dhan7 (Aus proposed) in Boro 2018-19

A total of 230 kg (1.3 t ha^{-1}) seed yield were obtained from BRRI hybrid dhan5 (BRRI7A/BRRI31R) and 130 kg (1.3 t ha^{-1}) from BRRI hybrid dhan7 (IR75608A/BRRI31R) respectively during T. Aman 2018 (Table 9). During Boro 2018-19 seasons, a total of 177 kg (2.4 t ha^{-1}) from BRRI hybrid dhan2, 760 kg (2.5 t ha^{-1}) from BRRI hybrid dhan3, 389 kg (2.0 t ha^{-1}) from BRRI hybrid dhan4, 572 kg (1.8 t ha^{-1}) from BRRI hybrid dhan5, 528 kg (1.9 t ha^{-1}) from BRRI hybrid dhan6 and 120 kg (1.3 t ha^{-1}) from BRRI hybrid dhan7 (Aus proposed) were obtained (Table 10).

Table 8. CMS multiplication of BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5 and BRRI hybrid dhan6 in Boro 2018-19.

Designation	Plant height (cm)		50% flowering (days)		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg/plot)	Seed yield (t ha^{-1})
	A line	B line	A line	B line	A line	A line			
BRRI10A/B	86	88	122	124	82	48	276	63	2.3
BRRI11A/B	88	90	124	121	80	47	2000	425	2.1
IR58025A/B	93	95	127	124	74	46	1057	222	2.1
BRRI7A/B	95	97	116	115	78	49	1591	351	2.2
IR79156A/B	82	83	123	120	70	45	1277	230	1.8

DS: B_1 = 02 Dec 2018; A/B_2 = 05Dec 2018; B_3 = 08 Dec 2018; DT: A/B = 07Jan 2019. DS: B_1 =07 Dec 2018; A/B_2 = 10Dec 2018; B_3 = 13 Dec 2018; DT: A/B = 13 Jan 2019. DS: B_1 =30 Nov 2018; A/B_2 = 03Dec 2018; B_3 = 06 Dec 2018; DT: A/B = 03 Jan 2019. DS: B_1 =05 Dec 2018; A/B_2 = 08 Dec 2018; B_3 = 11Dec 2018; DT: A/B = 08 Jan 2019. DS: B_1 =12 Dec 2018; A/B_2 = 15Dec 2018; B_3 = 18 Dec 2018; DT: A/B = 18 Jan 2019. PER=Panicle exertion rate, OCR= Out crossing rate.

Table 9. F_1 seed production of BRRI hybrid dhan5 and BRRI hybrid dhan7 (Aus proposed) during T. Aman 2018.

Hybrid	PHT (cm)		D50%F		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg/plot)	Seed yield (t ha^{-1})
	A Line	R Line	A line	R line					
BRRI7A/BRRI31R (BHD5)	91	103	87	105	71.3	41.2	1800	230	1.3
IR75608A/ BRRI31R (BHD7)	96	102	90	94	72.7	45.2	1000	130	1.3

DS: R_1 = 23 Jun 2018; R_2 = 30 Jun 2018; A = 14 Jul 2018; DT: R = 27 Jul 2018; A = 10 Aug 2018. DS: R_1=14 Jul 2018; R_2 =17 Jul 2018; A=20 Jul 2018; DT: R&A=08 Aug 2018. PER (%) = panicle exertion rate, OCR (%) = Out crossing rate

Table 10. F_1 seed production of BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5, BRRI hybrid dhan6 and BRRI hybrid dhan7 (Aus proposed) during Boro, 2018-19.

Combination	Plant height (cm)		50% flowering date		PER (%)	OCR (%)	Yield	
	A line	R line	A line	R line			kg/plot	t ha^{-1}
BRRI10A/BRRI10R	83	90	121	123	87	46	177	2400
BRRI11A/BRRI15R	84	89	122	123	88	48	760	2500
IR58025A/BRRI10R	87	92	120	122	88	41	389	2000
BRRI7A/BRRI31R	87	95	123	141	82	47	572	1800
IR79156A/BRRI20R	82	93	120	123	89	43	528	1900
IR75608A/BRRI31R (BHD7 proposed)	90	97	121	127	72	38.5	120	1300

DS: R_1 = 12 Dec 2018; R_2 = 18 Dec 2018; A = 15 Dec 2018; DT: R &A = 20 Jan 2019. DS: R_1 = 30 Nov 2018; R_2 = 08 Dec 2018; A = 04 Dec 2018; DT: R &A = 04 Jan 2019. DS: R_1 = 12 Dec 2018; R_2 = 18 Dec 2018; A = 15 Dec 2018; DT: R &A = 20 Jan 2019. DS: R_1 = 30 Nov 2018; R_2 = 07 Dec 2018; A = 26 Dec 2018; DT: R = 07 Jan 2019; A = 24 Jan 2019. DS: R_1 = 20 Dec 2018; R_2 = 29 Dec 2018; A = 23 Dec 2018; DT: R & A = 20 Jan 2019. DS: R_1 = 30 Nov 2018; R_2 = 07 Dec 2018; A = 21 Dec 2018; DT: R = 12 Jan 2019;; A=27 Jan 2019. PER (%) = panicle exertion rate, OCR (%) = Out crossing rate.

CMS line multiplication of released hybrids

In T. Aman 2018, seed yield of 476 kg/plot (1.4 t ha^{-1}), 364 kg/plot (1.3 t ha^{-1}), 180 kg/plot (1.5 t ha^{-1}), 192 kg/plot (1.2 t ha^{-1}), 180 kg/plot (1.5 t ha^{-1}), 456 kg/plot (1.2 t ha^{-1}) and 105 kg/plot (1.0 t ha^{-1}) were obtained from BRRI10A (BRRI hybrid dhan2), BRRI11A (BRRI hybrid dhan3), IR58025A (BRRI hybrid dhan4), BRRI7A (BRRI hybrid dhan5), IR79156A (BRRI hybrid dhan6) and IR75608A (BRRI hybrid dhan7) respectively in T. Aman 2018 (Table 11). In Boro 2018-19, seed yield of 276 kg (2.3 t ha^{-1}), 425 kg (2.1 t ha^{-1}), 222 kg (2.1 t ha^{-1}), 351 kg (2.2 t ha^{-1}) and 230 kg (1.8 t ha^{-1}) were obtained from BRRI10A (BRRI hybrid dhan2), BRRI11A (BRRI hybrid dhan3), IR58025A (BRRI hybrid dhan4), BRRI7A (BRRI hybrid dhan5) and IR79156A (BRRI hybrid dhan6) respectively (Table 12).

Table 11. CMS lines multiplication of BRRI10A, BRRI11A, IR58025A, BRRI7A, IR79156A and IR75608A in T. Aman 2018.

Combination	Plant height (cm)		50% flowering date		PER (%)	OCR (%)	Yield	
	A line	B line	A line	B line			kg/plot	(t ha^{-1})
BRRI10A/B	81	85	73	71	74	42	476	1.4
BRRI11A/B	78	81	72	71	71	41	364	1.3
IR58025A/B	104	105	93	94	75	49	180	1.5
BRRI7A/B	93	96	84	86	70	42	192	1.2
IR79156A/B	86	91	89	86	72	37	456	1.2
IR75608A/B	86	91	89	86	72	37	105	1.0

DS: B_1=08 Jun 2018; A/B_2=11 Jun 2018; B_3=13 Jun 2018; DT: A/B= 04 Jul 2018. DS: B_1=09 Jun 2018; A/B_2=12 Jun 2018; B_3=15 Jun 2018; DT: A/B= 07 Jul 2018. DS: B_1= 09 Jun 2018; A/B_2=12 Jun 2018; B_3=15 Jun 2018; DT: A/B=13 Jul 2018. DS: B_1=09 Jun 2018; A/B_2=12 Jun 2018; B_3=15 Jun 2018; DT: A/B=13 Jul 2018. DS: B_1=12 Jun 2018; A/B_2=15 Jun 2018; B_3=18 Jun 2018; DT: A/B=15 Jul 2018. DS: B_1=12 Jun 2018; A/B_2=15 Jun 2018; B_3=18 Jun 2018; DT: A/B=15 Jul 2018. PER=Panicle exertion rate, OCR= Out crossing rate.

Table 12. CMS multiplication of BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5 and BRRI hybrid dhan6 during Boro 2018-19.

Designation	Plant height (cm)		50% flowering (day)		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg/plot)	Seed yield (t/ha)
	A line	B line	A line	B line	A line	A line			
BRRI10A/B	86	88	122	124	82	48	276	63	2.3
BRRI11A/B	88	90	124	121	80	47	2000	425	2.1
IR58025A/B	93	95	127	124	74	46	1057	222	2.1
BRRI7A/B	95	97	116	115	78	49	1591	351	2.2
IR79156A/B	82	83	123	120	70	45	1277	230	1.8

DS: B1 =05 Dec 2018; A/B2 = 08 Dec 2018; B3 = 11 Dec 2018; DT: A/B = 07 Jan 2019. DS: B1 =10 Dec 2018; A/B2 = 13 Dec 2018; B3 = 16 Dec 2018; DT: A/B = 12 Jan 2019. DS: B1 =03 Dec 2018; A/B2 = 06 Dec 2018; B3 = 09 Dec 2018; DT: A/B = 08 Jan 2019. DS: B1 =07 Dec 2018; A/B2 = 10 Dec 2018; B3 = 13 Dec 2018; DT: A/B = 13 Jan 2019. DS: B1 =30 Nov 2018; A/B2 = 03 Dec 2018; B3 = 06 Dec 2018; DT: A/B = 06 Jan 2019. PER= Panicle exertion rate, OCR=Out crossing rate.

Table 13. Seed amount obtained from selected promising CMS lines in T. Aman 2018.

Designation	PHT (cm)		D50%F		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg /plot)	Seed Yield (t ha^{-1})
	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

PER (%) = Panicle exertion rate, OCR (%) = Out crossing rate.

Seed production of promising CMS lines and hybrids

Seed yield 7.8 kg/plot (1.5 t/ha), 8.0 kg/plot (1.1 t ha^{-1}), 3.6 kg/plot (1.2 t ha^{-1}), 2.3 kg/plot (1.8 t ha^{-1}), 3.5 kg/plot (0.9 t ha^{-1}), 17.0 kg/plot (1.1 t ha^{-1}). 16.0 kg/plot (1.06 t ha^{-1}), 13.0 kg/plot (0.87 t ha^{-1}), 14.5 kg/plot (0.97 t ha^{-1}) and 11.5 kg/plot (1.6 t ha^{-1}) were obtained from BRRI13A, BRRI25A, BRRI32A, BRRI35A, BRRI48A, BRRI50A, BRRI53A, BRRI72A, BRRI85A and IR78355A during T. Aman 2018, (Table 13). In Boro 2018-19, seed yield 23 kg/plot (1.5 t ha^{-1}), 27 kg/plot (1.8 t ha^{-1}) and 14.5 kg/plot (1.0 t ha^{-1}) were obtained from promising CMS lines BRRI97A, BRRI99A and IR75608A respectively (Table 14).

F_1 seed production of promising hybrids in T. Aman 2018

In T. Aman 2018, seed yield were obtained ranging from 0.2 to 8.5 kg/plot. Some combinations did not produce seed due to lack of flowering synchronization (Table 15).

Table 14. Seed amount obtained from selected promising CMS lines in Boro 2018-19.

Designation	Plant height (cm)		D50% flowering		PER (%)	OCR (%)	Yield (kg/plot)	Seed yield (t ha^{-1})
	A Line	B line	A Line	B line				
BRRI97A/B	102	104	109	106	70.0	51.3	23.0	1.5
BRRI99A/B	101	103	117	114	72.3	53.2	27.0	1.8
IR75608A/B	86.0	86.5	113	112	69.0	43.5	14.5	1.0
Average	96.33	97.83	113.00	110.67	70.43	49.33	21.50	1.43
Lsd $_{(0.05)}$	13.4	14.6	6.0	6.2	2.5	7.7	9.5	0.6
CV (%)	9.30	10.05	3.54	3.76	2.40	10.42	29.69	28.20

DS: B_1= 03 Dec 2018; B_2/A = 6 Dec 2018; B_3= 9 Dec 2018; DT: 07 Jan 2019. DS: B_1= 07 Dec 2018; B_2/A = 10 Dec 2018; B_3= 13 Dec 2018; DT: 10 Jan 2019. DS: B_1= 30 Nov 2018; B_2/A = 03 Dec 2018; B_3= 6 Dec 2018; DT: 04 Jan 2019. PER (%) = panicle exertion rate, OCR (%) = Out crossing rate.

Table 15. Seed amount obtained from promising hybrid rice combinations in T. Aman 2018.

Hybrid	D50% F		Yield (kg/plot)	Remark
	A Line	R Line		
BRRI35A/CHA15R	63	83	2.5	
BRRI48A/ CHA15R	70	87	3.0	
IR79156A/ CHA15R	80	87	7.5	Suitable combinations for T. Aman season coupled with slender grain and slight aroma
BRRI35A/ R line7	70	91	1.9	
BRRI48A/ R line7	70	91	1.5	
IR79156A/ R line7	80	91	5.7	
BRRI7A/CHH-32R	66	79	1.6	
BRRI13A/ CHH-32R	62	79	1.6	
BRRI35A/ CHH-32R	70	79	4.6	
BRRI48A /CHH-32R	70	79	3.3	
IR79156A/ CHH-32R	80	79	5.9	
BRRI13A/ Basmati L, Ind	62	87	2.8	
BRRI35A/ Basmati L, Ind	70	87	2.2	
BRRI48A / Basmati L, Ind	70	87	2.6	
IR79156A/ Basmati L Ind	80	87	4.2	
BRRI7A/EL254R	66	83	2.3	
BRRI13A/EL254R	62	83	3.0	
BRRI35A/EL254R	70	83	8.5	Combinations suitable for Boro season and seed production suitable in T. Aman season
BRRI48A/EL254R	70	83	2.7	
IR79156A/EL254R	80	83	6.6	
BRRI7A/EL255R	66	83	2.1	

Table 15. Continued

Hybrid	D50% F		Yield (kg/plot)	Remark
	A Line	R Line		
BRRI13A/EL255R	62	83	1.5	
BRRI35A/EL255R	70	83	6.9	
BRRI48A/EL255R	70	83	4.8	
IR79156A/EL255R	80	83	4.7	
BRRI7A/EL262R	66	82	1.6	
BRRI13A/EL262R	62	82	1.7	
BRRI35A/EL262R	70	82	8.3	
BRRI48A/EL262R	70	82	5.1	
BRRI35A/ Win1R	70	83	0.2	
BRRI48A/ Win1R	70	83	1.9	
IR79156A/ Win1R	80	83	2.1	Combinations suitable for both Boro and T. Aman season but seed production not good for all combinations
BRRI35A/ LPH14R	70	78	2.1	
BRRI48A /LPH14R	70	78	3.9	
IR79156A/ LPH14R	80	78	5.6	

DS: R_1= 10 Jul 2018; R_2=14 Jul 2018; A = Sowing in different date maintaining actual duration with its restorer lines; PER (%) = panicle exertion rate, OCR (%) = Out crossing rate.

Dissemination of hybrid rice technology

In the reporting year, Hybrid Rice Division supplied 10,585.0 kg seeds of parental lines and F_1 seeds to 19 seed companies along with farmers, BRRI staffs, BRRI RS and different projects (Table 16). A total of 81,000 kg F_1 seed was produced in Boro 2018-19 with the technical assistance from BRRI under nineteen seed companies and regional station of BRRI (Table 17).

Table 16. 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 Companies	19	1200	2,520	-	850
Farmers	87	3500	320	-	120
BRRI Scientists + Staffs	19	775	-	-	-
BRRI, RS (5)+SPIRA	6	1300	-	-	-
Total	131	6,775	2,840	-	970
Grand total				10,585	

Investigator: All staff of Hybrid Rice Division.

Table 17. Seed production activities of BRRI developed hybrids during Boro, 2018-19 both at private and public sectors.

Name of the organization/ person	Location	Var	Area (acre)	Yield achieved (ton)	Remarks
Sumaya seed	Kurigram	BHD3	4.0	3.5	Experienced
		BHD5	2.0	1.7	
Md Borhanuddin	Dumuria	BHD3	1.0	0.8	Experimental
Foloboti Seed Company	Khulna	BHD5	1.0	0.6	
Ruposhi Bangla Seed Company	Rangpur	BHD3	2.0	1.6	Experimental
Modina Green Tech	Tangail	BHD5	1.0	0.8	Experienced
		BHD6	2.0	1.8	
Shahjalal Seed Company	Naryanganj	BHD4	2.0	1.5	Experimental
		BHD6	3.0	2.6	

Table 17. Continued

Name of the organization/ person	Location	Var	Area (acre)	Yield achieved (ton)	Remarks
Aus Bangla Seed	Ishordi	BHD2	12.0	13.0	Experienced
		BHD3	5.0	4.5	
Bangladesh Seed Company	Naogaon	BHD3	2.0	1.6	Experienced
Md Zahidur Rahman Palashbari, Gaibandha	Gaibandha	BHD3	1.0	0.7	Experimental
Raja Seed Company	Rangpur	BHD3	1.0	0.7	Experimental
Metal Agro Ltd.	Sherpur	BHD3	5.0	5.2	Experienced
		BHD5	5.0	4.3	
Agro Link Enterprize	Rangpur	BHD3	1.0	0.7	Experimental
Madina Seed Company	Mymensingh	BHD4	5.0	4.2	Experienced
Ahasan Seeds and Agro Tech	Mymensingh	BHD2	2.0	1.7	Experienced
		BHD4	3.0	2.6	
Shimon, Sirajganj	Sirajganj	BHD3	4.0	3.7	Experienced
Super Discovery Agro Chemicals	Gopalganj	BHD3	1.0	0.8	Experienced
		BHD5	1.0	0.7	
Northern Agricultural and Industrial Company Ltd (NAICOL)	Thakurgaon	BHD6	3.0	2.5	Experimental
Lal Teer Seed Company Ltd	Valukha	BHD5	2.0	1.6	Experienced
Mannan Seed Company Ashulia, Savar	Tangail	BHD5	1.0	0.6	Experimental
		BHD6	2.0	1.7	
GF Agro, Rangpur	Sherpur	BHD3	3.0	3.2	Experienced
		BHD5	2.0	1.6	
BADC	Netrokona	BHD5	1.0	0.8	Experienced
BRRI RS, Habiganj	Habiganj	BHD5	1.0	0.3	Experimental
Babuganj, Barisal (Hired land by BRRI HRD)	Babuganj	BHD5	4.0	2.6	Experienced
Gazipur, HQ	Gazipur HQ	BHD5	0.5	0.3	Experienced
	BARI	BHD2	1.0	0.8	
	BARI	BHD4	1.0	0.7	
	BSCRI, Gazipur	BHD3	1.0	1.0	
		BHD7	0.5	0.3	
	BRRI HQ	BHD6	0.5	0.4	
		Total=	90.5	81.0	

Legend: BHD2 = BRRI hybrid dhan2, BHD3 = BRRI hybrid dhan3, BHD4 = BRRI hybrid dhan4
BHD5 = BRRI hybrid dhan5, BHD6 = BRRI hybrid dhan6, BHD7= BRRI hybrid dhan7.

Agronomy Division

SUMMARY

In T. Aus rice, BR9011-67-4-1 produced the highest grain yield (4.47-5.22 t ha^{-1}) over the check variety BR26 planted on 24 May to 8 June and matured within 103-108 days. In T. Aman rice, advanced breeding lines of Rangpur BR8189-10-2-3-1-5-RAN7 and BR10238-5-1-RAN6 produced significantly higher grain yield (4.82-5.32 t ha^{-1}) than the check variety BRRI dhan52 (3.03-4.95 t ha^{-1}). Zinc enriched lines, BR8442-12-1-3-1-B5 produced the highest grain yield (5.19-5.39 t ha^{-1}) over the check variety BRRI dhan72 (4.74-4.84 t ha^{-1}) up to 11 August planting and it matured within 136-141 days. Advanced breeding lines of Biotech BR (Bio) 8961-AC22-14 and BR(Bio)8961-AC22-16 produced significantly higher grain yield (5.39 t ha^{-1}) over the check variety BRRI dhan49 (4.74 t ha^{-1}) up to 11 August planting with similar growth duration. Zinc enriched lines, BR8631-12-3-5-P2 and BR8631-12-3-6-P3 gave higher grain yield (6.19 t ha^{-1}) than check variety BRRI dhan74 (4.86 t ha^{-1}) only at 9 January planting with similar growth duration (146-148 days). BR (Bio) 9777-26-4-3 and BR(Bio)9777-118-6-4 gave higher grain yield (6.71-8.20 t ha^{-1}) over the check variety (5.19-6.06 t ha^{-1}) up to 9 January planting and matured within 153-160 days. In T. Aman BRRI dhan71 performed better in 15 July planting. Soil test based nitrogen produced higher yield than BRRI recommended dose of nitrogen in all the planting dates. Forty-day-old seedlings produced satisfactory yield when soil test based nitrogen was applied. Application of 69 kg N ha^{-1} ($^1/_3$ as basal + $^1/_3$ at 15 DAT + $^1/_3$ at BPI) (N_1) followed by 69 kg N ha^{-1} (29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at heading) (N_4) would be a better option for higher yield by reducing sterility% in T. Aman rice (BRRI dhan75). The best nitrogen management practice for drought tolerant varieties could either urea splitting of 40% basal + 30% AT (active tillering) and 30% before PI (panicle initiation) or N application with prilled urea applicator after 7 DAT to obtain higher grain yield under rained condition. No phytotoxicity was observed due to application of herbicide in BRRI dhan28, BRRI dhan29, BRRI dhan58 and BRRI dhan81. New molecule herbicide had no detrimental effect on rice varieties. Weed control efficiency, growth and yield of different varieties were higher in different herbicidal treatments without any adverse effect. Most of the herbicides showed more than 80% weed control efficiency in different weed populations. Higher grain yield of 5.40 and 5.24 t ha^{-1} was observed in BRRI dhan75 and BRRI dhan70 respectively, with 75% BRRI recommended fertilizer dose + 25% N from Poultry manure followed by 5.16 t ha^{-1} grain yield from 75% RRF+ 25% N from vermicompost in BRRI dhan75 and 5.13 t ha^{-1} grain yield from RRF with DAP in BRRI dhan70. It is 8-9% higher compared to BRRI recommended doses.

PLANTING PRACTICES

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

Three promising lines BR9011-48-4-3, BR9011-64-1-2 and BR9011-67-4-1 were compared with BR26 (ck). Twenty-three-day-old seedling was transplanted on 9 May, 24 May and 8 June with 20 cm × 20 cm spacing using single seedling per hill. 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. Among the promising lines, BR9011-67-4-1 produced the highest grain yield (4.47-5.22 t ha^{-1}) planted on 24 May to 8 June and matured within 103-108 days. Among the planting times, the highest grain yield (5.22 t ha^{-1}) was found on 8 June planting. Higher number of panicles m^{-2} and heavier individual grain size contributed to higher grain yield (Tables 1 and 2). This line produced 1.5-3 t ha^{-1} higher yield than the check variety BR26 irrespective of planting date (Table 1).

Table 1. Effect of planting time on yield and yield components of advanced lines/varieties in Aus 2018, BRRI HQ, Gazipur.

Advanced line/Variety	Yield (t ha^{-1})			Panicle m^{-2}		
	9 May	24 May	8 Jun	9 May	24 May	8 Jun
BR9011-48-4-3	3.58 (111)	4.16 (108)	4.31 (103)	189	194	206
BR9011-64-1-2	3.43 (111)	3.77 (108)	4.31 (103)	194	191	219
BR9011-67-4-1	3.72 (111)	4.47 (108)	5.22 (103)	191	201	228
BR26 (ck)	2.27 (105)	4.13 (102)	2.39 (97)	163	193	173
CV (%)		12.5			6.2	
$LSD_{(0.05)}$		0.81			20.68	

Table 2. Effect of planting time on yield components of advanced lines/varieties in Aus 2018, BRRI HQ, Gazipur.

Advanced line /Variety	Grain panicle^{-1}			TGW (g)		
	9 May	24 May	8 Jun	9 May	24 May	8 Jun
BR9011-48-4-3	63	72	78	20.8	22.4	19.8
BR9011-64-1-2	74	60	75	18.4	19.4	19.5
BR9011-67-4-1	63	62	65	22.3	22.5	22.7
BR26 (ck)	77	51	53	18.5	20.6	18.6
CV (%)		22.5			6.9	
$LSD_{(0.05)}$		NS			NS	

TGW = 1000 grain weight.

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

The experiment was conducted at BRRI HQ farm, Gazipur in T. Aman 2018. Transplanting was started from 27 July to 10 September with the advanced lines. Advanced lines of Rangpur were: BR8189-10-2-3-1-5-RAN7, BR9392-6-2-1B-RAN5 and BR10238-5-1-RAN6 including the check varieties BR11 and BRRI dhan52, advanced lines of zinc enriched rice (ZER) were: BR8442-12-1-3-1-B5, BR8442-12-1-3-1-B1, BR7528-2R-19-HR16-E5-136-1 including the check varieties BRRI dhan49 and BRRI dhan72, advanced breeding lines of Biotech were: BR (Bio) 8961-AC22-14 and BR(Bio)8961-AC22-16 including the check variety BRRI dhan49, advanced lines of rainfed lowland rice (RLR) were: BR8841-22-2-4-2, BR8841-38-1-2-1 and IR10F102 including the check varieties BRRI dhan39 and BRRI dhan49. Among the advanced breeding lines of Rangpur, BR8189-10-2-3-1-5-RAN7 and BR10238-5-1-RAN6 produced significantly higher grain yield (4.82-5.32 t ha^{-1}) than the check variety BRRI dhan52 (3.03-4.95 t ha^{-1}) (Table 3). BR8189-10-2-3-1-5-RAN7 line shows slightly photosensitivity than other line when it was planted on 27 July and it's growth duration was 151 days. Among the zinc enriched lines, BR8442-12-1-3-1-B5 produced the highest grain yield (5.19-5.39 t ha^{-1}) over the check variety BRRI dhan72 (4.74-4.84 t ha^{-1}) up to 11 August planting and it matured within 136-141 days (Table 4). Advanced breeding lines of Biotech BR(Bio)8961-AC22-14 and BR (Bio) 8961-AC22-16 produced significantly higher grain yield (5.39 t ha^{-1}) over the check variety BRRI dhan49 (4.74 t ha^{-1}) up to 11 August planting with similar growth duration (Table 5). Among the planting times, advanced lines from each group produced higher grain yield on 27 July planting.

Table 3. Effect of planting time on yield and growth duration (in parenthesis) of advanced lines/varieties in T. Aman 2018, BRRI HQ, Gazipur.

Advanced line/Variety	Yield (t ha^{-1})			
	27 Jul	11 Aug	26 Aug	10 Sept
BR8189-10-2-3-1-5-RAN7	5.32 (151)	5.33 (136)	5.06 (131)	4.82 (133)
BR9392-6-2-1B-RAN5	4.63 (141)	4.87 (136)	4.89 (131)	3.83 (133)
BR10238-5-1-RAN6	5.26 (141)	4.99 (136)	4.91 (131)	2.95 (133)
BR11 (ck)	5.66 (141)	5.28 (136)	4.76 (131)	4.26 (133)
BRRI dhan52 (ck)	4.95 (141)	4.65 (136)	4.38 (131)	3.03 (133)
CV (%)		8.2		
$LSD_{(0.05)}$		0.64		

Table 4. Effect of planting time on yield and growth duration (in parenthesis) of advanced lines/varieties in T. Aman 2018, BRRI HQ, Gazipur.

Advanced line/Variety	Yield (t ha^{-1})			
	27 Jul	11 Aug	26 Aug	10 Sep
BR8442-12-1-3-1-B5	5.39 (141)	5.19 (136)	5.00 (133)	3.18 (124)
BR8442-12-1-3-1-B1	5.05 (141)	5.06 (136)	4.61 (133)	4.24 (124)
BR7528-2R-19-HR16-E5-136-1	5.02 (141)	4.84 (136)	4.78 (133)	4.38 (124)
BRRI dhan49 (ck)	5.21 (141)	4.67 (136)	4.65 (133)	4.40 (124)
BRRI dhan72 (ck)	4.84 (141)	4.74 (136)	4.67 (131)	4.57 (133)
CV (%)		4.7		
$LSD_{(0.05)}$		0.37		

Table 5. Effect of planting time on yield and growth duration (in parenthesis) of advanced lines/varieties in T. Aman 2018, BRRI, Gazipur.

Advanced line/Variety	Yield (t ha^{-1})			
	27 Jul	11 Aug	26 Aug	10 Sep
BR (Bio) 8961-AC22-14	5.39 (142)	5.30 (136)	4.84 (131)	4.04 (133)
BR (Bio) 8961-AC22-16	5.35 (142)	5.11 (136)	4.99 (131)	3.98 (133)
BRRI dhan49 (ck)	5.21 (142)	4.74 (136)	4.67 (131)	4.57 (133)
CV (%)		6.7		
$LSD_{(0.05)}$		0.56		

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

The promising lines of premium quality rice (PQR) of ALART were: BR8590-5-2-5-2-1, BR8590-5-2-5-2-2 and BR9207-45-2-2 including the check varieties BRRI dhan50 and BRRI dhan81, Advanced lines of zinc enriched rice (ZER) of ALART were: BR8631-12-3-5-P2 and BR8631-12-3-6-P3 including the check varieties BRRI dhan28 and BRRI dhan74, advanced lines of ALART (Favourable Boro) of Breeding Division were: IR99056-B-B-15 and BR8938-30-2-4-2-1 including the check varieties BRRI dhan28 and BRRI dhan58, advanced lines of ALART (Favourable Boro) of Biotech were: BR(Bio)9777-26-4-3 and BR (Bio) 9777-118-6-4 including the check variety BRRI dhan58. Zinc enriched lines, BR8631-12-3-5-P2 and BR8631-12-3-6-P3 produced higher grain yield (6.19 t ha^{-1}) than the check variety BRRI dhan74 (4.86 t ha^{-1}) only at 9 January planting with similar growth duration (146-148 days) (Table 6). BR (Bio) 9777-26-4-3 and BR (Bio) 9777-118-6-4 gave higher grain yield (6.71-8.20 t ha^{-1}) over the check variety BRRI dhan58 (5.19-6.06 t ha^{-1}) up to 9 January planting and matured within 153-160 days (Table 7). BR (Bio) 9777-26-4-3 line produced 7.07 t ha^{-1} grain yield with growth duration of 147 days even when planted on 24 January.

Table 6. Effect of planting time on yield and growth duration (in parenthesis) of advanced lines/varieties in Boro 2018-19, BRRI HQ, Gazipur.

Advanced lines/Variety	Yield (t ha^{-1})			
	25 Dec	9 Jan	24 Jan	8 Feb*
BR8631-12-3-5-P2	5.04 (159)	6.19 (148)	4.49 (143)	-
BR8631-12-3-6-P3	4.88 (154)	6.17 (146)	4.95 (143)	-
BRRI dhan28 (ck)	5.76 (154)	5.74 (146)	3.94 (143)	-
BRRI dhan74 (ck)	4.72 (154)	4.86 (146)	3.87 (143)	-
CV (%)	20.0			
$LSD_{(0.05)}$	NS			

***** Crop establishment was not possible (given seeds were not germinated).

Table 7. Effect of planting time on yield and growth duration (in parenthesis) of advanced lines/varieties in Boro 2018-19, BRRI HQ, Gazipur.

Advanced lines/Variety	Yield (t ha^{-1})			
	25 Dec	9 Jan	24 Jan	8 Feb**
BR(Bio)9777-26-4-3	8.20 (160)	6.69 (153)	7.07 (147)	-
BR(Bio)9777-118-6-4	6.71 (160)	6.99 (153)	5.30 (147)	-
BRRI dhan58 (ck)	6.06 (163)	5.19 (151)	3.92 (145)	-

****** Data analysis not done due to one replication.

Nitrogen management for BRRI dhan71 with aged seedlings at variable planting time

The experiment was conducted in T. Aman 2018 at BRRI HQ farm, Gazipur to determine the appropriate nitrogen management for BRRI dhan71 with aged seedlings at variable planting time. The experiment was laid out in split plot design with three replications. The main plot treatment was nitrogen rate: N_1 = Soil test based (STB) (87 kg ha^{-1}), N_2 = >25% of STB, N_3 = <25% of STB and N_4 = BRRI recommended dose (70 kg ha^{-1}). The sub plot treatment was seedling age: A_1 = 20 days, A_2 = 30 days and A_3 = 40 days. Three sets of experiment were conducted in three different planting dates 15 July, 30 July and 15 August using one seedling per hill with 20 × 20 cm spacing. Nitrogen was applied in three splits ($1/3^{rd}$ as basal, $1/3^{rd}$ at 15 days after transplanting and $1/3^{rd}$ at 30 days after transplanting). Among the treatments significant difference was found in panicle m^{-2}, grain $panicle^{-1}$ and yield in all the planting dates. At 15 July planting N_1A_1 produced the highest panicle m^{-2} but N_2A_2 produced the highest grains $panicle^{-1}$ and gave highest grain yield. When seedlings become 30-day-old then higher dose of nitrogen yielded the highest at 15 July planting. At 30 July planting the highest panicle m^{-2} was found in N_1A_1 but the highest grain $panicle^{-1}$ and yield was found in N_2A_3. When seedlings become 40-day-old than higher dose of nitrogen yielded the highest at 30 July planting. At 15 August planting, the highest panicle m^{-2}, grains $panicle^{-1}$ and yield was found in N_2A_1 (Table 8). In all the planting dates higher yield was found in STB than BRRI recommended dose of nitrogen and comparatively 15 July planting performed better.

Effect of nitrogen management at the reproductive phase of rice

An experiment was conducted in T. Aman 2018 at BRRI HQ farm, Gazipur to investigate whether urea top dressing at reproductive stage is harmful or useful for rice cultivation. BRRI dhan75 was tested under four nitrogen management options. Fertilizer rate was (N-P-K-S-Zn @ 69-10-41-16 kg ha^{-1} and N was splitted as, i. N_1 = 23 kg as basal + 23 kg at 15 DAT + 23 kg at BPI (BRRI recommended practice) ii. N_2 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at 10 days after PI (DAPI), iii. N_3 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at 20 days after PI (DAPI)/Booting and iv. N_4 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at heading stage. Initial soil status of the experimental field was pH = 6.3, N = 0.12%, P = 39.9 µg/g, K = 0.149 me/100g, S =12.06 µg/g and Zn = 0.83 µg/g. Among N management treatments, BRRI recommended. Practice (N_1) and 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} (N_4) produced the highest grain yield (5.32 and 5.20 t ha^{-1}). The lowest grain yield was observed from

Table 8. Effect of nitrogen management for BRRI dhan71 with aged seedlings at different planting date, BRRI HQ, Gazipur.

Nitrogen	Seedling age	15 Jul			30 Jul			15 Aug		
		Panicle m^{-2}	Grain $panicle^{-1}$	Yield (t ha^{-1})	Panicle m^{-2}	Grain $panicle^{-1}$	Yield (t ha^{-1})	Panicle m^{-2}	Grain $panicle^{-1}$	Yield (t ha^{-1})
N_1	A_1	228	1137	6.06	231	991	5.36	184	1106	4.65
	A_2	225	1150	5.74	215	1130	5.29	181	1160	4.71
	A_3	213	1053	5.42	228	1060	5.14	166	1107	4.31
N_2	A_1	219	1119	5.91	222	1021	5.21	192	1174	4.82
	A_2	226	1199	6.27	211	1101	5.23	179	1145	4.64
	A_3	219	1041	5.31	227	1247	5.47	176	1093	4.32
N_3	A_1	220	1003	5.17	203	1093	4.81	166	952	4.13
	A_2	222	917	4.71	203	1072	4.76	172	1016	3.62
	A_3	219	907	4.65	201	1043	4.63	166	952	3.80
N_4	A_1	213	1032	5.22	210	1047	5.03	182	1049	4.32
	A_2	207	999	4.83	208	1039	4.84	165	937	3.87
	A_3	215	965	4.72	215	1052	5.14	176	871	3.69
CV%		2.91	2.88	2.06	4.18	2.40	4.04	3.92	2.13	2.13
$LSD_{0.05}$		11.37	50.86	0.20	18.26	42.45	0.41	15.24	0.24	0.24

N_1 = STB, N_2 = >25% STB, N_3 = <25% STB and N_4 = BRRI recommended dose A_1 = 20 days, A_2 = 30 days and A_3 = 40 days.

N_3 and N_2 treatment (4.82 and 4.58 t ha^{-1}). There was significant difference among different N management techniques in grain $panicle^{-1}$ and sterility (%) (Table 9). Application of 69 kg N ha^{-1} ($^{1}/_{3}$ as basal + $^{1}/_{3}$ at 15 DAT + $^{1}/_{3}$ at BPI) (N_1) followed by 69 kg N ha^{-1} (29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at heading) (N_4) would be a better option for higher yield by reducing sterility% in T. Aman rice.

Best management practices developed for drought tolerant varieties

The experiments were conducted during 2018 to find out best management package for drought tolerant varieties BRRI dhan57, BRRI dhan66 and BRRI dhan71 in rainfed condition in Gazipur and Kishoreganj of Bangladesh. Farmer's management practice were compared with improved management (Researcher's management) practice at Gazipur and Kishoreganj. Researcher management practice (Table 10) produced more than 0.5 t ha^{-1} yield. Among the varieties, BRRI dhan71 was the highest yielder with growth duration of 116 days whereas BRRI dhan57 produced lower yield. In Kishoreganj, where Robi crops were grown, farmers choosed short duration variety BRRI dhan57 instead of long duration variety.

Table 9. Yield and yield components affected by different N management in BRRI dhan75 at BRRI HQ farm, Gazipur.

Treatment	Panicle m^{-2}	Grain $panicle^{-1}$	1000 grain wt (g)	Sterility (%)	Grain yield (t ha^{-1})
N_1 = 23 kg as basal + 23 kg at 15 DAT + 23 kg at BPI (BRRI recom. practice)	233	149	20.6	20.2	5.3
N_2 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at 10 days after PI (DAPI)	242	98	20.7	27.9	4.5
N_3 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at 20 days after PI (DAPI)	235	85	20.6	36.1	4.8
N_4 = 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1}	235	111	20.4	21.7	5.2
LSD $_{(0.05)}$	NS	33.9	NS	9.94	0.52
CV (%)	3.8	15.3	2.3	18.8	5.3

Table 10. Best management practices for drought tolerant varieties at Pakundia of Kishoreganj and Kapasia of Gazipur district.

Seeding time	5th Jul
Transplanting time	25 Jul
Seedling age	20 days
Seedlings/hill	2-3 seedling $hill^{-1}$
Spacing	20 × 15 cm
Fertilizer (Gazipur)	Urea-TSP-MoP-gypsum-$ZnSO_4$ 152-60-70-39-2 kg ha^{-1}
Fertilizer (Kishoreganj)	Urea-TSP-MoP-gypsum-$ZnSO_4$ 152-60-80-39-2 kg ha^{-1}
Fertilizer application method	All the fertilizers and 1/3 of urea to be applied as basal in final land preparation. Rest 1/3 of urea fertilizer to be applied as top dress with at 15 DAT and another 1/3 of urea to be applied before PI (30-35 DAT)
Others management	Standard crop management practices such as weeding, controlling disease and insect pests to be followed as and when necessary.

Best nitrogen management practice in drought tolerant rice varieties under rainfed condition in Gazipur and Kishoreganj district (T. Aman 2018)

Experiments were conducted in on station (BRRI, Gazipur) and on farm (Kapasia, Gazipur and Pakundia, Kishoreganj) condition to observe the effect of urea application in different splits on grain yield of drought tolerant varieties in rainfed condition. BRRI released drought tolerant varieties BRRI dhan57, BRRI dhan66, BRRI dhan71 and BRRI dhan49 and farmers' local varieties Kartiksail were used in the experiments. Nitrogen management treatments were: prilled urea 100% basal, prilled urea 50% basal+ 50% before PI, prilled urea 40% basal + 30% AT and 30% before PI, prilled urea application by prilled urea applicator within 7 DAT and compared with farmer's N management practices. Results indicate that N treatment with 40% basal + 30% AT and 30% before PI produced the highest grain yield in BRRI dhan66, BRRI dhan71 and BRRI dhan57 followed by PUA at 7 DAT application. In all the varieties, 100% basal N produced lower yield compared to other N treatments except the control (-N). Control treatment produced the lowest grain yield in all the varieties. Therefore attention should be given to N splitting with treatment 40% basal+30% AT and 30% before PI to achieve higher yield. N application with prilled urea applicator is better choice for obtain higher grain yield in all the varieties.

WEED MANAGEMENT

Screening of rice varieties for weed competitiveness

The experiment was conducted at two sites at BRRI farm, Gazipur sadar and Sultanpur, Kapasia of Gazipur to determine the weed competitive ability of most popularly grown 14 rice varieties in Boro season. The experiment was conducted following RCB design with three replications. BR17 seems most promising for weed competitiveness. BR17 have the ability to suppress weed and at pre flowering stage dead-dried weeds were found in BR17 plots (Table 11). Grain yield of BR17 were 5.05 and 5.06 t ha^{-1} in weedy and unweeded plot respectively in Gazipur (Table 11). In Kapasia, BR17 obtained 5.06 t ha^{-1} in weedy plots and weed free plots it was 5.64 t ha^{-1} (Table 12). Grain yield of BR17 in weedy and weed free plots were similar, which was more than 5.0 t ha^{-1} in both the areas. Among the other varieties BRRI dhan45 and BRRI hybrid dhan5, hybrid mollica and SL8 showed weed competiveness to some extent based on weed population, weed dry matter weight, plant height, initial tillering ability and dry matter weight of crops.

Table 11. Weed occurrence in weedy plot and grain yield in weedy and weed free plot of Boro 2018-19 in BRRI, Gazipur.

Variety	35 DAT		50 DAT		75 DAT		Grain yield (t ha^{-1})		
	Weed no. m^{-2}	Weed wt. (g m^{-2})	Weed no. m^{-2}	Weed wt. (g m^{-2})	Weed no. m^{-2}	Weed wt. (g m^{-2})	Un weeded	Weed free	Yield difference
V_1	11	3.14	14	15.92	7	6.18	5.05	5.06	0.01
V_2	38	7.89	13	47.46	12	8.18	2.90	6.60	3.70
V_3	27	6.92	14	38.94	11	7.08	3.11	6.90	3.80
V_4	17	3.92	17	21.56	10	7.76	4.54	5.71	1.17
V_5	29	7.61	15	37.92	14	9.03	4.81	5.67	0.86
V_6	27	6.99	16	30.56	16	10.93	3.23	6.58	3.35
V_7	29	6.97	16	43.65	19	11.69	2.65	6.38	3.73
V_8	29	7.00	10	39.67	10	11.19	2.74	6.61	3.87
V_9	32	6.76	35	52.00	16	10.15	1.81	5.33	3.52
V_{10}	30	5.35	21	39.43	13	9.49	2.88	5.42	2.54
V_{11}	19	4.83	20	21.01	11	6.97	4.55	6.91	2.36
V_{12}	34	11.47	28	56.97	11	13.49	3.53	5.63	2.10
V_{13}	27	10.17	24	33.38	14	13.00	4.87	5.71	0.84
V_{14}	24	7.40	29	42.88	12	9.76	5.42	6.64	1.22

BRRI dhan17 (V_1), BRRI dhan29 (V_2), BRRI dhan50 (V_3) BRRI dhan67 (V_4), BRRI dhan84 (V_5), BRRI hybrid dhan5 (V_6), SL-8 (V_7), BRRI dhan28 (V_8), BRRI dhan45 (V_9), BRRI dhan58 (V_{10}), BRRI dhan81 (V_{11}), BRRI dhan86 (V_{12}), Jholok (V_{13}), Mollica (V_{14}).

Table 12. Weed occurrence in weedy plot and grain yield in weedy and weed free plot in Boro 2018-19 at farmer's field of Kapasia.

Variety	35 DAT		50 DAT		75 DAT		Grain yield (t ha^{-1})		
	Weed no. m^{-2}	Weed wt. (g m^{-2})	Weed no. m^{-2}	Weed wt. (g m^{-2})	Weed no. m^{-2}	Weed wt. (g m^{-2})	Un weeded	Weed free	Yield difference
V_1	18	15.43	21	23.22	28	15.33	5.06	5.64	0.58
V_2	100	49.33	72	87.99	53	54.78	3.16	5.87	2.71
V_3	64	28.17	64	123.43	53	76.88	3.88	6.27	2.39
V_4	43	23.44	47	67.44	51	45.33	4.15	5.84	1.69
V_5	73	26.50	79	89.44	64	56.87	2.23	5.01	2.79
V_6	77	32.33	59	121.33	55	69.87	2.73	5.75	3.02
V_7	92	42.00	98	118.44	62	75.54	2.78	5.34	2.56
V_8	103	45.83	87	117.45	84	80.76	2.03	5.08	3.05
V_9	71	28.17	84	132.00	73	71.22	2.72	5.44	2.71
V_{10}	70	29.07	66	95.33	63	76.98	3.15	5.71	2.55
V_{11}	93	43.67	86	126.33	70	77.88	4.43	6.42	1.99
V_{12}	71	29.00	88	140.00	48	56.78	3.75	6.04	2.29
V_{13}	28	24.67	38	45.87	52	34.33	4.59	5.97	1.38
V_{14}	32	21.32	39	38.87	55	23.56	4.70	5.73	1.03

Study on bio-efficacy and varietal sensitivity of different herbicides

The experiments were conducted at BRRI HQ farm, Gazipur to evaluate the efficacy of different herbicide and varietal tolerance of Boro rice to different herbicide applications. Treatments included four Boro varieties viz i. BRRI dhan28 ii) BRRI dhan29 iii) BRRI dhan58 iv) BRRI dhan81 and four weed management systems. Weed management treatments were i) Pre emergence herbicide (Mefenecet + Bensulfuron methyl) + 1HW ii) Post emergence herbicide (Phenoxlum) + 1HW iii) Weed Free by three hand weeding and iv) Unweeded control. No phytotoxicity was observed due to herbicide application. In some plants, slightly yellowish leaves were observed (Table13). Weed management by pre and post emergence herbicide effectively control weeds in different varieties. Weed number and dry matter weight was lower in herbicidal treatment (Table 14). However, the lowest weed number and dry matter weight were observed in weed management by three hand weeding irrespective of variety in both 45 and 60 DAT. Weed control efficiency (%) was observed 91-96% in three hand weeding plots although herbicidal treatment showed 87-93% weed control efficiency (Table 14). Higher crop resistance index (CRI) was observed after 60 DAT irrespective variety compared to 45 DAT. Crop resistance index varied 7-26 at 45 DAT whereas at 60 DAT, crop resistance index varied 11-37. The aboveground biomass of rice (DMP) and crop resistance index (CRI) was closely related to each other. Higher the biomass, higher the CRI and lower the biomass lower the CRI. With increase in rice biomass, corresponding crop resistance index was increased (Fig. 1a). A positive linear correlation was observed in crop resistance index and dry matter production of rice (rice biomass) at 45 and 60 DAT. The relationship of grain yield with weed biomass indicating significant negative correlation with grain yield (Fig. 1b). Among weed management treatment herbicide and hand weeded treatments produced statistically similar grain yield (Table 15). Herbicide treatment strongly influenced grain yield as it produced 40-49% higher yield than that of the season long unweeded check.

Table 13. Phytotoxicity of herbicide in different rice varieties.

Variety	Herbicide treatment	Scoring of phytotoxicity	Toxicity symptom observed in rice crop
BRRI dhan28	Mefenecet+ Bensulfuron methyl 53%wp	1.2	No phytotoxicity. Slightly yellowing of leaves. Required 3-4 days to recover
	Penoxsulam 240 SC	1.12	No phytotoxicity. Very slightly yellowing of leaves. Required 3-4 days to recover
BRRI dhan29	Mefenecet + Bensulfuron methyl 53%wp	1.1	No phytotoxicity. Very slightly yellowing of leaves. Required 2-3 days to recover
	Penoxsulam 240 SC	1.1	No phytotoxicity. Very slightly yellowing of leaves. Required 2-3 days to recover
BRRI dhan58	Mefenecet + Bensulfuron methyl 53%wp	1.1	No phytotoxicity. Very slightly yellowing of leaves. Required 3-4 days to recover
	Penoxsulam 240 SC	1.13	No phytotoxicity. Very slightly yellowing of leaves. Required 3-4 days to recover
BRRI dhan81	Mefenecet + Bensulfuron methyl 53% wp	1.2	No phytotoxicity. Slightly yellowing of leaves. Required 3-4 days to recover
	Penoxsulam 240 SC	1.14	No phytotoxicity. Slightly yellowing of leaves. Required 3-4 days to recover

Table 14. Effect of weed management treatments on weed occurrence, WCE and CRI in Boro 2019 at BRRI, Gazipur.

Treatment		45 DAT				60 DAT			
Variety	Weed mgt.	Weed no. (m^{-2})	Weed wt. (g m^{-2})	WCE (%)	CRI	Weed no. (m^{-2})	Weed wt. (g m^{-2})	WCE (%)	CRI
BRRI dhan28	W1	15	9.50	87	7.52	10	7.35	90	11.3
	W2	12	8.33	89	12.7	7	6.22	91	16.3
	W3	8	5.51	93	11.3	6	4.24	94	23.1
	W4	113	75.99			108	70.10		
BRRI dhan29	W1	10	12.16	85	9.4	8	10.01	86	11.5
	W2	8	11.02	86	9.4	8	6.70	91	23.4
	W3	7	7.05	91	14.3	6	3.16	96	37.6
	W4	117	79.43			105	72.40		
BRRI dhan58	W1	11	8.36	89	11.5	7	6.55	91	15.6
	W2	9	7.58	90	13.5	6	5.18	93	22.0
	W3	6	5.46	92	19.8	5	4.35	94	24.4
	W4	97	72.73			107	70.23		
BRRI dhan81	W1	7	8.59	92	19.6	6	7.06	91	15.7
	W2	9	7.76	93	20.0	8	6.44	92	15.0
	W3	6	7.04	94	26.9	5	4.33	95	25.4
	W4	150	113.50			132	80.07		
$LSD_{(.05)}$ for main plot (V)		5.40	3.08			3.40	ns		
$LSD_{(.05)}$ for subplot (W)		6.75	2.99			4.52	4.46		
$LSD_{(.05)}$ for VxW		13.50	5.98			9.05	ns		
CV (%)		21.9	12.9			16.1	23.3		

Table 15. Yield and yield contributing character of different varieties as affected by weed management treatment during Boro 2019 at BRRI farm, Gazipur.

Variety	Weed mgt	Panicle m^{-2}	Grain panicle^{-1}	1000 grain wt (g)	Grain yield (t ha^{-1})	YIOC (%)
BRRI dhan28	W1	292	108	21.59	7.11	45
	W2	297	114	22.52	7.17	45
	W3	348	129	23.14	7.58	48
	W4	204	77	21.10	3.92	
BRRI dhan29	W1	319	124	21.07	7.33	46
	W2	353	137	21.37	7.73	49
	W3	360	144	22.02	7.74	49
	W4	205	79	19.81	3.98	
BRRI dhan58	W1	324	118	22.55	7.40	45
	W2	335	134	23.30	7.49	46
	W3	299	109	22.04	6.83	40
	W4	210	80	20.36	4.08	
BRRI dhan81	W1	303	109	21.48	6.47	42
	W2	290	101	21.09	6.28	40
	W3	318	111	21.69	6.57	42
	W4	201.7	77	20.06	3.78	45
$LSD_{(.05)}$ for main plot (V)		ns	ns	ns	ns	
$LSD_{(.05)}$ for subplot (W)		21.34	10.42	1.37	0.52	
$LSD_{(.05)}$) for V x W		ns	ns	ns	ns	
CV (%)		9.9	8.7	11.3	7.6	-

YIOC= Yield increase over control.

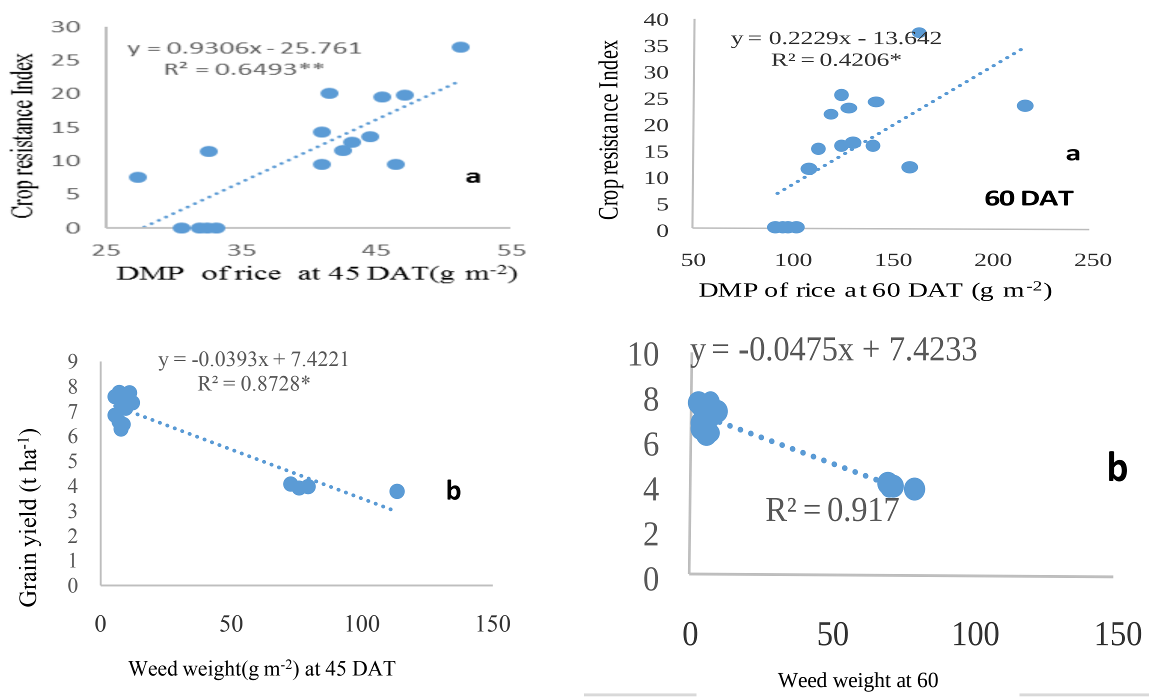


Fig. 1. Relationship of crop resistance index and dry matter production at 45 and 60 DAT (a) and dependence of grain yield on weed weight at 45 and 60 DAT (b).

Evaluation of candidate herbicides for transplanted rice

Field trials were conducted at the BRRI, Gazipur during T. Aman 2018 and Boro 2018-19 seasons to evaluate the efficacy of nine different groups of 15 candidate herbicides. Thirty-day-old seedlings of BRRI dhan56 in T. Aman, and BRRI dhan28 for Boro seasons were transplanted at a spacing of 20 × 20 cm with 2-3 seedlings hill^{-1}. Pre emergence herbicides were applied at 4 DAT and post emergence herbicides at 1-2 leaf stage of weed. Weed sampling was done at 40 DAT for T. Aman and 45 DAT for Boro season. Weed control efficiency was calculated on weed dry weight basis. Most of the herbicide obtained more than 80% weed control efficiency in different weed populations observed in the field (Table 16). Only *cynodon dactylon* cannot be controled >80% by any herbicide. Among nine groups of herbicide, four groups were for post emergence weed control and five were for pre emergence weed control.

Table 16. Herbicide chemical name, dose and weed efficacy of different herbicides evaluated during T. Aman 2018 and Boro 2018-19 at BRRI farm, Gazipur.

Chemical	Dose/ha	Weed control efficiency (%)					Remark
		Cynodon dactylon	*Echinochloa crus-galli*	*Monochoria vaginalis*	*Scirpus maritimus*	*Cyperus difformis*	
Fenoxyprop-p-ethyl 7%+ Bensulfuron methyl 15%	2.5 kg	75	84.88	82.50	80.33	80.12	Pre to early post emergence Satisfactory
		60	81.70	82.50	80.43	80.10	
Oxadiazone	2.0 L	75.60	80.22	80.90	85.20	84.50	Pre emergence Satisfactory
		74.11	82.89	81.29	81.27	82.54	
Pendamethalin	2.5 L	78.76	80.30	83.65	80.66	82.48	
		72.80	82.00	84.20	81.66	85.00	
Fluazifop-p-butyl 12.5% EC	1.0 L	60.76	86.00	80.50	83.60	82.90	Pre emergence to early post emergence Satisfactory
		77.80	81.58	80.90	82.75	78.47	
Pretilachlor	1.25 L	78.90	80.22	83.55	79.88	80.90	Pre emergence Satisfactory
		77.50	82.20	80.75	80.50	80.75	
		69.90	82.00	84.45	81.76	80.50	
Bensulfuron 2% + Pretilachlor 28%	9.00 kg	65.52	70.74	82.50	83.20	81.80	Pre emergence Satisfactory
Bensulfuran methyl 4% + Acetachlor 14%	500 g	60.90	80.80	80.90	80.75	82.41	Pre emergence Satisfactory
		64.60	83.00	86.60	80.80	80.62	
Bensulfuran methyl 4% + Quinclorac 34%	600 g	65.60	84.33	80.66	80.00	83.11	Post emergence Satisfactory
		73.20	72.90	79.40	80.06	80.76	
2.4 D Amine 72%	1.5 L	70.00	80.22	83.60	84.00	80.5o	Post emergence Satisfactory
		56..66	81.45	80.20	82.30	81.40	

YIELD MAXIMIZATION

Yield maximization of aromatic rice through integrated nutrient management

The experiment was conducted at BRRI farm, Gazipur during T. Aman 2018 to evaluate appropriate integrated nutrient management practice in aromatic rice. The treatments included inorganic and organic combinations of nutrient management and varieties. The experiment was conducted following RCB factorial design with three replications. Nutrient management treatments were recommended rate of fertilizer (RRF) @ 24-10-13-9-1.3 kg bigha^{-1} of urea-TSP-MoP-Gypsum-Zn sulphate for BRRI dhan70 and 20-7-11-8-1.5 kg bigha^{-1} of urea-TSP-MoP-Gypsum-Zn sulphate for BRRI dhan75 (F_1), RRF with DAP

(Reduced 4 kg urea for BRRI dhan70 and 2.8 kg for BRRI dhan75 bigha^{-1}) (F_2), RRF with trio compost (2 t ha^{-1}) (mixture of water hyacinth, rice husk and cow dung) (F_3), 75% RRF + 25% from N from PM (F_4), 75% RRF + 25% N from vermicompost (F_5), Control (without fertilizer) (F_6). 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. 2). Regression analysis showed that (Fig. 2) LAI at booting stage was significantly correlated with grain yield. The type of regression between LAI and grain yield was of linear nature. Interaction effect of variety and INM was significant in grain yield and yield components (P> 0.05) but individual effect of variety not was not significant, as INM significantly varied (Table 17). Higher grain yield of 5.40 and 5.24 t ha^{-1} was observed in BRRI dhan75 and BRRI dhan70 respectively with 75% BRRI recommended fertilizer dose + 25% N from PM followed by 5.16 t ha^{-1} grain yield from 75% RRF+ 25% N from vermicompost in BRRI dhan75 and 5.13 t ha^{-1} grain yield from RRF with DAP in BRRI dhan70.

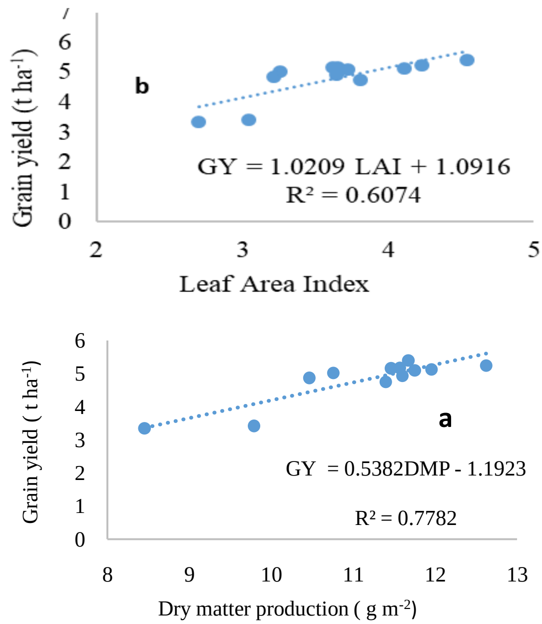


Fig. 2. Relationship of dry matter production and grain yield (a) and relationship of leaf area index and grain yield (b) as affected by variety and integrated nutrient management.

Table 17. Yield and yield characters of BRRI dhan70 and BRRI dhan75 as affected by integrated nutrient management.

Treatment BRRI dhan70	Nutrient management	Panicle m^2	Grain panicle-1	1000 grain weight (g)	Grain yield (t ha^{-1})
	F_1	190	131	19.18	4.75
	F_2	201	141	20.12	5.13
	F_3	197	135	21.04	5.10
	F_4	205	151	18.92	5.24
	F_5	193	128	20.29	4.94
	F_6	186	111	19.12	3.41
	F_1	200	107	21.11	5.03
	F_2	199	104	20.66	4.86
BRRI dhan75	F_3	206	136	20.54	5.15
	F_4	210	154	20.88	5.40
	F_5	208	142	19.84	5.16
	F_6	178	92	20.08	3.35
LSD (0.05) for variety (V)	-	ns	ns	1.03	ns
LSD for nutrient management (NM)	-	12.09	26.70	ns	0.44
LSD for V × NM	-	16.83	36.86	ns	0.67
CV (%)	-	5.1	17.1	3.0	8.3

Soil Science Division

SUMMARY

BR89207-45-2-2 would be worth used as high yielding-N use efficient PQR line. Out of the studied FBR lines IR99056-B-B-15 and BR8938-30-2-4-2-1 required lower N fertilizer and had greater potential to utilize native soil N. Lower optimum N application rate but higher yield of BR (Bio) 9777-118-6-4 is indicative of its potential as efficient N use FBR line. The study on ZER's N response trial demonstrates that BR8631-12-3-5-P2 may employ as efficient N use ZER line.

Application of urea-HA nano-fertilizer as N source may curtail 50% urea-N use during Boro rice season. The calculated economically optimum N for BRRI dhan75, BRRI dhan89 and BRRI dhan58 was 85 kg/ha, 149 kg/ha and 144 kg ha^{-1} respectively. BRRI dhan50 and BRRI dhan63 produced higher yield with STB chemical fertilizer, however combination of organic and inorganic fertilizer also gave a satisfactory yield. A combination of 50 kg K and 50 kg N for BRRI dhan72 and 100 kg K and 120 kg N for BRRI dhan74 cultivation seems to be suitable for desired yield. Despite the variations in soil P levels, application of recommended dose of P fertilizer might be useful to recover the rice yield loss. In the first, second and third crop cycle, AEZ based chemical fertilizer seems to be enough for obtaining potential yield of each crop in both the patterns. Mechanical fertilizer application may save labour cost, however the highest grain yield was observed in the recommended dose of urea by hand broadcasting @135 Kg N ha^{-1} which was statistically higher than PU or USG @ 78 kg/ha by applicator.

Long-term application IPNS based fertilizers showed increasing trend of rice yield, while inorganic fertilizer alone showed yield plateau. So, IPNS based fertilizer management is necessary for sustainable rice production in Bangladesh. STB (50%) + MM treatment may improve soil health. Cumulative yield of triple cropping was always higher than double rice cropping pattern irrespective of treatments. Soil nutrient availability and ratios influenced crop production. Grain yield was the lowest in Gazipur and Rangpur soil compared to Habiganj and Bhanga, might be due to unfavourable C:N and S:Zn ratios. The industrial polluted soils of Gazipur and Sripur have high organic matter and high Fe content which induced Fe toxicity in rice. In these soilsthere was no or little effect of added organic matter and biochar was recorded.Application of bio-organic fertilizer (1-2 t ha^{-1}) along with 30% reduced urea and 100% removal of TSP fertilizer increased or produced similar grain yield at different locations. Bio-organic fertilizer increased rice yield in saline soil.

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. High temperature induced more soil carbon emission from both chemical fertilizer and integrated plant nutrient system.

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. Separate field trials were conducted for PQR, FBR and ZER genotypes following RCB design at BRRI HQ farm, Gazipur (AEZ 28) during Boro season of 2018-19. Tested three PQR lines were BR8590-5-2-5-2-1, BR8590-5-2-5-2-2 and BR89207-45-2-2, four FBR lines were BR(Bio)9777-26-4-3 and BR (Bio) 9777-118-6-4, IR99056-B-B-15, BR8938-30-2-4-2-1 and two ZER lines were BR8631-12-3-5-P2, BR8631-12-3-6-P3. Six urea-N doses (kg ha^{-1}): N_0, N_{40}, N_{80}, N_{120}, N_{160} and N_{200} with standard doses of P, K, S were applied for each experiment. Over all the tested ALART materials, grain yields responded diversely to applied N rates. Quadratic regression model was well fitted (R^2= 0.72 to 0.99) to the grain yield vs N rates irrespective of lines. The additional grain yield of 1.2 to 1.4 t ha^{-1} with optimum N rate of 160 kg N ha^{-1} in BR89207-45-2-2 directed its worth-use as high yielding-N use efficient PQR line. Comparable grain yield at optimum N rate of 148 kg N ha^{-1} in BR8590-5-2-5-2-1 indicated it as another N use efficient PQR line. Among the FBR lines, the higher grain yield in N_0 and lower optimum N doses in IR99056-B-B-15 (142) and BR 8938-30-2-4-2-1 (171) indicated their greater potential to utilize native soil N. The lowest optimum N doses (113 kg N ha^{-1}) with extra yield advantages of 1.2 to 1.3 t ha^{-1} in N_0 of BR(Bio)9777-118-6-4 than other two FBR genotypes indicated its higher aptitude to uptake native soil N and consider as efficient N use line. Comparable grain yields but lower optimum N rate (169 kg N ha^{-1}) of BR8631-12-3-5-P2 (213-214 kg N ha^{-1}) employed it as efficient N use ZER line with no yield sacrifice. Nevertheless, the lowered grain yield (by 0.9 to 2.2 t ha^{-1}) and optimum N rate (121 kg N ha^{-1}) of BR8631-12-3-6-P3 pointed out its apt use as low N input ZER line, but with yield penalty.

Increasing N use efficiency and determining nutrient requirements of MV rice. Increasing N fertilizer use efficiency through nano-strategies in paddy cultivation of Bangladesh is crucial, it may save national investment and minimize environmental (water and air) harms with increased farm profitability. A rice growth pot experiment was conducted in BRRI Soil Science greenhouse, to evaluate N use efficiency of typically synthesized urea-HA (hydroxyapatite) nanohybrid over prilled urea using terrace paddy soil of BRRI farm Gazipur during 2019 Boro (dry) season. Urea-HA nanohybrids was synthesized at urea to HA ratio of 6:1 according to approach suggested by Kottegoda *et al.* (2017) and BRRI dhan89 was grown in the greenhouse under continuous flooding for 116 days.

Biomass yield and N use efficiency. Overall the total biomass yield and yield contributing parameters such as number of effective tiller, panicle and filled grain per pot were lower in the N untreated pot (T_1) than in the N fertilizer treated pots (T_2, T_3 and T_4) (Table 1). Accordingly, the grain yield in N treated pots (T_2, T_3 and T_4) pots) ranged from 22-25 g pot^{-1} equivalent to 6.3-6.8 t ha^{-1} and was strikingly greater (by 1.4 to 4.7 g pot^{-1}equal to 1.0-1.4 t ha^{-1}) than in the N untreated counterpart (T_1). Maximal grain yield was recorded at T_3 while the lowest yield was obtained in theT_1. Grain yields at T_2 and T_4 were almost identical. Higher fertilizer N-agronomic (AE_N) efficiency (kg grain kg^{-1} N applied) was attained from the urea-HA nanohybrid treated pots i.e. from T_4 (16) and T_3 (12) over prilled urea treated pot, T_2 (9) (Table 1). This initial trial revealed that utilization of urea-HA nano hybrid increased rice grain yield and saved up to 50% urea use.

Grain yield and optimum nutrient management. The optimum N requirement of BRRI dhan75, BRRI dhan89 and fertilizer management for premium quality rice, BRRI dhan50 and BRRI dhan63 was determined. The experiments were laid out in a RCB design with three replications. The grain yield of BRRI dhan75 increased with the increased N rates up to 100 kg ha^{-1} then it declined. The calculated

Table 1. Grain yield, agronomic efficiency (AE_N) and typical yield attributes (means ± standard error) of the studied greenhouse rice growth pot experiment during Boro 2019.

Parameter	Treatment			
	T_1: PKSZn	T_2: Urea-N_{120}PKSZn	T_3: Nano fert.-N_{120}PKSZn	T_4: Nano fert.-N_{60} PKSZn
Grain yield (t ha^{-1})	5.4 ± 0.6	6.4 ± 1.1	6.8 ± 0.1	6.3 ± 1.1
1000 grain O.D. wt. (g)	19 ± 0.2	18 ± 0.0	18 ± 0.1	18 ± 0.2
Plant height (cm)	82 ± 0.6	80 ± 2.1	83 ± 1.3	81 ± 2.1
Effective Tiller no. pot^{-1}	14 ± 2.5	19 ± 1.1	18 ± 0.4	15 ± 1.4
Ineffective tiller no. pot^{-1}	3 ± 1.8	2 ± 1.1	2 ± 0.4	4 ± 2.8
Panicle no. pot^{-1}	14 ± 2.5	19 ± 1.1	18 ± 0.4	15 ± 1.4
Panicle length (cm)	22 ± 0.6	21 ± 0.7	22 ± 0.5	22 ± 0.4
Filled grain no. pot^{-1}	1056 ± 144	1180 ± 244	1386 ± 46	1221 ± 196
% sterility	21 ± 1.1	25 ± 7.3	24 ± 2.2	18 ± 1.0
AE_N (kg grain kg^{-1} N applied)	-	9	12	16

optimum N dose from the quadratic equation that maximized the grain yield was 91 kgha^{-1}. However, the economically optimum N dose appeared as 85 kgha^{-1}. The grain yield of BRRI dhan89 increased with the increased N rates up to 160 kgha^{-1}. The calculated optimum N dose from the quadratic equation showed maximum grain yield of BRRI dhan89 was 151 kgha^{-1}. However, the economically optimum N dose appeared as 149 kgha^{-1}. BRRI dhan50 and BRRI dhan63 gave significantly higher grain and straw yield at 100% soil test based (STB) chemical fertilizers, however the combination of organic and inorganic fertilizer gave a satisfactory yield of both the varieties (Table 2).

Nutrient management for growing four crops in a year. An experiment has been initiated in T. Aus 2016 to grow four crops in a year for sustainable soil fertility status as well as increasing productivity. Three fertilizer treatments, soil test based (STB) fertilizer (T_1), crop residues (CR) + STB fertilizer (T_2) and fertilizer control i.e. native soil nutrients (T_3) were tested with Mustard-Boro-T. Aus-T. Aman and Mustard-Mungbean-T. Aus-T. Aman patterns. Experiment design was randomized complete block with three replications. First crop mungbean was incorporated in T_2 treatment. After two crop cycle, T_1 and T_2 treatments gave similar yield in each crop. In the 3rd year and 3rd crop cycle, two cropping pattern were also gave their potential yield with AEZ based chemical fertilizer application (T_1) as well as with crop residue incorporation (T_2)). Yield was significantly lower in native nutrient condition (Table 3).

Influence of N and K rates. The objectives of the present study were to find out suitable N and K ratio for MV rice cultivation and to study their dynamics in soil-and plant systems. Five years study from T. Aman 2014 to Boro 2019 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 dhan72 was significant. In K deficient condition, application of increasing N significantly decreased grain yield and in N deficient condition, K rates were not responsible for increased

Table 2. Effect of organic and inorganic fertilizer management on grain and straw yield (t ha^{-1}) of BRRI dhan50 and BRRI dhan63 at BRRI, Gazipur in Boro 2018-19.

Treatment	BRRI dhan50		BRRI dhan63	
	Grain	Straw	Grain	Straw
T_1 = Control	1.87 d	1.8 d	1.74 d	1.47 d
T_2 = STB dose	6.16 a	6.07 a	6.29 a	5.33 a
T_3 = CD/ha (2.5 ton) + 50% STB	5.57 b	5.17 b	5.61 b	4.51 b
T_4 = CD/ha (5 ton)	4.38 c	3.48 c	4.53 c	3.31 c
CV (%)	4.26	5.38	4.15	7.14
LSD (0.05)	0.38	0.44	0.38	0.52

Table 3. Grain yield (t ha^{-1}) of T. Aus (BRRI dhan 65) T. Aman (BRRI dhan 62), Mustard (BARI sharisa14), Boro (BRRI dhan28) and Mungbean (BARI mung-6) at BRRI HQ Gazipurin 2018-19.

Treatment	T. Aus 2018		T. Aman 2018		Mustard 2018-19		Boro 2019	Mung bean 2019
	CP1	CP2	CP1	CP2	CP1	CP2	CP1	CP2
T_1= STB FERTILIZER DOSE	3.50 a	3.64 a	4.23 a	4.67 a	1.056 a	1.070 a	5.33 a	0.48 a
T_2= CROP RESIDUES (CR)+T_1	3.58 a	3.77 a	4.43 a	4.68 a	1.153 a	1.163 a	5.62 a	0.52 a
T_3= NATIVE NUTRIENT	1.74 b	1.76 b	2.24 b	1.92 b	0.122 b	0.128 b	2.90 b	0.27 b
CV (%)	6.1	1.7	2.5	1.9	2.9	2.3	3.72	11.81

grain yield. Application of N @ 50 kg ha^{-1} with 50 kg K ha^{-1} produced 5.20 t ha^{-1} rice grains, which was statistically identical with the highest grain yield of 5.26 t ha^{-1} achieved with a combination of 50 kg N and 100 kg K ha^{-1}. It proved that 50 kg K and 50 kg N combination is suitable for BRRI dhan72 rice cultivation to get optimum yield in Gazipur soil. Total N uptake significantly increased with the increase of N rates at different levels of K rates. At K deficient condition, increasing dose of N increases the total N uptake and also at N deficient condition N uptake increased with increasing level of K. Application of K after 150 kgha^{-1}decreased total N uptake. At K deficient condition, total P uptake was significantly decreased at 100 kgha^{-1}dose of N but at N deficient condition, increasing level of K increased total P uptake at different ranges. In Boro, application of N @ 120 kg ha^{-1} with 100 kg K ha^{-1} produced 6.03 t ha^{-1} rice grains, which was statistically identical with the highest grain yield of 6.40 t ha^{-1} achieved with a combination of 140 kg N and 150 kg K ha^{-1}. Thus it is evident that 100 kg K and 120 kg N combination is suitable for BRRI dhan74 rice cultivation to get optimum yield in Gazipur soil.

Performance of rice variety under phosphorus deficit conditions. Acute P deficiency reduces rice yield depending on internal and/or external mechanisms that allow greater soil P extraction. An experiment was conducted at BRRI farm, Gazipur during 2018-19 in dry season (Boro) 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. Soil available P groups were 1.70-2.30, 2.31-2.90, 2.91-3.50 and 3.51-4.10 mg kg^{-1} in dry season. Each plot received 150 kg N, 60 kg K and 10 kg S ha^{-1} in dry seasons as flat dose. In sub-plots, 0 and 20 kg ha^{-1}P fertilizer doses were arranged and BRRI dhan89 was used as tested genotype.

Grain and straw yield. The soil P and fertilizer P significantly influenced grain production of BRRI dhan89 in Boro season. Grain yield in the fertilizer P control plot progressively increased with the increasing level of soil P and the highest grain yield (4.41 t ha^{-1}) was recorded in the highest soil P level, which was significantly different from any other soil P levels. Significantly the highest grain yield (7.08 t ha^{-1}) of BRRI dhan89 in P fertilized plot was found at the highest soil P level (3.51-4.10 mg kg^{-1}), while the lowest yield (5.91 t ha^{-1}) was observed at the lowest soil P level (2.31-2.90 mg kg^{-1}). 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 in P fertilized condition.

Performance of prilledurea (PU) and urea super granule (USG) applicators in Boro rice. A field experiment was conducted on validation of PU and USG by applicators on yield and N mineralization in Boro rice 2018-19 at BRRI HQ farm Gazipur. Four treatment combinations of different N doses and methods of N application were tested to compare urea-N application by PU and USG applicator for rice yield.

Plant growth and yield. The tiller and panicle number per meter square, grain yield and straw yield were significantly influenced by applying N from different forms and application methods in Boro rice of BRRI dhan89 over control (Table 4). The highest tiller number was observed in T_2 treatment where PU was applied by hand broadcasting as recommendation dose which was comparable with T_3 and T_4 treatment where N was applied as USG and PU respectively by applicators. The highest panicle production per meter square was observed in urea broadcasting treatment followed by USG and PU by applicator treatments and the lowest in N control treatment. The significantly highest grain yield was observed in T_2 (7.30 t ha^{-1}) where N was used @ 135 kg ha^{-1} as PU hand broadcasting followed by T_3 (6.83 t ha^{-1}) and T_4 (6.72 t ha^{-1}) where N was used @ 78 kg ha^{-1} as USG and PU by applicators which were statistically lower than urea broadcasting (Table 4). A similar trend was observed for straw yield in different treatments. The filled grain percent was lower in USG and PU applied by applicators plots. The 1000 grain weight (TGW) was statistically similar for all N treatments including N control. But comparatively higher TGW was observed in USG deep placement (23.64 g) and PU deep placement (23.36 g) method (Table 4).

Table 4. Effect of PU and USG used by applicator on yield (t ha^{-1}) and yield components of Boro rice, at BRRI HQ, Gazipur in 2018-19.

Treatment	Tiller m^{-2}	Panicle m^{-2}	Grain yield	Straw yield	Filled grain (%)	1000 grain weight (g)
T_1 = N control	164 b	156 c	3.19 c	3.01 c	92.07 a	23.11
T_2 = N 135 kg ha^{-1} (as PU by hand broadcasting)	296 a	282 a	7.30 a	7.17 a	78.50 b	23.24
T_3 = N 78 kg ha^{-1} (as USG by applicator)	286 a	274 a b	6.83 b	6.64 b	62.51 c	23.64
T_4 = N 78 kg ha^{-1} (as PU by applicator)	287 a	272 b	6.73 b	6.58 b	62.87 c	23.36
CV (%)	2.82	2.08	2.93	2.94	8.86	2.02
LSD (0.05)	15	10	0.35	0.34	13.09	NS

Micronutrient status of some selected paddy soils of Bangladesh. This study was conducted to know the micronutrient status (Zn, Fe, Cu, Mn) of some selected paddy soils of Bangladesh. Soil samples were collected from different locations of Gazipur, Habiganj, Bhanga and Rangpur before Boro season. The soil samples were collected from 0-20 cm depth and rice based cropping pattern. In total 100 soil samples were collected from different locations. From each location 25 samples were collected.

Status of soil Zn, Fe, Cu and Mn. The status of soil Zn is above the critical limit of the most tested soil except few soils of the Rangpur area. The highest 51 ppm Zn was recorded in Gazipur soil. The Fe concentration ranged from 107-609 ppm, however it was higher in the Habiganj soil compared to other three studied soil. Copper concentration was high in the Bhanga soil. Except Rangpur soil the Mn concentration was high in other three studied soils. In comparison of these four regions, the soil of Rangpur contained lower Zn and Mn concentration (Table 5).

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 (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). 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. In the T. Aman and Boro seasons, omission of N, P, and K decreased rice yield compared to complete fertilizer treatment (Table 6).

Table 5. Ranges of Zn, Fe, Cu and Mn in ppm of some selected paddy soils of Bangladesh.

Location	Zn	Fe	Cu	Mn
Gazipur	4.81-51.27	107-376	4.40-6.52	7.90-83.41
Rangpur	0.63-4.78	145-426	3.27-5.11	1.04-5.40
Habiganj	4.31-14.15	220-609	3.51-6.81	8.65-84.46
Bhanga	3.47-14.61	149-394	10.8-15.4	4.04-87.77

In the T. Aman season, among the organic materials, CD and VC treated plot were produced the highest grain yield (5.65 and 5.57 t ha^{-1}). However, yield differences among the organic material treated plots were insignificant. In the Boro season, the complete fertilizer treatment gave 6.07 tha^{-1} grain yield, which was significantly decreased to 4.13, 2.81, and 2.49 t ha^{-1} due to omission of N, P and K respectively. Among the organic materials, application of CD @ 3 t ha^{-1} with IPNS based fertilizer produced the highest grain yield (6.55 tha^{-1}) followed by PM @ 2 tha^{-1} and VC 2 t ha^{-1} which were statistically insignificant with complete fertilizer treatment. Reduced dose of K @ 40 kg K ha^{-1} produced significant lower grain yield than complete fertilizer treatment.

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.

Rice production trend and annual nutrient removal. Annual rice production is in decreasing trend because of continuous rice cultivation without fertilizer application. In 2018, grain yield in control plot was 1.10-2.92 t ha^{-1} irrespective of season. When NPKSZnCu fertilizers were used as reverse treatment, total rice production jumped to 14.35 t $ha^{-1}yr^{-1}$ which was close to complete fertilization (14.09 t ha^{-1} yr^{-1}). In Boro, 2018 rice grain yield was higher (5.11 $tha^{-1)}$ in complete fertilizer (NPKSZn) treatment followed by reverse management (Fig. 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.

Table 6. Effect of organic and inorganic nutrients on rice grain and straw yield (t ha^{-1}) of BRRI dhan49 and BRRI dhan58 at BRRI HQ, Gazipur in 2018-19.

Treatment	T. Aman		Boro	
	Grain	Straw	Grain	Straw
NPKSZn@100-7-80-3-5 kg/ha	5.27	6.60	6.07	5.95
NPSZn (-K)	3.41	6.27	4.13	4.40
NKSZn (-P)	3.86	6.12	2.81	3.05
PKSZn (-N)	4.30	5.34	2.49	2.63
CD (3 t/ha) + IPNS	5.65	5.63	6.55	6.74
NPKS (-Zn)	5.31	5.54	6.28	6.47
NPKZn (-S)	5.27	5.26	5.95	6.31
PM (2t/ha) + IPNS	5.44	6.39	6.34	6.02
NPKSZn.@100-7-60-3-5 kg/ha	5.52	6.49	5.63	6.02
VC (2t/ha) + IPNS	5.57	6.54	6.19	6.28
NPKSZn@100-7-40-3-5 kg/ha	5.13	5.94	5.10	5.33
Control	3.26	4.58	1.59	1.90
$LSD_{0.05}$	0.45	1.67	0.79	1.04
CV (%)	3.12	9.54	6.45	8.19

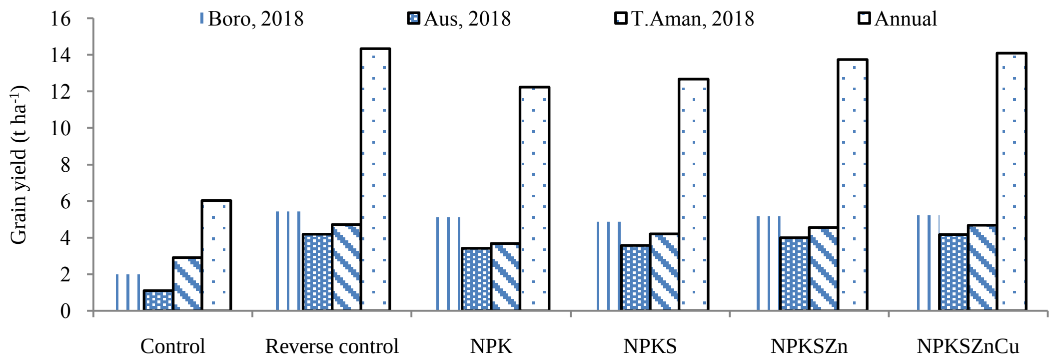


Fig. 1. Effect of NPKSZnCu on yield of triple rice crop at BRRI farm, Gazipur, in 2018.

Delineating of rice yield limiting soil factors for some selected paddy soils. The yield of same rice variety varied with different locations. The variation of yield offers a great opportunity to conduct research and find out indigenous soil nutrient ratios, yield limiting soil factors and the relationship of nutrient ratios with rice yield. Soil samples from 0-20 cm depth were collected from Gazipur (AEZ 28), Habiganj (AEZ 21), Rangpur (AEZ 3) and Bhanga (AEZ 12) using global positioning system (GPS) record along with plot history. Collected samples were analyzed for physical and chemical properties.

Native soil nutrient ratio and grain yield. Indigenous soil nutrient availability and ratios influence crop production in different ecosystems depending on crop variety and water management. Organic C and essential plant nutrients were high in these two soils compared to Gazipur and Rangpur. In Habiganj (AEZ 21), C:P, N:P and Ca:P ratios were the widest compared to Bhanga (AEZ 12) and Rangpur (AEZ 3) (Table 7). These clearly indicated that soils were deficient in P. Similar ratios of C:P, N:P and Ca:P were also found in Gazipur (AEZ 28) because of lower soil P levels. The C:N ratio ranged from 9.76 to 12.57. The C:K, N:K and P:K ratios were higher in AEZ 28 and AEZ 3 because of lower soil K levels. Our result indicated that grain yield was the lowest in AEZ 28 and AEZ 3 compared to other studied locations (Table 8), might be because of unfavourable C:N and S:Zn ratios. The lower S:Zn ratio indicates higher soil Zn availability might have affected S uptake and thus reduced rice yield.

Table 7. Native soil nutrient ratio of the studied soils.

Sand%	Silt%	Clay%	C:N	C:P	C:K	N:P	N:K	N:Mg	N:Zn	P:K	P:Zn	K:Ca	K:Mg	Ca:P	Ca:Zn	S:Zn
							Habiganj (AEZ 21)									
44	18	38	10	224	54	216	5	3	322	0.02	1	0.2	0.6	252	375	15
							Bhanga (AEZ 12)									
24	21	55	11	463	52	53	6	3	554	0.11	11	0.1	0.5	86	904	24
							Gazipur (AEZ 28)									
10	55	35	13	353	412	347	41	3	517	0.12	1	0.02	0.1	379	565	9
							Rangpur (AEZ 3)									
13	67	21	10	489	16	35	12	2	589	0.34	17	0.1	0.2	22	368	6

Table 8. Grain yield at different studied soils without fertilizer management.

Soil	BRRI dhan49		BRRI dhan58	
	Panicle no./pot	Grain weight/pot (g)	Panicle no./pot	Grain weight/pot (g)
Gazipur	17	19.7	13	24.0
Rangpur	16	19.5	15	29.7
Habiganj	34	44.2	44	54.3
Bhanga	18	20.2	40	48.6
$LSD_{0.05}$	5	7.5	3	3.5

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 2017-18 and T. Aman 2018 under double cropping pattern, 50% STB + MM fertilizer dose produced significant higher grain yield than 100% STB fertilizer dose. But under triple cropping pattern 100% STB and 50% STB + MM fertilizer doses produced statistically similar grain yield in Boro 2017-18, T. Aus 2018 and T. Aman 2018. However in double and triple rice cropping pattern, all treatments produced significantly higher grain yield than native nutrient. In T. Aman 2018 under double and triple cropping pattern insignificant yield difference were observed between 100% STB and FP fertilizer dose. But in Boro 2017-18 under double and triple cropping pattern, 100% STB fertilizer dose produced significant higher yield than FP fertilizer dose. Cumulative yield of triple cropping was always higher than double rice cropping pattern irrespective of treatments (Fig. 2).

Performance of vermicompost (VC) and poultry manure (PM) 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. PMcontained 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 4m × 5m sized plot and repeated three times in a RCB design. Seedlings of BRRI dhan29 and of BRRI dhan49 were transplanted at 20cm × 20cm spacing in Boro and T. Aman seasons. Chemical fertilizers (N-P-K-S-Zn @ 138-10-80-5-5 kg 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 2018-19. 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.

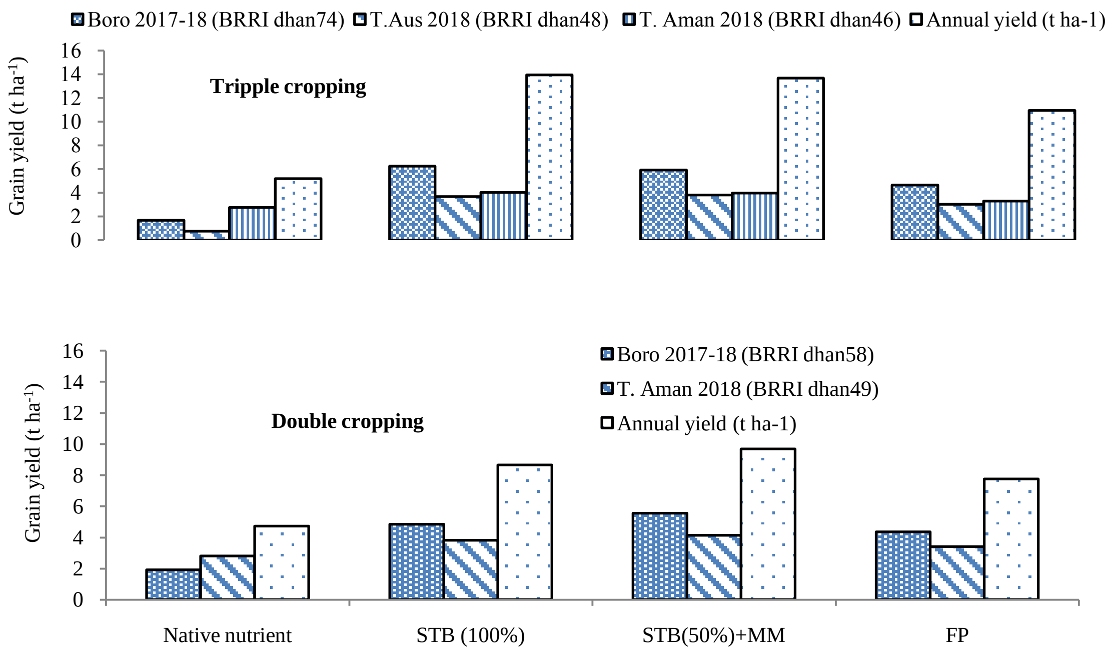


Fig. 2. Annual grain production (t ha^{-1}) of double and triple cropping pattern under continuous wetland condition, BRRI HQ farm, Gazipur.

SOIL AND ENVIRONMENTAL PROBLEMS

Greenhouse gas emissions from rice field. Field experiments were conducted at BRRI HQ farm, Gazipur (T. Aman 2018 and Boro 2018-19) and farmer's field at Bhaluka, Mymensingh (Boro 2018-19) under both AWD and CSW conditions. At 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 and two splits in T. Aman at 7-10 DAT, while urea briquettes (UB) were applied as a single application during first top dressing (TD) of PU. UB were placed at 7-10 cm below the soil surface between four hills at alternate rows. IPNS based organic fertilizers, i.e., poultry litter (PL), vermicompost (VC) was applied before transplanting. At 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 harvesting. Under AWD condition, irrigation water was applied when water falls below 12-15 cm of soil surface. For 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. A closed chamber technique was used to collect gas samples to measure CH_4 emissions. The concentration of CH_4 flux in the collected samples were measured using a gas chromatograph (Shimadzu GC-2014) equipped with a flame ionization detector (FID) and electron capture detector (ECD).

Rice yield, N uptake and NUE. In T. Aman, grain yields recorded in control treatment were 3.5 t ha^{-1} in AWD and 3.4 t ha^{-1} in CSW condition, while in Boro season it was 3.0 t ha^{-1} in AWD and 3.1 t ha^{-1} in CSW. N fertilizer treatments showed insignificant variation in rice yield in T. Aman season under both water management practices. Deep placement of UB significantly increased grain yield compared to broadcast PU at similar N rate in Boro under both the water management practices. No significant variation in rice yield was observed among the IPNS based organic amendments in Boro season. However, 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. Similarly, IPNS based organic fertilizers, except the UB+IPNS with PL showed a slight peak of floodwaterNH_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. 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. In Gazipur site, cumulative CH_4 emissions were measured. Control treatments produced significantly lower seasonal CH_4 emission compared to other treatments in both the seasons (Figs. 3 and 4). Although IPNS based organic amendments showed slightly higher cumulative CH_4 emission with broadcast PU and deep placement of UB in both AWD and CSW conditions, the variation was insignificant in T. Aman and Boro season. However, seasonal cumulative CH_4 emissions were measured only in Boro season lower at Bhaluka site and it was relatively lower than Gazipur site 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.

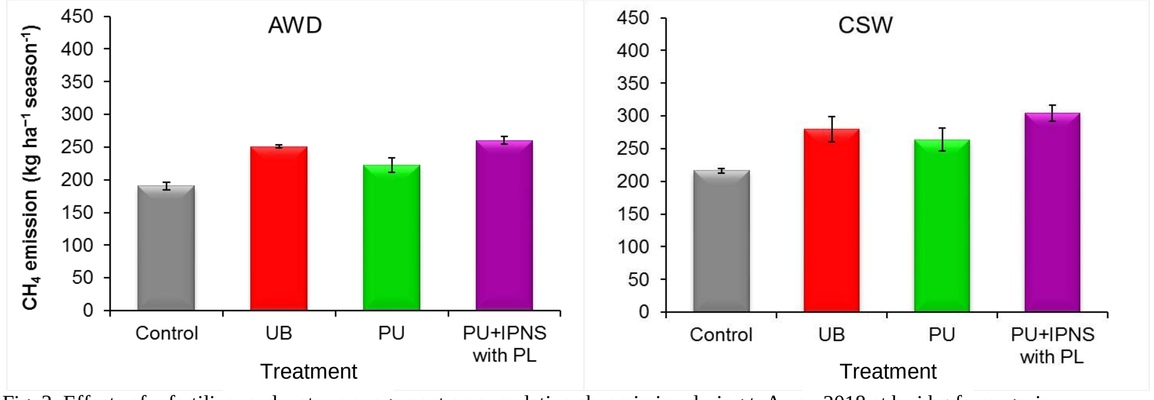


Fig. 3. Effects of n fertilizer and water management on cumulative ch_4 emission during t. Aman 2018 at brri hq farm, gazipur.

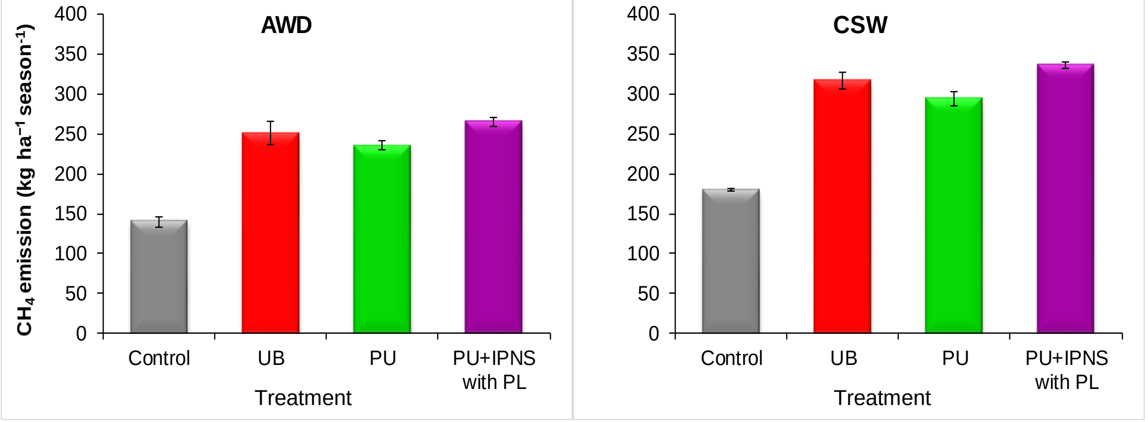


Fig. 4. Effects of n fertilizer and water management on cumulative ch_4 emission during boro 2019 at brri hq farm, gazipur.

Soil bio-physico-chemical properties of industrial polluted area of Sripur, Gazipur. The rice soils of Sripur, Mirzapur and Pirojali were irrigated with contaminated industrial water. Moreover soils of Mirzapur and Pirojali remain under contaminated water for 5-7 months in a year. A benchmark survey was done with 30 rice soil samples (0-15cm depth) of that area.

Soil biochemical properties. Soils of Sripur, Pirojali and Mirzapur contained high organic matter (>2.5%), high level of Fe (87 to 38 ppm), Mn (7 to150 ppm), Cu (1 to 7 ppm), and Zn (3 to 65 ppm). Soils of Mirzapur and Pirujali were acidic in nature and pH ranged from 4.95 to 5.88 and 4.42 to 6.0, respectively. The soil microbial population (bacteria, fungi and actinomycetes) were also quite lower compared to any other healthy rice soil. In the Sripur soil the total bacteria population ranged from 9.4×10^6 to 3.3×10^9cfu/g dry soil. The population of free-living N_2 fixing bacteria was 8.5×10^4 to 4.2×10^6cfu/g dry soil and population of phosphate solubilizing bacteria (PSB) was 1.4×10^6 to 8.8×10^6cfu/g dry soil. The fungus population was also very low and it ranged from 1.1×10^4 to 6.6×10^4cfu/g dry soil. In the Pirojali soil, total bacteria population was lower than Sripur soil. Fungus population was totally missing in that sampling area. The free-living N_2 fixing population in these soils ranged from 7.7×10^3 to 3.3×10^6cfu/g dry soil and PSB population was 2.2×10^5 to 2.0×10^7cfu/g dry soil. In Mirzapur, total bacteria ranged from 3.3×10^5 to 1.1×10^9cfu/g dry soil. Fungus population was also missing in this area. The population of free-living N_2 fixing and PSB were 1.8×10^4 to 8.8×10^5 and 3.0×10^2 to 6.1×10^6cfu/g dry soil.

Effect of organic amendment on soil Fe^{++} content. Eight field experiments were conducted at Boro 2018-19 in those areas with different organic amendment. Four treatmentsT_1-Vermicompost 3 t ha^{-1} + IPNS (N-P-K-S kg ha^{-1} @ 40-0-48-10), T_2-Biocher 2 t ha^{-1} + Chemical fertilizer (N-P-K-S kg ha^{-1} @ 100-20-80-10), T_3-organic fertilizer 3 t ha^{-1} + (N-P-K-S kg ha^{-1} @ 40-0-35-10), T_4- Chemical fertilizer (N-P-K-S kg ha^{-1} @ 100-20-80-10) and T_5- No Fertilizer. Each plot size was 5m × 6 m. The design of the experiment was RCBD with three replications. Rice grown nearest the contaminated irrigation sources (5-500 m) exhibited Fe toxicity symptom in leaves and roots after 30-50 days of transplanting. There were no significant effect of applied biochar and organic matter found on paddy yield. The soils of Sripur, Mirzapur and Pirujali contained high organic matter and Fe. The higher the organic matter of the soils, the more amorphous and crystalline Fe^{3+} compounds were used as electron acceptors and the more intensive is the accumulation of Fe^{2+} in flooded soil which might be the possible cause of Fe toxicity in such soil. There was a positive relationship ($r = 0.80$) found between soil organic matter and Fe content of the study areas (Fig. 5).

Field evaluation of BRRI bio-organic fertilizer. A number of three field experiments were conducted in the T. Aus 2018, T. Aman 2018, and Boro 2018-19 at BRRI HQ farm, Gazipur. Bio-organic fertilizers were used at 2 t ha^{-1} for both Aman and Boro seasons and 1 t ha^{-1} in Aus season.

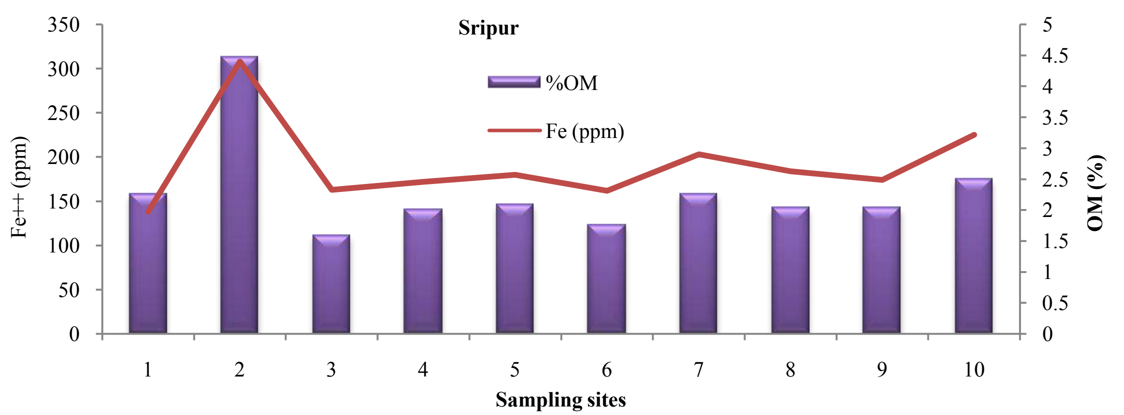


Fig. 5. Relationship between soil organic matter and soil Fe^{++} content at Sripur soil.

The treatment combinations for BRRI Gazipur was T_1 = Control, T_2= NPKS, T_3= NKS (100%), T_4 = Bio- organic fertilizer @ 2 t ha^{-1} + NKS (100%), T_5= NPKS (75%), T_6= Bio- organic fertilizer @ 2 t ha^{-1} + N (70%) + KS (100%), T_7 = Bio- organic fertilizer @ 2 t ha^{-1}, T_8= soil inoculation. About 21-day-old rice seedlings of BRRI dhan48 in Aus and 35-day-old rice seedlings of BRRI dhan62 in T. Aman and BRRI dhan50 in Boro season were transplanted at 20 × 20 cm^2 spacing. At BRRI RS, Cumilla, another experiment was conducted in both T. Aman and Boro season following treatments as; T_1= Bio- organic fertilizer @ 2 t ha^{-1} T_2= NPKS (100%), T_3 = Bio- organic fertilizer @ 2 t ha^{-1} + N (70%) + KS (100%), T_4= N (70%) + PKS (100%), T_5 = NPKZnS (100%) and T_6 = control. Recommendation rates of chemical fertilizers for AusAman and Boro were N-P-K @ 45-7.5-45 ha,$^{-1}$ N-P-K-S @ 67-10-41-10 ha^{-1} and N-P-K-S @ 140-20-80-10 kg ha^{-1} respectively. Each treatment was assigned in 4 × 5 m^2 sized plot and repeated three times in a randomized block design. In the Cumilla RS, BRRI dhan75 was grown in T. Aman and BRRI dhan58 at Boro season.

Effect of bio-organic fertilizer on grain yield. Bio-organic fertilizer (BoF$_1$ @ 2 t ha^{-1}) has potential to supplement 25-30% N and 100% P requirement for HYV rice in Gazipur and Cumilla soil without sacrificing yield. In Gazipur, bio-organic fertilizer (BoF) @ 1.0 t ha^{-1} has potential to supplement 30% of N and 100% P requirement for BRRI dhan48. In the T. Aman season, application of bio-organic fertilizer with 100% NKS gave the highest grain yield of 4.38 t ha^{-1} and it was statistically similar with 100% NPKS and 30% reduced N with 100% KS treatment. In Boro season, statistically similar grain yield was obtained in biofertilizer with reduced chemical and 100% chemical fertilizer applied treatments followed by biofertilizer and soil inoculation. The significantly lowest grain yield was obtained at control treatment. At Cumilla, bio-organic fertilizer with 30% reduced N and 100% omission of TSP produced statistically similar grain yield (5.22 t ha^{-1}) with full dose of chemical fertilizer and reduced chemical fertilizer in T. Aman season. However, in the Boro season, the highest grain yield (8.05 t ha^{-1}) was obtained from bio-organic fertilizer with reduced N and omission of TSP treatment.

Effect of bio-organic fertilizer on grain yieldin saline soil. Bio-organic fertilizer is capable to improve rice yield in saline soil where irrigation water salinity varied from 0.65-2.53 dS/m with the corresponding soil salinity ranged from 4.59-7.66 dS/m. In Amtali, Barguna site, application of bio-organic fertilizer 2 t ha^{-1} (dry weight basis) along with 30% reduced urea and 100% removal of TSP fertilizer increased panicle number (9%), filled grain/panicle (17%) and rice yield about 0.5 t ha^{-1} (11.3%) compared to full chemical fertilizer of BRRI dhan67. Whereas, in Dacope, Khulna site, bio-organic fertilizer increased panicle number (20%), filled grain per panicle (1%), and also rice yield by about 0.5 t/ha (9.5%) compared to balanced chemical fertilizer of BRRI dhan67.

Soil processes as influenced by temperature. Fourty-five days rice growth pot experiment was set up in the growth chamber of BRRI Soil science Division’s lab using a terrace paddy soil, to evaluate the influence of temperature on C mineralization and global warming in organic and chemical fertilizers amended soil. The soil (0-15 cm) was collected from a farmer’s paddy field growing rice at least two seasons year^{-1} for 30 years of Sripur, Gazipur. The soil is silt loam in texture comprising 33, 52 and 15% sand, silt and clay respectively. Four treatments i.e. T_1 (planted in untreated soil), T_2 (planted in soil treated with NPKSZn chemical fertilizers @ 160-20-80-10-1 kg ha^{-1}), T_3 (planted in soil treated with IPNS based fertilizers viz bio-organic fertilizer @ 2 t ha^{-1} + chemical fertilizers) and T_4 (unplanted soil) were tested. Each treatment replicated twice/thrice. In each PVC pot (16 cm H. × 10.3 cm Ø) 1.01 kg soil was filled forming a core of 10.5 cm height matching the field bulk density of 1.15 Mgm^{-3}. Per pot fourteen days old seedlings of BRRI dhan28 was transplanted in a single hill. Eleven pots (9 planted and 2 unplanted) were monitored for CO_2, CH_4 and N_2O emission. All pots were continuously flooded until 46 days after transplantation (DAT) with a 3-4 cm ponding water level by regular addition of deionized water.

Effect of temperature on C mineralization. Soil organic carbon gradually decreased over time irrespective of temperature and nutrient management practices. Throughout the monitoring period, temperature and humidity in the growth chamber ranged from 31 to 51°C and 4 to 64%, respectively (Fig. 6a and 6b), seemed the higher temperature and lower humidity ranges than normal rice growing condition in Bangladesh, but not surprising since the temperature is rapidly rising in the country, facing already the higher temperature up to 38°C in recent years. Regardless of presence or absence of rice plant, total C emission was increasing linearly towards the experimental period in all treatments (Fig. 2a). Unexpectedly, the accumulative C emission per measuring event did not significantly related to the temperature ($r = -0.54$ to -0.67, $p = 0.099$ to 0.210) and humidity ($r = 0.10$ to 0.25, $p = 0.593$ to 0.824) in every treatment.

Irrespective of fertilizer amendment, accumulative C emission in the rice transplanted treatments i.e. in T_1, T_2 and T_3 was strikingly greater than that in unplanted soil (T_4), predominantly between 31 to 46 DAT (Fig. 7a). During the entire 46 days, the total C emission (in mg kg^{-1}) and global warming potential (GWP) (in CO_2 eq. kg ha^{-1}) were statistically identical between the planted treatments (i.e. amongst T_1:1756 ± 69 and 9182, resp., T_2:1662 ± 130 and 8771, resp., and T_3: 1494 ± 102 and 9050, resp.) which were again significantly ($p<0.01$) greater than that in unplanted soil, T_4 (554 ± 46 and 3487, resp.).

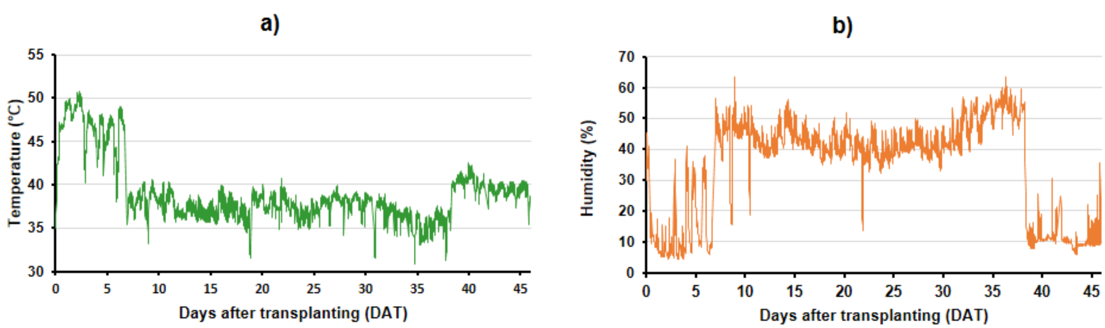


Fig. 6. Temperature (a) and humidity (b) varying throughout the experimental period in the growth chamber.

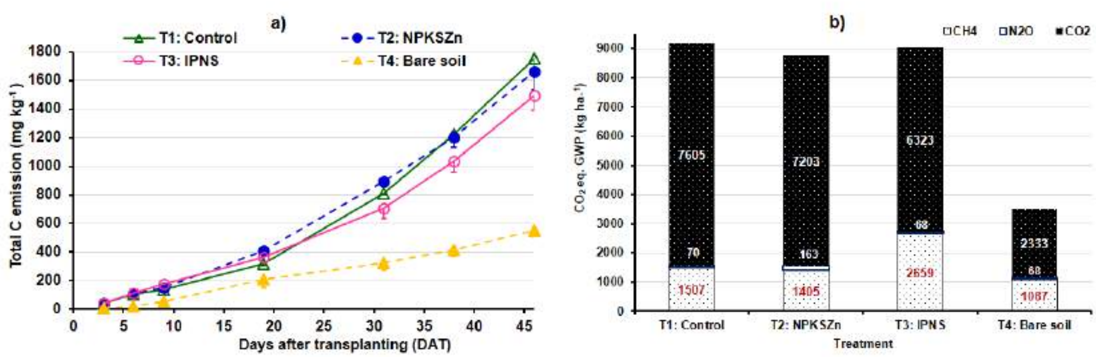


Fig. 7. Total C emission (mineralization) (a) and global warming potential (b) as impacted by elevated temperature during the experimental period (vertical bar denotes standard error of the means, n=3).

Irrigation and Water Management Division

SUMMARY

Thin irrigation practice with wet direct seeding was found better for both irrigation water saving and satisfactory yield. Different varieties have different water stress tolerance capacity. If it is determined, efficient use of water can be ensured. Drought simulation model is a good decision-making tool to apply irrigation. In Barisal region, enough water is available round the year in primary, secondary and tertiary canals. Salinity of these water remains in permissible limit for irrigation. There is a large scope of crop intensification through Boro rice cultivation. In the 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 range of 0.48-1.15 ds/m) could be irrigated in dry season. Solar power is one of the cleanest sources of energy because it does not emit any pollution. BRRI developed portable solar pump system is suitable for surface water irrigation system. In eastern gangetic plain area, polythene pipe distribution system saved water, time and cost, increased command area and water productivity. In the north-west region of Bangladesh Boro rice is the major crop grown in the dry season, which contributes more than 55% of the total rice production of the country from about 42% of the total cultivated rice area. Dacope, Khulna farmers liked BRRI dhan77 and BRRI dhan23 when Amtali, Barguna farmers preferred BRRI dhan76 in T. Aman season. In coastal region, ash mulching also reduced the field water salinity and hence, may be increased the rice yield. The river water was suitable for irrigation from July to November. The vermincompost (VC) organic manure practice during T. Aman rice cultivation could be an effective soil management practice to decrease CH_4 emission, while not impacting rice productivity.

WATER USE EFFICIENCY IMPROVEMENT IN IRRIGATED AGRICULTURE

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

The experiment was conducted in BRRI HQ farm, Gazipur during Boro 2018-19 to find out suitable method of Boro cultivation under water limiting condition with eight treatments. The treatments were: T_1- Transplanting with maintaining continuous standing water (TP-CSW); T_2- Transplanting with alternate wetting and drying irrigation practice (TP-AWD); T_3- Transplanting with thin irrigation practice (TP-TIP); T_4- Dry direct seeding maintaining continuous standing water (DS-CSW); T_5- Dry direct seeding with alternate wetting and drying irrigation practice (DS-AWD); T_6- Dry direct seeding with thin irrigation practice (DS-TIP); T_7- Wet direct seeding with alternate wetting and drying irrigation practice (WS-AWD) and T_8- Wet direct seeding thin irrigation practice (WS-TIP). BRRI dhan28 was grown under the current study. The experimental design was RCBD with three replications. In general, direct seeded rice, either in DS or WS, received 2-3 more irrigations compared to conventional TP rice (Table 1). The result suggests that this amount of water was saved firstly by shifting from TR to DS rice (160 mm) and secondly by shifting from CSW to TIP irrigation (85 mm). All TP treatments received 331 mm and all DS treatments received 416 mm rain during the Boro season, which was congenial for rice growth and reduce the irrigation amount (Table 1). The yield results showed that good yield could be achieved with both dry direct seeding and wet direct seeding (Table 2). Amount of irrigation was less in direct seeded plots compared to the transplanted plots. Thin irrigation practice with wet direct seeding was found better for both irrigation water saving and satisfactory yield. Dry direct seeding was found good for all the water management practices.

Table 1. Growth duration, number of irrigations, amount of irrigation applied for different treatments along with rainfall in Boro season 2018-19 at BRRI HQ farm, Gazipur.

Treat	Growth duration (day)	Irrigation No.	Amount of irrigation (mm)			Rainfall (mm)	Total water use (mm)
			Land preparation	Growing period	Total		
TP-CSW	130	14	190	570	760	331	1091
TP-AWD	129	12	190	490	680	331	1011
TP-TIP	129	16	190	440	630	331	961
DS-CSW	121	16	0	600	600	416	1016
DS-AWD	121	14	0	560	560	416	976
DS-TIP	120	19	0	515	515	416	931
WS-AWD	118	15	190	540	730	416	1146
WS-TIP	115	18	190	455	645	416	1061

Table 2. Irrigation applied and yield obtained under different crop establishment treatments along with water management during Boro season 2018-19 at BRRI HQ farm, Gazipur.

Treat.	Irrigation applied (mm)	Total water use (mm)	Yield (t ha^{-1})	Irrigation water saving (%)	Yield loss (%)	Irrigation water productivity (lit/kg)	Total water productivity (lit/kg)
TP-CSW	760	1091	5.23			1548.4	2085.5
TP-AWD	680	1011	5.04	-10.53	-3.58	1467.1	2004.4
TP-TIP	630	961	4.97	-17.11	-5.04	1248.0	1934.4
DS-CSW	600	1016	5.57	-21.05	6.51	1238.4	1823.5
DS-AWD	560	976	5.24	-26.32	0.16	1126.0	1862.7
DS-TIP	515	931	5.26	-32.24	0.56	1007.5	1769.7
WS-AWD	730	1146	5.50	-3.95	5.20	1326.5	2082.4
WS-TIP	645	1061	5.02	-15.13	-3.98	1333.8	2112.2

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

The experiment was conducted in a net house during Aman 2018 to quantify the tolerance capacity of soil moisture deficit for different advanced breeding lines. Two ALART materials namely BR (Bio) 8961-AC22-14 and BR (Bio)8961-AC26-16 along with check variety BRRI dhan49 were supplied from Biotechnology Division to evaluate in Aman season 2018. The treatments were as follows: T_1= Irrigation when water potential was -10 kPa at 10 cm soil depth, T_2= Irrigation when water potential was -30 kPa at 10 cm soil depth, which is equivalent to field capacity and T_3= Irrigation when water potential was -60 kPa at 10 cm soil depth, which is below field capacity. The soil in the water stress treatments dried rapidly after each irrigation (Fig. 1). Table 3 shows ALART BR (Bio) 8961-AC26-16 produced significantly higher yield than ALART BR (Bio) 8961-AC22-14 and check variety BRRI dhan49. Higher grain yield of two ALART lines and check variety was observed when water stress imposed as -10 kPa. Grain yield were decreased 37 to 62% if the water stress imposed as 30 and 60 kPa. Therefore, both the ALART lines and check variety have water stress tolerance capacity of -10 kPa. ALARTBR (Bio) 8961-AC26-16 showed better performance than ALARTBR (Bio) 8961-AC22-14 and check variety BRRI dhan49. Both ALART lines along with check variety showed better performance with -10 kPa (AWD) water stress. Yields were drastically reduced by 37 to 71% with the water stress of -30 kPa and -60 kPa.

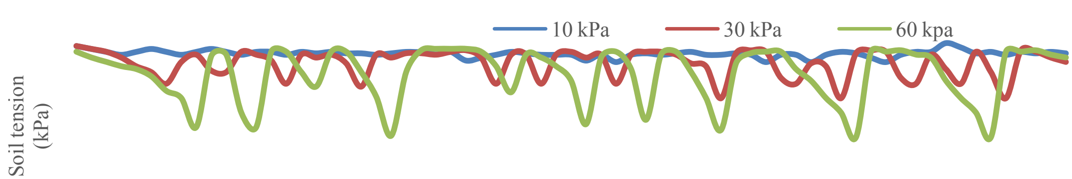


Fig. 1. Soil water tension in the 10, 30 and 60 kPa water stress treatments throughout the growing season in the greenhouse at BRRI, during August to November 2018.

Table 3. Grain yield of tested varieties as affected by different levels of water stress at whole growing season in Aman 2018.

ALART and check variety	Grain yield (gm/hill)			Tolerance capacity
	-10 kPa	-30 kPa	-60 kPa	
BR(Bio)8961-AC22-14	24.20	15.21(-37%)	9.19 (-62%)	-10 kPa
BR(Bio)8961-AC26-16	34.65	16.13 (53%)	13.32 (-61%)	-10 kPa
BRRI dhan49	31.49	10.35 (-67%)	8.98 (-71%)	
$LSD_{0.05}$				4.77
CV%				15.2

LAND PRODUTIVITY IMPROVEMENT IN THE COSTAL ENVIRONMENT

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

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 (Fig. 2). Water samples were collected from the rivers in different locations of Barishal, Jhalokhati, Pirojpur, Patuakhali and Barguna districts to measure the electrical conductivity. Table 4 shows the points in Boleswar, Bishkhali, Buriswar and Tentulia river where annual maximum water salinity was found closer to 1 dS/m during 2016-2019. The maximum electrical conductivity in Boleswar river at Chotomasua, Mothbaria was found as 2.287 dS/m. The other points are within the permissible limit (< 1.0 dS/m), which indicate that water of the upstream side from this point was suitable for irrigation during dry season. Fig. 3 also shows that areas above the red line are suitable for irrigation development with river water. The adjacent area of the rivers could be used for irrigated crop production.

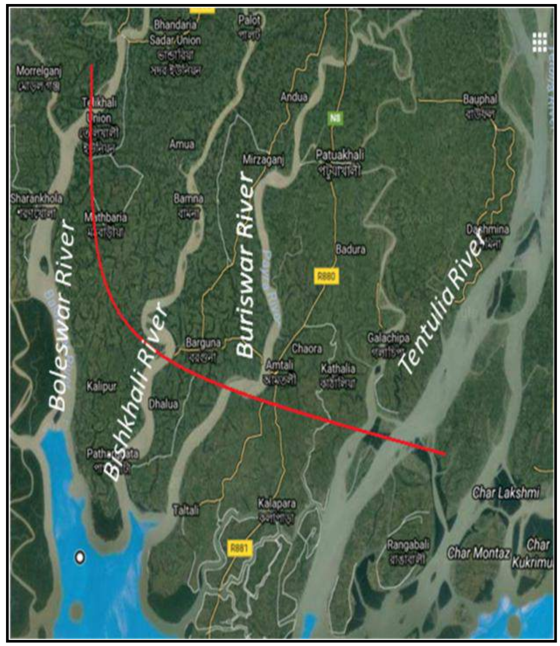


Fig. 2. Map showing areas above the red line are suitable for surface water irrigation during dry season.

Table 4. Points in different rivers from which upstream water can be used for irrigated crop production.

Location	River	Maximum water salinity (dS/m)			
		2016	2017	2018	2019
Chotomasua, Mathbaria	Boleshwar	2.600	1.180	3.080	2.287
Charkahli ferry ghat, Bhandaria, Pirojpur	Boleswar	0.981	0.910	1.080	0.990
Kalmegha, Patharghata	Bishkhali	1.22	0.92	0.480	0.873
Kakchira ferry ghat, Barguna sadar, Barguna	Bishkhali	0.968	0.560	0.550	0.693
Taltoli launch ghat, Taltoli	Buriswar	9.400	4.240	0.670	-
Chotobogi, Taltali, Barguna	Buriswar	0.930	0.840	0.480	0.752
Pairabondor, Khepupara	Tentulia	-	22.900	-	-
Panpatti, Golachipa, Patuakhali	Tentulia	-	0.550	0.760	0.655

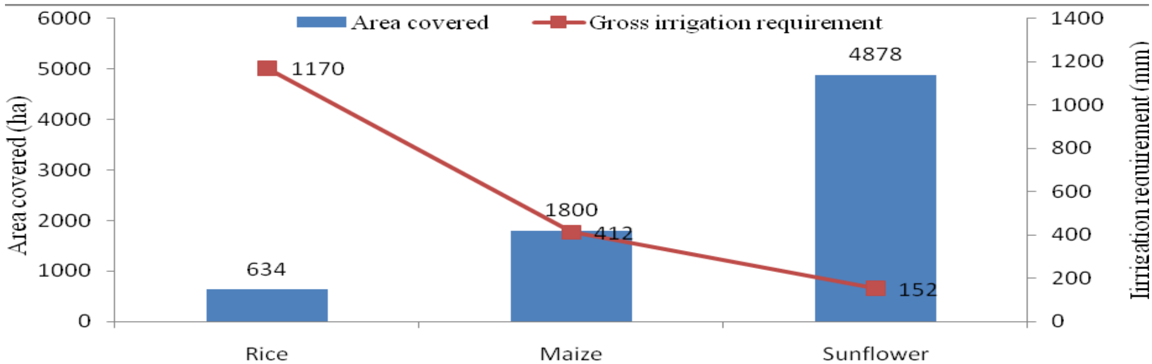


Fig. 3. Gross irrigation water requirement (mm) and area coverage (ha) by each crop considering the entire canals trapped at polder 43/1 at Amtali, Barguna.

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

The study was conducted in polder number 43/1 situated at Amtali, Barguna to delineate suitable water resources during dry season and to determine the amount of fresh water available for crop production during the period. The peripheral length of the polder is about 66.9 km and the total area enclosed by the polder is 13,539 ha. Width and depth of canals were measured at regular distance. Length of canal was measured using Google earth tools. Volume of water stored in a canal section was calculated. Water salinity of each canal was monitored using EC meter. CROPWAT8.0 model was used to calculate crop water and irrigation water requirement of different crops in the polder area. Total 151 km long primary and secondary canals were surveyed in polder 43/1. Total stored volume of water was 74,14,503 m^3 in April. Among the surveyed canal 11.1 km long canal was affected by salinity ranges from 1-2.2 dS m^{-1}. Considering all the canals trapped with fresh water during dry season, the maximum cultivable area by different crops with this water was analyzed (Fig. 3). It shows that 4878 ha sunflower field can be successfully irrigated with the 74,14,503 m^3 water. On the other hand, irrigation is possible in 1800 ha and 634 ha land of Maize and Boro rice respectively. There is a large possibility of dry season crop cultivation using canal water in polder 43/1.

Use of less saline water resources for increasing cropping intensity in Barishal region

This experiment was conducted at Bakerganj, Barishal, Nolcity and Sadar upazila of Jhalokathi district during 2018-19 to bring fallow land under Boro cultivation and to improve water and land productivity in the region by technology intervention such as low lift pump, plastic pipe distribution system and AWD technology. Boro cultivation was done using fresh tidal water from canal. A total of 7.3 ha of fallow lands were brought under cultivation by BRRI dhan47, BRRI dhan58, BRRI dhan67 and BRRI dhan74. The water salinity was measured in both the locations throughout the period and was less than 0.5 dS/m, which is very suitable for irrigation (Table 5). Water was available in the canal during the whole season. In Nolcity, Jhalokati, the highest 18 number of irrigation (1050 mm) was applied in BRRI dhan58. Enough water was present in the canal during the whole growing period to irrigate more fields.

In Nolcity, Jhalokati, BRRI dhan74 produced the highest yield of 6.3 t ha^{-1}. In Jhalokathi sadar, BRRI dhan74 gave the higher yield of 6.1 t/ha. In Bakerganj BRRI dhan74 performed the best among the four varieties. Enough water is available round the year in the canals of Barishal region. Salinity of these water remains in permissible limit for irrigation. There is a large scope of crop intensification through Boro rice cultivation.

Table 5. Yield and water used by different varieties in Barishal region during Boro 2018-19.

Variety	Water salinity (dS/m)	Number of irrigations	Amount of irrigation (mm)	Yield (t ha^{-1})
		Nolcity, Jhalokati		
BRRI dhan58		18	1050	5.8
BRRI dhan67	0.25-0.45	15	950	5.7
BRRI dhan74		16	980	6.3
		Sadar, Jhalokati		
BRRI dhan67	0.2-0.3	18	1020	5.6
BRRI dhan74		15	970	6.1
		Bakerganj, Barishal		
BRRI dhan47		15	920	5.3
BRRI dhan58	0.2-0.4	16	960	5.7
BRRI dhan67		14	840	6.0
BRRI dhan74		17	990	6.1

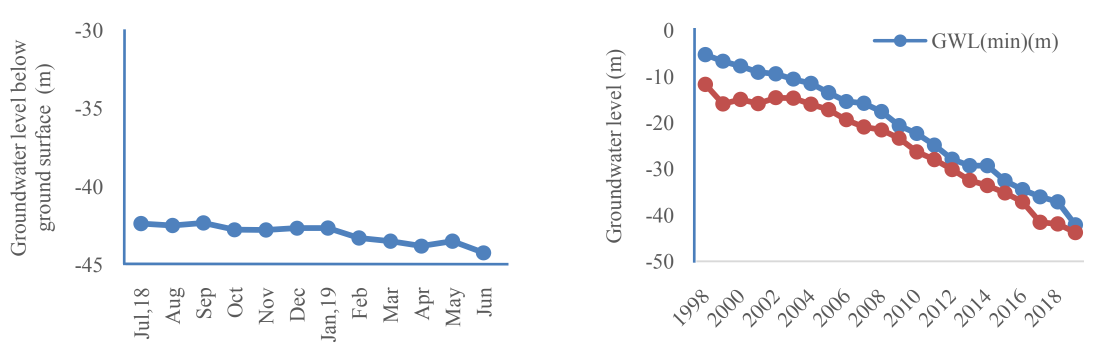
SUSTAINABLE MANAGEMENT OF WATER RESOURCES

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

In this study, available water level recorder was used for measuring groundwater fluctuation in BRRI HQ Gazipur and all regional stations. Data were recorded weekly and those were calculated to obtain monthly average.

Groundwater level in Gazipur. Figure 4 shows monthly groundwater level fluctuations at Gazipur during 2018-19. During this period maximum lowering of groundwater (41.94 m) was observed in April and minimum (37.08 m) in May. The fluctuation was within 4.86 m. The fluctuation was lower than the previous year as the rainy season started early. In 1998 the maximum groundwater level was about 11.68 m (Fig. 4) from the ground surface, which was 41.94 m in 2018. So, the lowering was about 30.26 m in 21 years. During the initial five years the lowering rate was not so high, and it was only 2.89 m. But in the last five years (2013-2018) the lowering was about 9.46 m.

Groundwater level in BRRI regional stations. Groundwater levels in the southern areas (Bhanga, Faridpur and Barishal) were within the suction limit of STW (8 m), whereas, in Rajshahi that goes below suction limit at peak irrigation period (Fig. 5). In Habiganj, GW level was in critical level of STW suction limit.



a) Yearly GW fluctuation

b) Long-term GW declination

Fig. 4. GW fluctuation (2018-19) and long-term (1998-2019) GW declination at BRRI farm, Gazipurduring 2018-19.

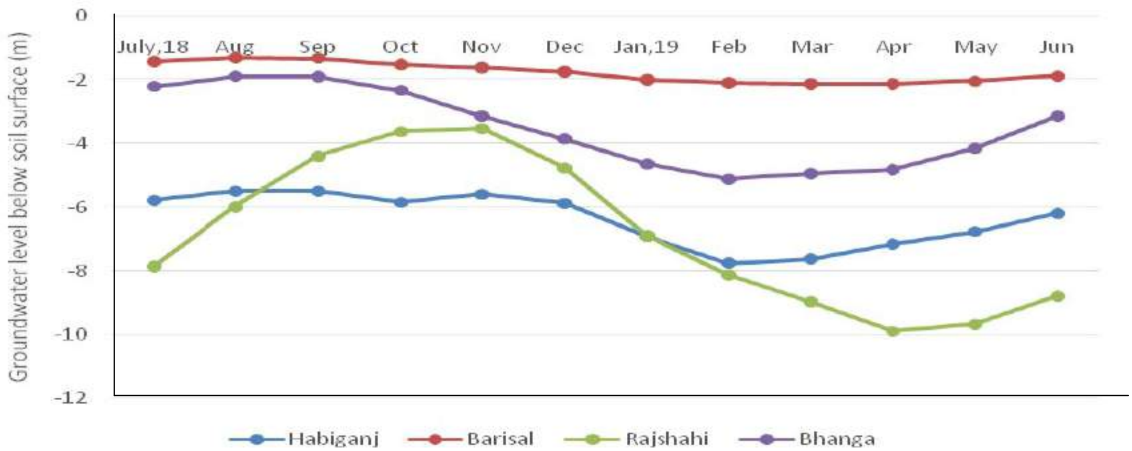


Fig. 5. Yearly GW level fluctuations in different BRRI RSs in 2018-19.

RENEWABLE ENERGY

Evaluation of smallholder surface water solar irrigation system for crop production

BRRI IWMD have designed and implemented a portable type 2.56 kW solar panel that can run a 2 HP irrigation pump comfortably at BRRI HQ Farm, Gazipur during 2018-19. The panel is provided a foldable facility to reduce surface area of the panel for easy movement from place to place. This 2-HP solar pump had a discharge of 5-7 liter/sec even at a suction lift of 6.73 m (surface water) and average operating hours found ranging from 7.48 to 7.53 both off and manual tracking conditions respectively when delivery head is constant. There was no significant difference found in the performance characteristics of the solar pump. Average operating times were found between 8.06 to 8.31 hours respectively at off and manual tracking conditions when the suction head was constant. As an additional activity, the solar system could operate a 1.5 kW BRRI open drum paddy thresher at the rate of 250-350 kg paddy/hr. On the other hand, it can generate about 7-10 kWHr energy per day when it is connected in on-grid at off season.

BRRI developed portable solar pump system is suitable for surface water irrigation system. In the off-season it can be used to operate open drum thresher. It can also be used in on grid solar home system and contribute to electricity in the grid line.

TECHNOLOGY VALIDATION IN THE FARMERS' FIELD

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 through intensive monitoring of the groundwater irrigation by STWs and DTWs in six selected sites in Rajshahi, Pabna, Bogura, Rangpur, Dinajpur and Thakurgaon districts.

The study was carried out during 2016-17 and 2018-19 crop seasons at four locations (Pabna, Bogura, Rangpur, and Thakurgaon districts) across the region. Use of polythene pipe irrigation water distribution system reduced water supply by 20-25% and saved irrigation time by 25% (Table 6). AWD technique for irrigation scheduling was found effective for reduction in irrigation water supply by about 14-18% in Boro rice cultivation. Overall water productivity in traditional farmers practice varied from 0.69 to 0.73 kg/m^3, which is equivalent to 1475-1514 lit/kg and that of AWD varied from 0.81 to 0.83 kg/m^3, which is equivalent to 1293-1302 lit/kg of paddy production (Fig. 6). AWD irrigation method reduced 160 kg CO_2/ha emission and reduced 23-36% methane flux emission from rice field compared to continuous flooding.

Table 6. Irrigation water and application time saving by polythene pipe compared to earthen canal.

Year	Water sullied (mm)		Reduction in water supply (%)	Irrigation application time (min/decimal)		Irrigation time saved (%)
	Earthen canal	Polythene pipe		Earthen canal	Polythene pipe	
2016-17	634.6	506.9	20.4	33.8	26.9	20.0
2017-18	698.0	520.0	25.2	35.76	26.42	25.4

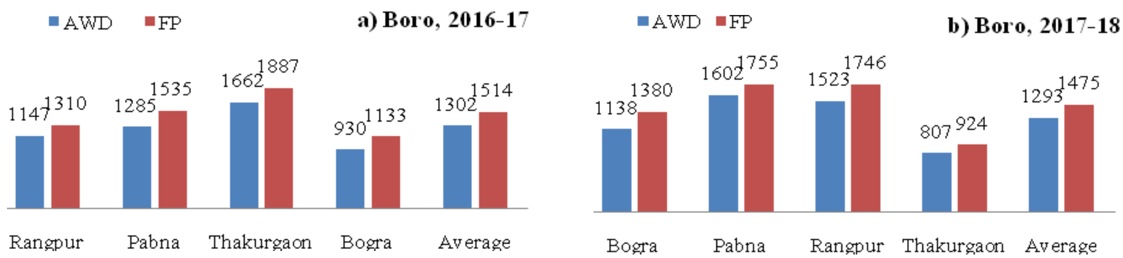


Fig. 6. Average reverse water productivity (lit/kg) for FP and AWD in different sites in Boro 2016-18.

Cropping systems intensification in the salt-affected coastal zones of Bangladesh and West Bengal, India

The main objectives of the study are to understand the surface and groundwater salt and water dynamics in polder scale and to develop the crop production response at various improved polder water and salinity management strategies for improving the cropping intensification and enhance food security in coastal region of Bangladesh and West Bengal, India. In Bangladesh, two polders were selected based on salinity i.e. Polder # 43/1 at Amtali, Barguna (medium salinity area) and Polder # 31 at Dacope, Khulna (high salinity area). The project was funded by ACIAR, Australia and KGF, Bangladesh.

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 to find out the suitable varieties for improving the facility for timely sowing of Rabi crops and to improve the land and water productivity with rice varieties were BR11, BR23, BRRI dhan53, BRRI dhan54, BRRI dhan66, BRRI dhan73, BRRI dhan76 and BRRI dhan77 along with the popular local varieties. Dacope area, BRRI dhan77 produced the highest grain yield (5.8 t/ha) followed by BRRI dhan76, BRRI dhan23 and BR11 (Table 7) and most of the farmers of that locality showed their interest to cultivate BRRI dhan77 and BRRI dhan23 in next T. Aman season. In Amtali area, BRRI dhan76 produced the highest grain yield (5.6 t/ha) followed by BRRI dhan77 and BR23 and most of the farmers showed their interest to grow. In Dacope, though the farmers used modern varieties in trial and non-trial plots, the trial farmers get comparatively higher grain yield due to balanced fertilizer use and also for latest modern rice varieties and farmers were interested to grow BRRI dhan77 and BRRI dhan76 in the next T. Aman season. In Amtali area, most of the farmers cultivate local varieties and some farmers showed their interest to grow BRRI dhan76 and BRRI dhan77 and BR23 in the next T. Aman season. Most of the farmers in both the locations tend to use more seed and more amount of urea with fewer amounts of other fertilizers.

Table 7. Performance of tested variety at Dacope, Khulna and Amtali, Barguna in T. Aman 2018.

Variety	Dacope, Khulna			Amtali, Barguna		
	Sowing date	Maturity date	Yield (t ha^{-1})	Sowing date	Maturity date	Yield (t ha^{-1})
BRRI dhan54				13-28 July	25 Nov-17 Dec	4.35c
BRRI dhan66				4-7 July	2-7 Nov	2.6d
BRRI dhan73	25-Jul	18-Nov	2.3c			
BRRI dhan77	25-Jul	17-Dec	5.8a	23-25 July	5-12 Dec	5.45ab
BRRI dhan76	25-Jul	17-Dec	5.6a	23-25 July	7-12 Dec	5.6a
BR23	15-25 July	8-10 Dec	5.5ab	6-25 July	5-15 Dec	5.23b
BR11	15-25 July	23 Nov-4 Dec	5.2b	4-22 July	5-12 Dec	5.04b
CV			6.7			7.6

Growing vegetables 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. In Dacope site, farmers were cultivating different types of creeping vegetables with different rice varieties. The yield of T. Aman rice varied from 4.35 to 5.42 t/ha. Farmers got 494 to 1000 kg of rice with 1156 to 2468 kg of different vegetables based on the cultivated land area (Table 8). Farmers reported that they got about 10% yield loss due to land occupied by bag placement in the rice land. The returns from rice varied from 9,880 to 20,000 Tk/plot. However, vegetables return varied from 27,879 to 51,965 Tk/plot (Table 9). Farmers got the additional crops of vegetables with rice in wet season, which created the opportunity for extra income.

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 10 shows yield and yield components of Aus rice in trials of both the areas. In Dacope area, BRRI dhan48 produced the yield of 4.92 t/ha and in Amtali area it gave 4.99 t/ha yield, whereas local latest variety BRRI dhan82 produced the highest yield of 5.09 t/ha (Table 12). Both the locations, farmers facing troubles in seedling raising of Aus rice due to shortage of fresh water and high salinity of their land.

Table 8. Yields of vegetables with rice cultivated field, Dacope, T. Aman 2018.

Farmer	Area (dec.)	Vegetables name	Vegetable yield (kg)	Rice yield (kg)
Okhil Halder	28	Bitter gourd, snake gourd, ridge gourd, long yard bean, sweet gourd	1156	560
Poritosh Ray	26	Bitter gourd, snake gourd, ridge gourd, long yard bean, sweet gourd, water gourd	2171	494
Md Imran Sheikh	36	Bitter gourd, snake gourd, ridge gourd, long yard bean, sweet gourd, tomato	2279	756
Md Sain Gazi	50	Bitter gourd, snake gourd, ridge gourd, long yard bean, sweet gourd	2468	1000
Total	140			

Table 9. Returns from vegetables with T. Aman rice at Dacope, T. Aman, 2018

Farmer	Area (dec.)	Rice yield (kg)	Vegetables yield (kg)	Returns from rice (Tk/plot)	Returns from veg. (Tk/plot)	Total return (Tk/plot)
Akhil Halder	28	560	1156	11200	27879	39079
Poritosh Ray	26	494	2171	9880	38208	48088
Md Imran Sheikh	36	756	2279	15120	45597	60717
Md Sain Gazi	50	1000	2468	20000	51965	71965
Total	140	2810	8074	56200	163649	219849

Table 10. Characteristics and yield performance of T. Aus varieties at Amtali, Barguna and Dacope, Khulna in 2018.

Variety	Date of transplanting	Date of harvesting	Plant height (cm)	Panicle m^2	Filled grain panicle	Yield (t ha^{-1})
			Amtali, Barguna			
BRRI dhan48	21/05/2017	25-29/08/2018	107	283a	71a	4.99a
BRRI dhan82	21-27/05/2017	25-29/08/2018	106	300b	68a	5.07a
LSD(0.05)				32	28.6	0.46
CV(%)				5.9	10.4	5.5
			Dacope, Khulna			
BRRI dhan48	12/05-06/06, 2018	16/08-04/09, 2018	109	295a	134a	4.92a
BRRI dhan67	22-26/05/2018	24-29/08/2018	130	310a	113b	4.57a
LSD(0.05)				28	22.8	0.42
CV (%)				4.9	11.4	6.5

Evaluation of different mulching materials in rice under saline areas

The study was conducted at Dacope, Khulna and Amtali, Barguna during the dry season of 2018-19. The experiment involved five mulching treatments viz no mulch, mulching with ash, mulching with saw dust, mulching with rich husk and mulching with rich straw. Measured quantities of irrigation water with flow meter were applied directly to the experimental plots. Rice yield varied based on the mulching materials in both the locations (Fig. 7). The highest grain yield was found in ash mulching and the lowest grain yield was found in saw dust mulching in both the locations. It was observed that the saw dust might have developed toxicity in the field after application and in both the locations the water colour became red and crop appeared to be stunted. Ash mulching treatment produced comparatively higher yield in both the locations. It might happened due to higher potassium content in ash, which may reduce the salinity effect from rice field. Ash mulching showed 3.25 to 7.35% yield advantage over the conventional no mulching treatment.

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

The experiment was conducted in BRRI HQ farm, Gazipur during Aman 2018 and Boro 2018-19 to identify greenhouse gas emission and net ecosystem carbon budget under different fertilizer and water management conditions. Five different fertilizer management 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). During Boro 2018-19, the experiment was involved in five fertilizer management treatments with two different irrigation regimes. The fertilizer 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 = Vermi compost (2 t ha^{-1}) + IPNS, T = Absolute control (No fertilizer application). Irrigation treatments were continuous standing water and alternate wetting and drying (AWD) irrigation method.

Under different organic amendments, the seasonal CH_4 fluxes during rice cultivation were 240-713 kg ha^{-1} during T. Aman season (Table 11). The VC treatment significantly decreased the seasonal CH_4 fluxes by 31% and increased grain yield over that of the PM. The VC organic manure during rice cultivation was very effective to decrease about 31% CH_4 emission than other organic treatments. Therefore, VC organic manure practice during T. Aman rice cultivation could be an effective soil management practice to decreased CH_4 emission.

In Boro 2018-19 under continuous flooding, the seasonal CH_4 during rice cultivation were 147-568 kg ha^{-1}, under different fertilizations. Whereas the AWD irrigation, seasonal CH_4 flux were 102-411 kg ha^{-1} (Table 12). The AWD irrigation significantly decreased the seasonal

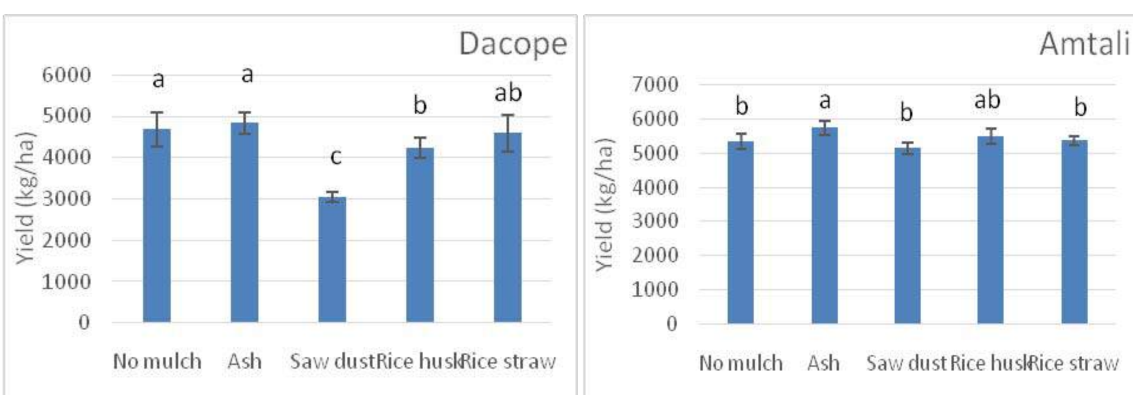


Fig. 7. Yield performance of different mulching materials at Dacope and Amtali in Boro 2018-19.

CH_4 fluxes by 23-36% over that of the continuous flooding. Rice productivities were slightly higher (1.7-4%) under the continuous flooding than under the AWD. The AWD irrigation was very effective to reduce seasonal CH_4 flux about 23-46% than continuous flooding. There was no significant difference in terms of rice yield with either continuous flooding or AWD irrigation. AWD drainage practice during rice cultivation could be very effective soil management practice to reduce GHG emission impact from rice fields.

Table 11. Characteristics of greenhouse gas emission under different organic amendment in T. Aman 2018.

Parameter	Treatment				
	NPKSZn	CD with IPNS	PM with IPNS	VC with IPNS	Control
Grain yield (kg ha^{-1})	3720d	4450c	4750b	4810a	3220e
CH_4 emission (mg m^{-2} day^{-1})	66c	97ab	122a	84b	54d
CH_4(kg ha^{-1})	386d	564b	713a	490c	240e

Table 12. Total CH_4 flux and rice yield under continuous flooding and AWD during Boro rice cultivation.

Treatment	Continuous flooding		Alternate wetting and drying irrigation (AWD)	
	CH_4 flux (kg ha^{-1})	Rice yield (t ha^{-1})	CH_4 flux (kg ha^{-1})	Rice yield (t ha^{-1})
NPKSZn	215	5.22	159	5.13
CD+IPNS	585	6.78	344	6.58
PM+IPNS	796	6.88	471	6.79
VC+IPNS	510	7.09	288	7.01
Control	126	2.86	96	2.90

Plant Physiology Division

SUMMARY

Twenty-two experiments under seven different projects have been carried out during 2018-19 in Plant Physiology Division of BRRI. Among the different research projects, most of the experiments were pertaining to five major stress environment i.e. salinity, submergence, drought, heat and cold. Only few experiments were associated with growth studies and yield potential. In salinity stress, around 408 germplasm and 58 plant breeding lines were characterized, and 25 of them were found moderately tolerant at seedling stage. A total of 20 significant QTLs were identified for salinity tolerance at reproductive phase. QTLs in chromosome 6 was found consistent for filled grain number, filled grain weight and spikelet fertility traits with R^2 ranged from 47.89%-51.68%, which could be the prime target for developing future reproductive phase salinity tolerance from Ashfalbalam. Under two weeks of complete submergence environment, out of 114 only one germplasm (Acc. No. 1028) found tolerant and seven germplasm found moderately tolerant. Out of 250 advanced breeding lines, three lines were found moderately tolerant under flash flood submergence. In stagnant flooding conditions, out of 43 genotypes, only eight genotypes were found moderately tolerant. In drought tolerant experiments, six advanced breeding lines, 200 germplasm, seven genotypes from India and 33 selected germplasm were examined under drought condition. Results revealed that two advanced breeding lines, 13 germplasm, one genotype from India and one selected germplasm showed better performance in relation to yield under drought stress at reproductive phase. Under marker assisted breeding programme for heat tolerance, during T. Aman season 2018 head to row of previously selected progenies were grown and 41 lines (BRRI dhan28 × N22) and 50 lines (BRRI dhan29 × N22) were selected. During Boro 2019 season head to row of previously selected progenies were grown and 17 lines (BRRI dhan28 × N22) and 24 lines (BRRI dhan29 × N22) were selected. Among 50 BRRI Genebank germplasm, three accessions (BRRI Acc no. 1522, 1523 and 1527) were found tolerant to heat at reproductive phase with more than 60% spikelet fertility. Fifty breeding lines out of 97 (BC_2F_6) were selected for further evaluation at high temperature environment. Some 470 rice genotypes of different sources were screened for seedling stage cold tolerance of which none was found cold tolerant while BRRI dhan67, Koshihikari, 34 BRRI Genebank germplasm and 21 advanced breeding lines were selected as moderately tolerant. For reproductive stage cold tolerance, six advanced breeding lines were tested in growth chamber, 16 advanced rice genotypes and three BRRI varieties were evaluated under natural condition. Results showed that five rice genotypes TP7594, TP16199, BR8907-B-1-2-CS1-4-CS2-P3, BR8562-11-2-6-1-1-1 and BR (Bio) 9777-124-1-1-2 were moderately cold tolerant at reproductive phase. Seven rice genotype of IRTON-IRRI were evaluated in Rangpur of which a genotype SVIN258 was found as moderately cold tolerant. On the basis of RPS BRRI dhan78, BRRI dhan79, BRRI dhan80 and BRRI dhan87 are weakly photoperiod-sensitive, BRRI dhan51 and BRRI dhan52 are moderately photoperiod-sensitive but BRRI dhan75 is photoperiod insensitive. Among the three breeding lines IR92704 is moderately photoperiod sensitive and other two lines are weakly photoperiod sensitive. To explore the desirable physiology through trait discovery required to maintain good balance between source-sink relationships for boosting future rice yield potential through ideotypic approach, two experiments were conducted during Boro (2017-18) and T. Aman (2018) season considering 20 and 10 genotypes respectively. Results showed that panicle dry weight (PDW), harvest index (HI) and total dry matter (TDM) had strong, significant and positive relationships to the yield of the tested genotypes revealing these traits could be the most important for considering yield improvement while using as donor.

SALINITY TOLERANCE

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

Four hundred eight germplasm along with standard tolerant IR58443 and sensitive check IRRI154 were screened according to Gregario *et al.*, 1997 at the seedling stage of rice, and out of the tested germplasm, 21 (Acc. no. 1631, 1762, 1986, 2009, 2011, 2012, 2037, 2046, 2833, 2834, 2838, 2845, 2846, 2862, 2863, 2865, 2881, 2924, 2961, 3003 and 3004) were found having moderately tolerant (SES score and survivability ranged from 4.5-5.0 and 60-100% respectively).

Screening of advanced breeding materials for salinity tolerance at seedling stage

Rice genotypes supplied by Plant Breeding Division (IRSSTN materials) and Biotechnology Division (somaclonal line) along with tolerant check IR58443-6B-10-3 and susceptible check IRRI154 were screened out under 14 dS/m salinity stress (Gregario *et al.,* 1997)

IRSSTN materials (plant breeding). Four genotypes, out of 44, were found tolerant to moderately tolerant (SES 3-5 and survivability 72.2-100%)

Advanced line and somaclonal line (Bio). Among fourteen lines none of the genotypes found tolerant to salinity (SES 6.5-9 and survivability 0-66 %).

Re-mapping QTLs for salinity tolerance of Ashfalbalam at reproductive stage

A linkage map of 105 KASP SNP markers in 200 $F_{2:3}$ population of the cross between BR11/Ashfalbalam was constructed and subsequent QTL mapping was also carried out by Inclusive Composite Interval Mapping method reported in 2016-2017. During this mapping, 10 significant QTLs were identified for filled grain number (1), filled grain weight (1), unfilled grain number (3), spikelet damage (4) and flag leaf damage (1) for reproductive stage salinity tolerance from Ashfalbalam by phenotyping the populations in the soil based screening system described by Gregorio, *et al.* 1997. To confirm the previously identified QTLs, an advanced generation population (F_4) was used. This time phenotyping was carried out in the salinity tank with moderate stress (6 dS/m) for whole growth period (transplanting till maturity). A total of 20 significant QTLs were identified for plant height (1), filled grain number (10), unfilled grain number (4), spikelet fertility (2) and shoot dry weight (3). In both of the mapping, one cluster of QTL in chromosome 6 was found consistent for filled grain number, filled grain weight and spikelet fertility traits with R^2 ranged from 47.89%-51.68% (Table 1 and Fig. 1). This QTL region could be the prime target for developing future reproductive stage salinity tolerance from Ashfalbalam.

Table 1. Significant QTLs identified for reproductive stage salinity tolerance from Ashfalbalam.

Trait name	Chr. no.	Position (cm)	Left marker	Right marker	LOD	PVE (%)	Add	Dom
PH	1	23	K_id1028615	K_id1024973	8.34	32.15	15.08	-2.33
FGN	2	28	id2010481	K_id2000618	4.99	47.83	164.24	-178.12
FGN	3	81	K_id3003557	K_id3007320	5.87	50.57	105.58	-170.27
FGN	4	41	id4010800	id4000734	3.92	53.61	-159.84	-160.39
FGN	4	130	id4005212	id4005825	3.04	42.11	191.01	-138.51
FGN	5	81	id5003661	id5009280	3.30	59.37	132.41	-168.29
FGN	6	153	id6007312	K_id6011324	3.37	51.68	185.79	-142.48
FGN	10	64	id10006389	id10003870	3.41	35.94	-101.90	-106.36
FGN	10	94	id10003686	id10001118	4.67	58.95	148.68	-155.26
FGN	12	4	id12001582	id12006327	4.82	27.90	-287.53	-296.11
FGN	12	40	id12006327	id12004974	4.33	47.92	-148.98	-183.39
UFGN	3	13	id3000757	id3001772	3.95	15.22	-31.94	16.96
UFGN	4	28	id4010800	id4000734	4.65	37.42	-84.17	-70.59
UFGN	6	88	id6000009	id6012115	5.15	36.98	-82.47	-71.95
UFGN	7	169	id7001153	id7001003	3.61	12.39	-1.39	47.52
Fertility	6	145	id6006868	id6007312	4.30	36.42	-18.69	18.41
Fertility	6	155	id6007312	K_id6011324	3.09	38.08	17.10	11.12
SDW	2	36	id2010481	K_id2000618	3.56	36.42	2.40	-2.33
SDW	4	129	id4005212	id4005825	3.54	37.38	3.70	-1.92
SDW	10	62	id10006389	id10003870	8.11	55.60	-2.63	-2.08

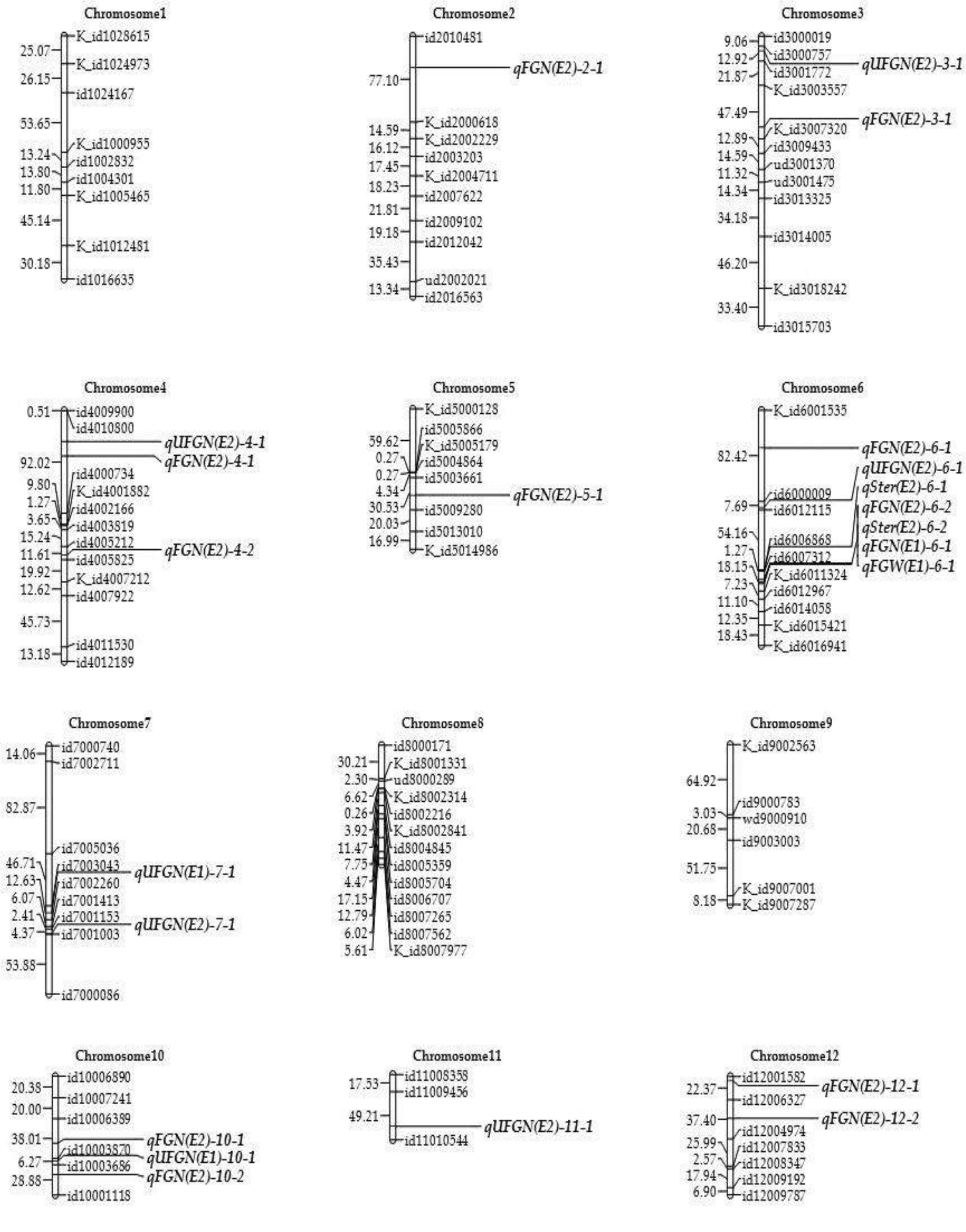


Fig. 1. Genetic linkage map of 12 rice chromosomes and QTLs detected for reproductive phase salinity tolerance of Ashfal balam.

SUBMERGENCE TOLERANCE

Identification of rice germplasm for two weeks flash flood submergence tolerance

About 114 germplasm were tested to identify tolerant germplasm for two weeks complete submergence condition. Out of 114 germplasm only one germplasm (Acc. no. 1028) was found tolerant (SES score 1) with 100 percent survivability. Seven germplasm (Acc. no. 1002, 1011, 1012, 1029, 1030, 1042, 1061) was found moderately tolerant with SES score 5 and survivability 77-92%, while survivability of tolerant check FR13A was 100%.

Identification of breeding lines for flash flood submergence tolerance

About 250 advanced breeding lines were tested to identify tolerant advanced breeding lines which could survive for 16 days or more days under complete submergence condition. Out of 250 advanced breeding lines only three PVS lines (IR13F441, IR13F458 and IR 92704-SUB-SUB-140-2-B) showed more than 50% survivability with SES score 7. Among the four check variety BINA dhan12 had the highest survivability (70%) with SES score 7. Whereas, the SES score of other three check varieties BRRI dhan51, BRRI dhan52 and BRRI dhan79 was 9 with survivability 12, 40 and 42% respectively.

Effect of submergence duration on growth and yield of some submergence tolerant varieties

An experiment was conducted to evaluate growth and yield performance of BRRI dhan52 and BRRI dhan79 under different submergence duration. Three submergence conditions (10 days, 14 days and 18 days) were applied at crop vegetative stage. One set was grown in normal environmental condition. No significant GD and yield differences were found for 10 days submerged and normal environmental condition. Plant mortality rate also was found minimum. There was no mortality of BRRI dhan79 up to 14 days of complete submergence, while BRRI dhan52 had only 2% mortality. However, BRRI dhan52 survived 6% more than BRRI dhan79 after 18 days of complete submergence. BRRI dhan79 required 1 day more time to recover than BRRI dhan52 with the increasing of submergence duration upto 18 days. Yield reduction of BRRI dhan52 (25%) was higher than BRRI dhan79 (17%) after 14 days of complete submergence, but it was more or less similar (48%) at 18 days of complete submergence.

Screening for stagnant flooding tolerance of advance breeding lines and BRRI rice varieties at whole growth period during T. Aman season

Sixteen advanced breeding materials and 27 T. Aman varieties along with two check varieties (BINA dhan11 and BINA dhan12) were tested in 60 cm (gradually increase) water pressure till maturity to identify stagnant flooding tolerance genotypes. Among the genotypes three advanced breeding lines namely IR 13F458-5, IR 13F458-1 and IR 13F712-5 were found moderately tolerant. Among 27 varieties five varieties were found moderately tolerant viz BRRI dhan46, BRRI dhan33, BRRI dhan53, BR23 and BR10.

DROUGHT TOLERANCE

Screening of rice germplasm for drought tolerance at reproductive phase, T. Aman 2018

Two hundred rice germplasm collected from BRRI GeneBank along with check variety BRRI dhan56, BRRI dhan66, BRRI dhan71 and IR64 were tested during T. Aman season 2018 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 four weeks after transplanting and field were drained out properly for not allowing any standing water until maturity. Out of 200 germplasm, 13 genotypes showed best performance in relation to yield under drought stress at reproductive phase.

Physiological performance for advanced breeding lines under control drought condition at reproductive phase

Six advanced breeding lines along with check varieties BRRI dhan56, BRRI dhan71 and IR64 were evaluated in Plant Physiology net house shaded by polythene sheet at BRRI HQ, Gazipur during T. Aman season 2018. 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 drained out from the 2nd set so that the plants experiences drought stress from the reduction division stage. The water table depth and soil moisture was recorded. At severe drought stress some life saving water was applied and calculated as follows: = Πr^2h Where, r = 56/2 = 28 cm (The radius of the circumference of pot was at the base of the hill) h=0.5 cm/day (the approximate evapotranspiration at the period of Nov-Dec.

Out of six RYT materials IR96321-1099-402-B-4-1-2 performed better followed by IR96321-1447-428-B-1-1-1.

Evaluation of exotic genotypes collected from India under control drought stress at reproductive phase

Seven genotypes collected from India along with check varieties BRRI dhan56, BRRI dhan71 and IR64 were evaluated under control drought condition in Plant Physiology Division at BRRI HQ, Gazipur during T. Aman 2018. The methodology was same as previous experiment. Among the seven genotypes DRR dhan44 showed better performance under drought condition followed by CR SugandhDhan 907 (CR 2616-3-3-3-1).

Evaluation of previously selected germplasm under drought stress at reproductive phase in the rain-out shelter

This experiment was conducted in the rain-out shelter, Plant Physiology Division at BRRI HQ, Gazipur during T. Aman season 2018 to evaluate previously selected 33 germplasm 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 was below 1 m and soil moisture was around 20%. Under control drought condition in the rainout shelter, out of 33 germplasm BRRI Genebank Acc. no. 1353 yielded highest followed by Acc. no. 1434 and 1069 which have 1 to 5 tolerance score in previous year in the field that reveals a positive correlation with field performance.

HEAT TOLERANCE

Marker assisted introgression of spikelet fertility QTL from N22 in to two Bangladeshi mega rice variety BRRI dhan28 and BRRI dhan29

Development of heat tolerant BRRI dhan28 and BRRI dhan29 by introgressing spikelet fertility QTL (*qHTSF4.1*) through MABC is on-going. From second backcross population, 375 plants from BRRI dhan28 × N22 cross and 360 plants from BRRI dhan29 × N22 cross at BC2F6 stage were selected for more uniformity. During T. Aman season-18, head to row of previously selected progenies were grown and 41 lines (BRRI dhan28 × N22) and 50 lines (BRRI dhan29 × N22) were selected. In Boro 2019 season, head to row of previously selected progenies were grown and 17 lines (BRRI dhan28 × N22) and 24 lines (BRRI dhan29 × N22) were selected. During harvesting of the selected lines phenotypic similarity with reference to the respective recurrent parents (BRRI dhan28 and BRRI dhan29) were also compared.

Screening rice germplasm and advanced breeding lines for heat tolerance

Two experiments were conducted to evaluate the breeding lines/germplasm of rice to develop a high temperature tolerant rice variety. Seeds of 97 breeding lines (BC_2F_6) 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 (80±5%) for seven days. Among the breeding lines, 50 entries showed 60 to 80% fertility under heat stress treatment and got SES score 3, which were selected for further advancement. Following the same procedure 50 BRRI GeneBank germplasm (Aus) were screened against high temperature. Among the 50 germplasm 22 scored 5 and 3 (Acc. no. 1522, 1523, 1527) scored 3.

COLD TOLERANCE

Screening rice genotypes for seedling stagecold tolerance

Some 470 rice genotypes of different sources (202 BRRI Genebank Germplasm, four BRRI varieties, 264 advanced breeding lines and six exotic materials) along with four check varieties namely BRRI dhan28, BRRI dhan36, Mineasahi 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 3 leaf stage. The plastic trays were then placed into cold water tanks adjusted to constant temperature at 13°C.

Among the tested rice genotypes, BRRI dhan67, an exotic rice genotype Koshihikari, 34 BRRI GeneBank germplasm (Acc. no. 1821, 1822, 1826, 1837, 1841, 1842, 1856, 1858, 1868, 1869, 1874, 1875, 1876, 1877, 1879, 1881, 1882, 1884, 1892, 1893, 1897, 1898, 1901, 1902, 1903, 1904, 1905, 1906, 1910, 2128, 2129, 2130, 2161 and 2162) and 21 advanced rice genotypes showed moderately cold tolerant at seedling stage. Selected advanced rice genotypes are BR11001-5R-8, BR11002-5R-129, BR10717-5R-67, BR10717-5R-70, BR10707-5R-16, BR10707-5R-34, BR10707-5R-75, BR10707-5R-98, TP26716, IR100740-89-B-2, BR8910-B-6-3-CS1-5-CS2-P3-1-4, BR9989-23-CS1-1-CS2-21-2-1, BR8909-B-12-2-CS1-4-CS2-P6-5-2, 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-P2-1-4, BR8909-B-12-2-CS1-4-CS2-P2-3-2, BR11662-23-6-1, BR11662-25-2-2, BR11662-25-5-1 and BR11663 (14A2)-1-5.

Screening of advanced breeding lines for reproductive phase cold tolerance at artificial condition

Cold induced spikelet sterility of rice is a major problem in early planted Boro rice in Bangladesh. Six advanced rice genotypes were tested along with BRRI dhan28, BRRI dhan36, Bhutani rice, Mineasahi and HbjB-VI as checks for reproductive phase cold tolerance in BRRI HQ Gazipur during Boro 2018-19 season. Twenty-day-old seedlings were transplanted in pots at Plant Physiology nethouse. Three pots of each genotype at reduction division stage were introduced into a growth chamber (GC) at 17°C for 10 days. On the other hand, three pots of same genotypes were kept at natural condition as control. 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.

Growth duration was increased by 10 days in cold treated BR8562-11-2-6-1-1-1 and BR(Bio)9777-124-1-1-2, which was comparable to BRRI dhan28 and BRRI dhan36, but significantly higher than tolerant check varieties Mineasahi, Bhutani rice and HbjB-VI. It was 15-16 days in other advanced lines. On the other hand, cold treatment reduced plant height by around 12 cm in BR8562-11-2-6-1-1-1 and BR(Bio)9777-124-1-1-2, which was also comparable to BRRI dhan28 and BRRI dhan36, but significantly higher than tolerant check varieties. After cold treatment, similar trend was also observed in reduction of last internode and panicle exertion. Cold induced spikelet sterility of BR8562-11-2-6-1-1-1 and BR(Bio)9777-124-1-1-2 was similar and it was significantly lower than BRRI dhan28 and BRRI dhan36, but higher than tolerant checks (Table 2). Out of six advanced rice genotypes BR8562-11-2-6-1-1-1 and BR(Bio)9777-124-1-1-2 showed moderate level of cold tolerance. Other advanced lines were susceptible.

Table 2. Effect of cold treatment on selected advanced breeding lines, Boro2018-19.

Genotype	Growth duration (d)		Plant height (cm)		Last internode length (cm)		Last leaf sheath length		Panicle exertion (%)		Sterility (%)	
	Cold treat	Control	Cold treat	Control	Cold treat	Control	Cold treat	Control	Cold treat	Control	Cold treat	Control
BR8562-11-2-6-1-1-1	161	151	61.6	73.22	16.15	23.5	20.23	25.14	80.23	100	55.32	17.69
BR8562-11-2-6-2-2-2	163	151	71.67	89.5	15.2	27.77	23.44	27.23	65.12	98.24	89.45	18.49
BRRI dhan29-SC3-28-16-10-6-HR6-P4	156	140	70.2	88.12	14.25	23.33	23.41	23.69	55.45	99.68	95.12	23.45
BRRI dhan29-SC3-28-16-10-6-HR6-P8	155	140	70.8	88.76	13.3	24.58	25.15	25.33	50.37	95.54	94.27	25.62
BRRI dhan29-SC3-28-16-10-6-HR6-P11	155	140	70.13	89.96	13.66	24.99	24.0	24.97	50.46	100	93.78	24.15
BR(Bio)9777-124-1-1-2	156	146	75.74	87.7	21.43	29.16	24.11	28.0	90.27	100	56.85	13.15
Bhutani rice (Tol. ck)	148	141	108.7 3	115.5	36.69	40.5	29.37	31.5	100	100	32.61	17.09
Mineasahi (Tol. ck)	147	142	99.6	104.0	28.83	30.51	26.58	27.5	100	100	26.16	19.22
HbjB-VI (Tol. ck)	157	150	104.7 9	112.2	28.45	33.25	27.5	30.69	100	100	39.07	16.49
BRRI dhan28 (ck)	157	146	77.17	90.13	18.17	26.33	25.08	26.45	82.29	100	68.89	12.86
BRRI dhan36 (ck)	159	148	76.76	90.17	17.1	26.25	25.5	26. 96	71.76	100	77.32	14.11
LSD $_{5\%}$ Genotype (G)	2.38		6.37		1.32		1.48		13.57		12.85	
LSD$_{5\%}$ Sowing time (S)	0.82		2.35		0.49		0.52		5.25		4.35	
LSD$_{5\%}$ for G*S	3.64		8.87		1.78		1.91		17.34		19.86	

Characterization and evaluation of some selected rice genotypes for cold tolerance

Some 16 advanced breeding lines, three BRRI varieties (BRRI dhan81, BRRI dhan84 and BRRI dhan86) along with five check varieties namely BRRI dhan28, BRRI dhan36, Bhutani rice, Mineasahi and HbjB-VI were evaluated in natural field condition. There were three seeding times 15 October, 1 November and 15 November. Thirty-day-old seedlings were transplanted in main field. Early planting (15 October and 1 November) were done with a view to falling rice reproductive phase at cold. Changes in different parameters of rice after natural cold treatment were compared with control treatment which was sown on 15 November.

Among the tested genotypes, none was found cold tolerant at reproductive phase. Natural cold stress at reproductive phase changed different physiological parameters and caused longer growth duration, poor panicle exertion, higher percentage of sterility, shorter plant height and last internode length over control treatment in all rice genotypes. Cold shock altered above mentioned physiological parameters of all the advanced breeding lines, BRRI dhan86, BRRI dhan84 and BRRI dhan81 significantly more than cold tolerant check varieties Mineasahi, Bhutani rice and HbjB-VI (Table 3). BRRI dhan86 was found the most cold sensitive variety. However, only five genotypes TP7594, TP16199, BR8907-B-1-2-CS1-4-CS2-P3, BR8562-11-2-6-1-1-1 and BR(Bio)9777-124-1-1-2 were found as moderately cold tolerant at reproductive phase (Table 3).

Table 3. Physiological parameters of some rice genotypes as affected by natural cold treatment.

Genotype	Growth duration increased (day)		Pl height reduced (cm)		Last internode length reduced (cm)		Panicle exertion (%)		Sterility (%)		Yield (t/ha)	
	15 Oct	1 Nov	15 Oct	01 Nov	15 Oct	1 Nov	15 Oct	1 Nov	15 Oct	1 Nov	15 Oct	1 Nov
TP7594	21	10	18.21	12.24	6.85	4.32	92.34	100	74.29	20.15	1.18	6.16
TP16199	21	10	17.87	11.99	7.12	4.25	90.29	100	76.84	19.24	1.14	6.13
BR8907-B-1-2-CS1-4-CS2-P3	24	11	21.07	12. 78	8.26	5.62	88.31	96.12	9.99	21.37	0. 85	6.11
BR8562-11-2-6-1-1-1	23	10	20.01	12.65	8.21	4.45	86.52	96.24	1.26	21.45	0.88	6.04
BR(Bio)9777-124-1-1-2	23	10	19.98	12.68	8.37	4.57	85.27	97.15	2.24	21.15	0.87	6.12
BRRI dhan81	27	12	24.27	16.85	11.32	10.62	61.27	82.19	95.65	30.77	0.172	5.33
BRRI dhan84	27	12	24.78	16.57	10.45	9.46	79.61	96.26	1.63	26.68	0.233	5.03
BRRI dhan86	28	13	25.89	17.59	11.78	10.65	45.37	63.45	98.62	62.73	0.060	2.69
BRRI dhan28 (ck)	24	11	22.21	15.45	8.24	6.59	75.72	99.56	92.35	25.68	0.195	5.65
BRRI dhan36 (ck)	23	11	21.46	14.85	7.86	6.56	71.85	97.48	95.75	30.62	0.176	5.33
HbjB-VI (Tol. ck)	14	8	13.35	7.89	5.87	3.31	99.12	100	53.62	18.63	1.32	3.20
Bhutani rice (Tol. ck)	12	7	10.56	6.68	2.25	1.89	100	100	4.56	19.27	1.69	2.27
Mineasahi (Tol. ck)	10	6	7.86	5.79	1.94	1.32	100	100	22.45	21.98	2.87	2.64
LSD $_{5\%}$ Genotype (G)	1.75		1.86		1.61		11.23		12.47		0.63	
LSD$_{5\%}$ Sowing time (S)	0.62		1.26		0.78		3.58		4.43		0.49	
LSD$_{5\%}$ for G*S	2.79		3.62		3.64		14.28		16.24		1.56	

International temperate rice observational nursery (IRTON), 2018-19

Seven rice genotypes of IRTON-IRRI along with BRRI dhan28, BRRI dhan36, BRRI dhan58, BRRI dhan69 and BRRI dhan89 as checks were tested in BRRI RS, Rangpur. Vegetative vigour (Vg) 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. On the basis of phenotypic acceptance, growth duration, sterility, grain size, yield and cold tolerance ability a genotype SVIN258 was selected as moderately cold tolerant.

GROWTH STUDIES

Response to photoperiod of some BRRI released modern T. Aman varieties and IRRI advanced line

An experiment was conducted to know the response to photoperiod of six BRRI released modern T. Aman varieties and three IRRI advanced lines. Sprouted seeds of all genotypes were sown in the line 20 cm apart on April 2018. After emergence the plants were thinned. Ten hour photoperiodic treatment was started from seed sowing. One set were grown at natural day length. The experiment was replicated four times. Observations were made on dates of seeding and heading. Basic vegetative phase (BVP), photoperiod sensitive phase (PSP) and relative photoperiod sensitivity (RPS) were determined using the following equations.

BVP= Growth duration (sowing to heading) at 10 hours photoperiod - 30 days (Mohapatra *et. al*, 2011, Advances in Agronomy, Vol 110, Elsevier Inc) PSP= Growth duration (sowing to heading) in natural day length photoperiod - Growth duration (sowing to heading) at 10 hours photoperiod

RPS = PSP of the Entry/PSP of Nizersail ×100

Compared to Nizersail, BRRI dhan78, BRRI dhan79, BRRI dhan80 and BRRI dhan87 are weakly photoperiod-sensitive. BRRI dhan51, BRRI dhan52 are moderately photoperiod-sensitive but BRRI dhan75 is photoperiod insensitive. Although BRRI dhan80 and BRRI dhan87 are classified as weakly photoperiod sensitive, their sensitivity to photoperiod is very low. Among the three breeding lines IR92704 is moderately photoperiod sensitive but other two lines (IR13F441 and IR92466) are weakly photoperiod sensitive (Table 4).

YIELD POTENTIAL

Physiological characterization for morpho-physiological traits of rice 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. Since, then none of the concept such as New Plant Type (NPT) and MAS for pyramiding of major effect QTLs/Genes able to produce desirable ideotype expected by researchers for boosting yields at least 20%. Therefore, the current research aimed to explore the desirable physiology through trait discovery required to maintain good balance between source-sink relationships for boosting future rice yield potential through ideotypic approach. Two experiments were conducted during Boro (2017-18) and T. Aman (2018) season considering 20 and 10 genotypes respectively. Panicle dry weight (PDW), harvest index (HI) and total dry matter (TDM) showed strong, significant and positive relationships to the yield of the tested genotypes revealing these traits could be the most important for considering yield improvement while using as donor. Growth duration (GD) significantly affects the following three traits for high yield in the Boro season, however, it showed poorer performance for the T. Aman season (Figs. 2 and 3). BRRI dhan28 was identified as the most consistent yielder i.e. less affected by the seasonal variation. Bash Full (3954) and BR9680-2-3-2 was identified for better top 3 leaf length and breadth. However, for top 3 leaf angle, BRRI dhan29, BRRI dhan47, BRRI dhan87, Habataki and CN6 was selected for having leaf angles within the recommended ranges (5°-10°-20°) (Fig. 4). Maximum PAI was found for germplasmButa and Dudkat (5.5 and 5.8) but among the modern varieties, BRRI dhan29 showed highest 5.6 at the 9th weeks after transplanting (WAT). The quickest canopy coverage was observed for BRRI dhan28, BRRI dhan29, BRRI dhan87 and Dudkat at 6 WAT while PAI was reached to 4.0. Flag leaf photosynthesis was found highest in CN6 compared to BRRI dhan28. Number of spikelets per square meter was found within the recommended range (45000-55000) for BRRI dhan29, Bash Full (3954) and Koshihikari in the Boro season and CN6 in the T. Aman season.

Table 4. BVP, PSP and RPS of some BRRI released T. Aman varieties and IRRI lines.

Variety	BVP	PSP	RPS (%)	Remark
BRRI dhan51	33.35 (±0.94)	72.37(±3.04)	60.26	Moderately photosensitive
BRRI dhan52	24.99 (±0.61)	61.28±2.89	51.02	Moderately photosensitive
BRRI dhan75	39.61 (±0.83)	7.27 (±1.55)	6.63	Insensitive
BRRI dhan78	32.92 (±0.74)	42.81 (±4.34)	35.63	Weakly photosensitive
BRRI dhan79	45.28 (±0.45)	38.47 (±2.82)	32.03	Weakly photosensitive
BRRI dhan80	60.36 (±0.87)	26.51 (±4.79)	24.53	Weakly photosensitive
IR13F441	44.48 (±0.62)	58.68 (±2.16)	48.87	Weakly photosensitive
IR92704	30.63 (±0.45)	74.92 (±3.14)	62.39	Moderately photosensitive
IR92466	36.85 (±0.71)	60.18 (±2.40)	50.10	Weakly photosensitive
BRRI dhan87	29.97 (±0.65)	32.24 (±1.19)	26.84	Weakly photosensitive
Nizersail	19.21 (±0.74)	120.11 (±0.06)	100	Check

Values are average of four replications and figures in the parentheses denote standard error.

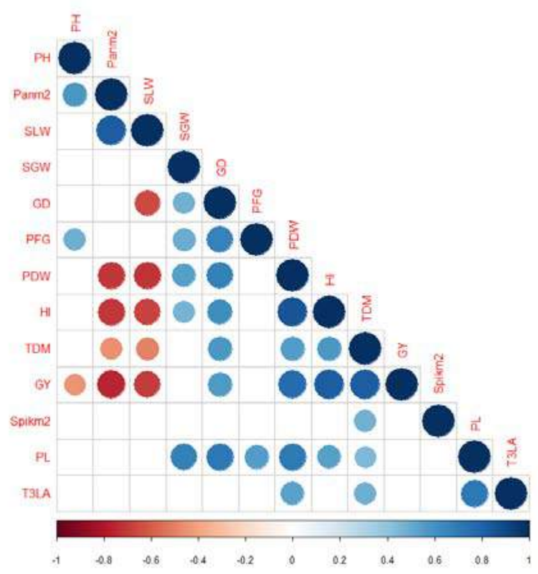


Fig. 2. Correlogram with significant correlations among 13 phenotypic traits recorded for the tested 20 genotypes at field condition (Boro, 2017-18).

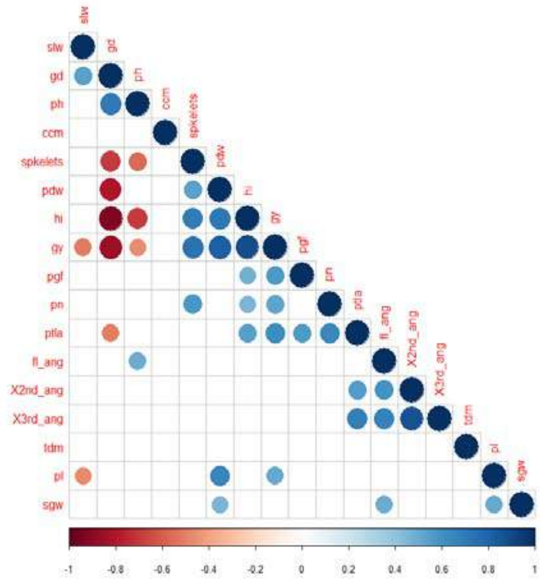


Fig. 3. Correlogram with significant correlations among 17 phenotypic traits recorded for the tested 10 genotype at field condition (T. Aman 2018).

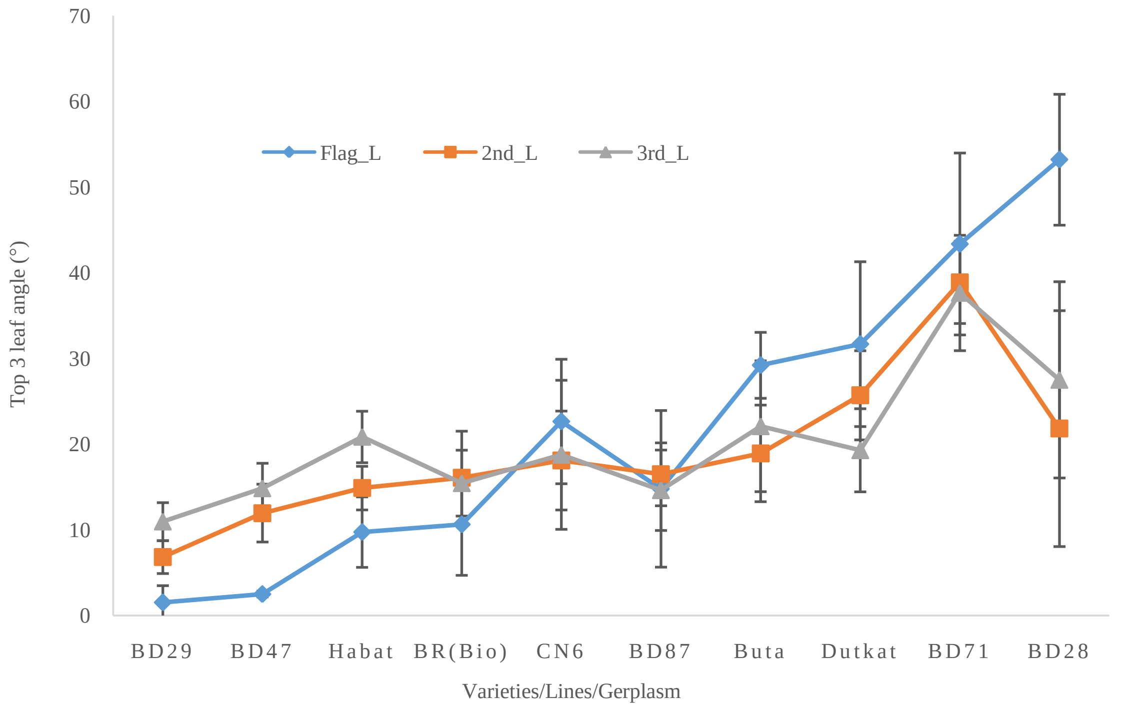


Fig. 4. Top 3 leaf angles during grain filling stage. Each marker is the mean of 3 hill data ±SD.

Entomology Division

SUMMARY

Comparatively higher incidences of insect pests were observed in Aus and T. Aman seasons than the Boro season during weekly sampling at BRRI HQ, Gazipur. On the other hand, more insect pests were observed in rice seedbed than other habitats in all three seasons. Higher numbers of natural enemies were found in the Aus season than the Boro and T. Aman seasons. Insect pests population and its damage intensity were below the ETL in all the three rice seasons.

The highest catch of insect pests and natural enemies in light trap was recorded at BRRI HQ followed by BRRI RS Rajshahi and Barishal. In contrast, incidence of both insect pest and natural enemies was lower in BRRI RS Rangpur, Cumilla and Sonagazi than the other BRRI RSs.

Significant number of caseworms, yellow stem borer, green leafhopper, rice bug, mole cricket, field cricket and leafroller were trapped in BRRI developed solar light trap when placed in five locations of Gazipur, Patuakhali, Jashore, Narsingdi and Khulna.

Prediction of future temperature and rainfall patterns in coastal areas, based on historical climatic data collected from Bangladesh Meteorological Department, Dhaka, shows that, according to RCP 4.5 scenario, temperatures on three time-slices, F_1 (2006-39), F_2 (2040-69) and F_3 (2070-2095), and comparing with the baseline of 1981-2005, increase in maximum temperatures by 0.76°C, 1.56°C and 2.04°C and minimum by 0.78°C, 1.55°C and 2.01°C during F_1, F_2 and F_3 respectively in coastal areas.

Rice weevil laid higher number of eggs on BRRI hybrid dhan3 followed by BRRI dhan29 and Black rice, when development of rice weevil was investigated in laboratory. Rice weevil infested significant higher number of grains of black rice than that of other two varieties. However, higher number of adult weevil was developed from hybrid rice indicating that hybrid rice induces higher population development of this insect.

Significantly higher natural enemies and parasitism were found in rice field surrounded by flowering plants on bunds, indicating enhanced ecosystem could increase natural enemies and parasitism activity in the rice field. So, farmers should avoid the toxic and hazardous insecticides to control the insect pests by growing nectar-rich flowering plants on the bunds of surrounding rice crops.

A total of 47 commercial formulations of insecticides were evaluated against brown planthopper (BPH). A total of 45 insecticides out of 47 were found effective against BPH with 80% mortality or above.

No significant impact was observed in golden rice on the abundance of insect pests and natural enemies of rice. Statistically similar number of YSB, leafroller, rice bug, carabid beetle and parasitoids were found both in golden rice and BRRI dhan29.

Use of sex pheromone trap showed significant reduction of leafroller in rice field indicating a promising tool for pest management in rice field.

A total of 207 advanced breeding lines/varieties were evaluated at green house of Entomology Division. One IRBPHN genotype (SVIN036) and one RYT (FBR), one ALART (Kalizira type) breeding line (BR 8850-10-12-2-3) and one RLR line (IR11N202) were found moderately resistant (score 3) to BPH, WBPH and GLH respectively.

SURVEY AND MONITORING OF RICE ARTHROPODS

Pest and natural enemy incidence at BRRI HQ 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 HQ farm, Gazipur. The overall insect pest incidence was low in all seasons. Comparatively higher incidences of insect pests were found in Aus and T. Aman seasons than the Boro season. Green leafhopper (GLH), white leafhopper (WLH) and grasshoppers (GH) were the most abundant pests found in all the three seasons. The highest number of rice bug was found in Aus 2018. Higher number of pest population was found in seedbed than the rice field among all the habitat of Aus, T. Aman and Boro. Higher numbers of natural enemies were found in the Aus season than the Boro and T. Aman seasons. Spider (SPD), damsel fly (Dam. fly), ladybird beetle (LBB) and carabid beetle (CDB) were the dominant predators in all the habitats of the reporting seasons.Visual counting from 20 hills showed that the population and the damage of insect pests were below the economic threshold level (ETL) in all the three rice seasons.

PI: Mir Md Moniruzzaman Kabir, **CI:** 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 throughout the year by Pennsylvanian light trap from dusk to dawn throughout the year at BRRI HQ, Gazipur and BRRI RSs. The highest number of insect pest and natural enemies was found in BRRI HQ followed by BRRI RSs, Rajshahi and Barishal (Fig. 1). In contrast, incidence of both insect pest and natural enemies was lower in BRRI RSs Rangpur, Cumilla and Sonagazi. The abundance of BPH, WBPH, YSB and GLH was observed almost all the locations (Fig. 2). The highest number of BPH was observed in October and November at Gazipur and Rajshahi. BPH had an additional minor peak in April to June 2019 at Gazipur. Like BPH, both Gazipur and Rajshahi had one peak in October (Fig. 2). The highest peak of YSB was observed at Rajshahi in October and May, followed by Barishal in November and March (Fig. 2). Two peaks of GLH were observed the first one was on October for Gazipur and Rajshahi while on November for Barishal. However, the second peak of GLH was observed in the end of April for Gazipur and May for Rajshahi.

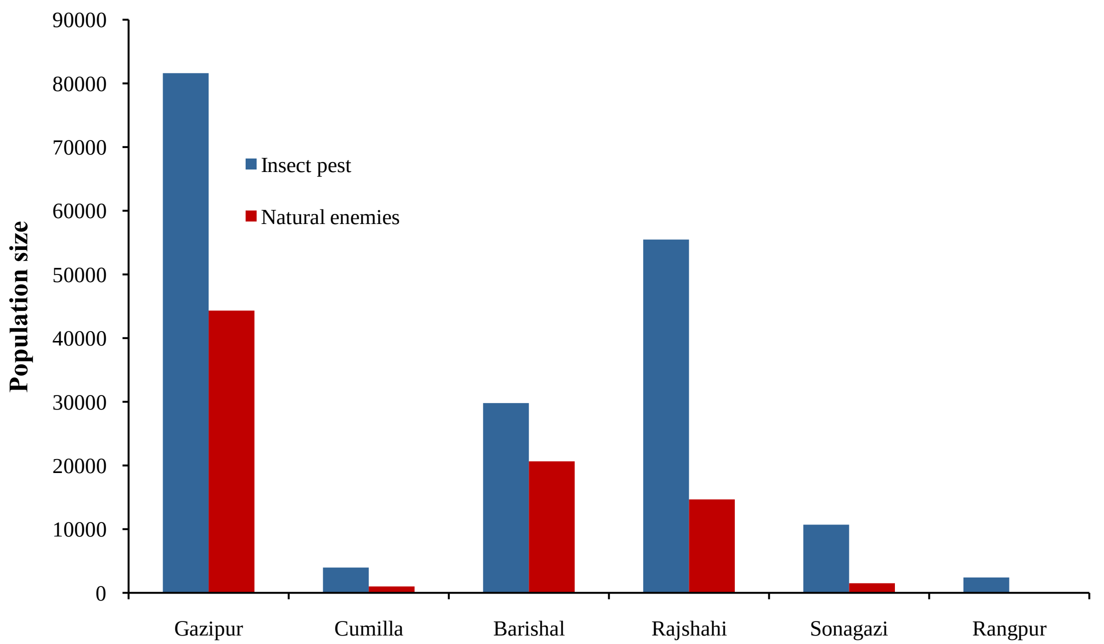


Fig 1. Total population of insect pests and natural enemies at brri hq, gazipur and five regional stations (RS).

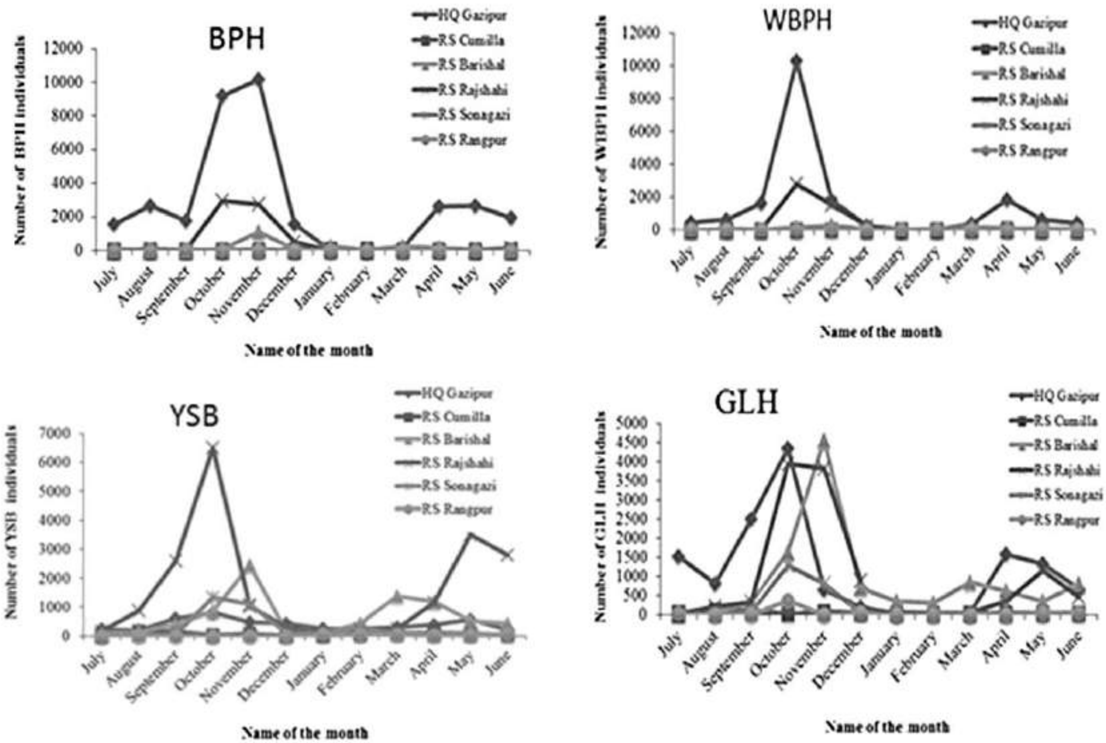


Fig. 2. Incidence pattern of major insect pests in light trap, BRRI HQ, Gazipur and regional stations, during July 18-June 19.

Among the natural enemies carabid beetle (CDB) had two major peaks in different months of the year in three locations, Gazipur, Rajshahi and Barishal (Fig. 3). In Gazipur, peaks were observed in November and May, for Rajshahi in October, while two peaks for Barishal were in November and March. Like CDB, several peaks of staphylinid beetle (STPD) were observed in the same locations. In Barishal, the highest peaks were found in December and March, In Gazipur, two peaks were found in December and February while Rajshahi had the major peak in March (Fig. 3). One major peak of green mirid bug (GMB) was observed in Gazipur in November (Fig. 3).

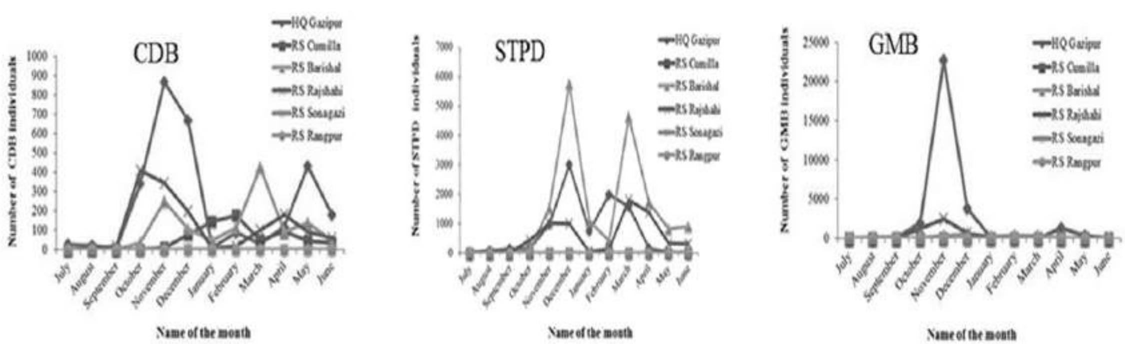


Fig. 3. Incidence pattern of natural enemies of rice insect pest in light trap, BRRI, Gazipur and regional stations, during July 18-June 19.

PI: Mir Md Moniruzzaman Kabir, **CI:** Sadia Afrin,
PL: Sheikh Shamiul Haque

Use of solar light trap for insect pests management in crop field

Pilot scale research and field trials were conducted in rice and vegetable fields of six locations in Bangladesh including Gazipur, Narsingdi, Jashore, Bogura, Patuakhali and Khulna. Five solar light traps were installed at each location and insect pest catches from each light trap were monitored every day. Significant number of insect pests that cause damage to rice were caught in each trap at every location (Fig. 4). Rice insect pests including yellow stem borer (YSB), green leafhopper (GLH), white leafhopper (WLH), leafroller (LR), caseworm (CW), brown planthopper (BPH), mole cricket, field cricket, grasshoppers, rice bug (RB) and vegetable insect pest such as brinjal shoot and fruit borer (BSFB) were recorded in solar light trap in each location. The highest numbers of insect pests were trapped in May than that of April. The highest number of GLH and YSB were recorded from solar light trap of Gazipur in April 2019 (Fig. 4). The highest incidence of YSB was observed at May followed by GLH. More than 900 YSB were caught in each light trap per month at Jashore. Among the insect pests, GLH was the dominant that trapped in solar light trap in Narsingdi. In Koyra, Khulna stem borer was the dominant insect that was caught in solar light trap. This result indicates that solar light trap would be a promising pest control tool in rice field as well as vegetable crops in Bangladesh.

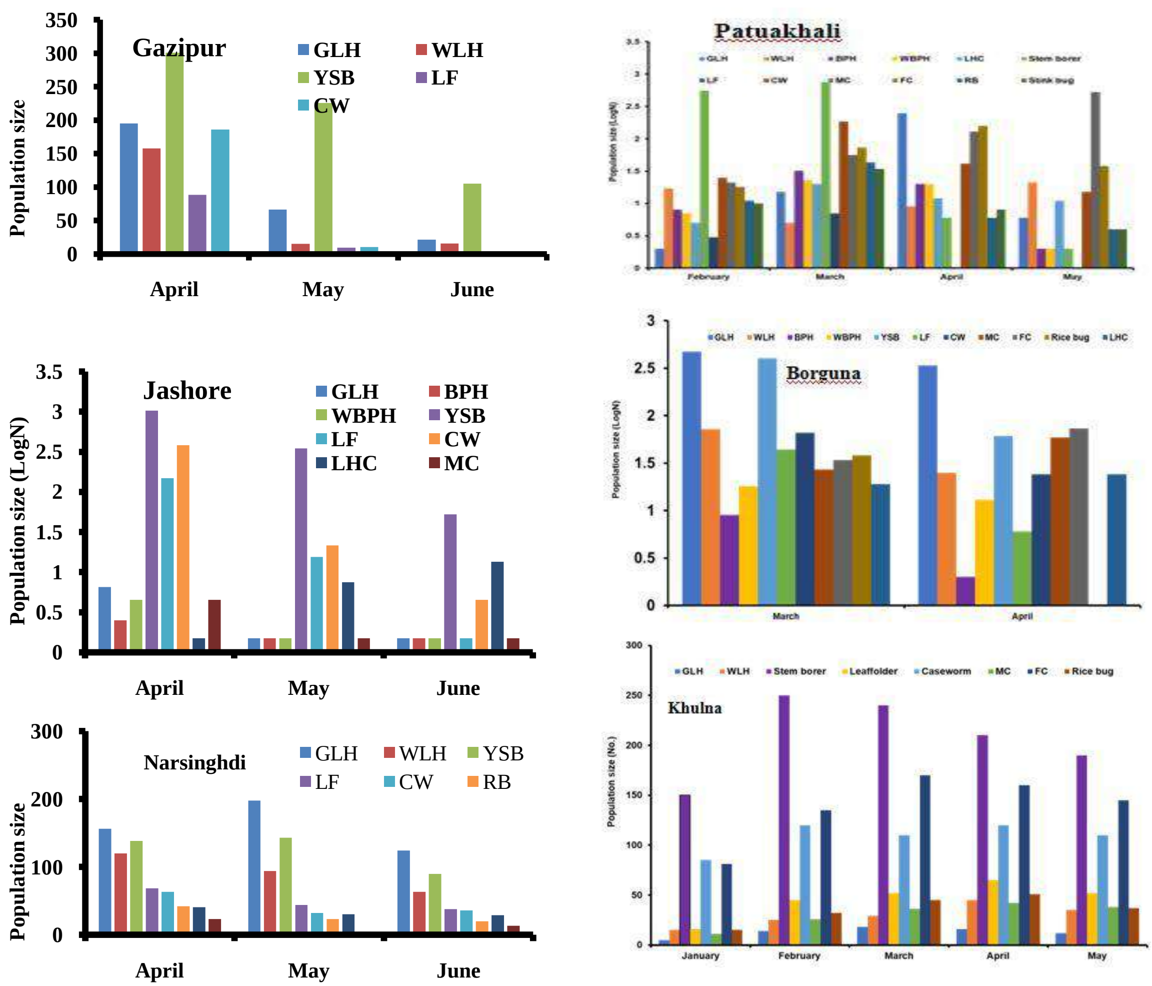


Fig. 4. Rice insect pest caught in solar light trap at different locations during Boro 2018-19.

YSB= yellow stem borer, GLH= green leafhopper, WLH= white leafhopper, F=leafroller, CW= caseworm, and RB= rice bug, ZLH= zigzag leafhopper, MC= mole cricket, FC= field cricket.
PI: Md Panna Ali, **PL:** Sheikh Shamiul Haque

Development of bioclimatic models to forecast the dynamics of rice insect pests
In order to explore the potential impacts of projected future climate change on rice production and ecosystem services on coastal areas of bangladesh, future projections of annual precipitation and maximum (t_{max}) and minimum (t_{min}) air temperatures were generated for a set of locations of ten selected areas on that coastal region. This data set was generated from daily time step model outputs obtained from 21 statistically downscaled and bias corrected 0.25° × 0.25° spatial resolution general circulation models (gcms) belonging to the nasa earth exchange global daily downscaled projections (nex-gddp; https://cds.nccs.nasa.gov/nex-gddp) product (thrasher *et al*., 2012). Available climate data span the historical period between 1950 and 2005, with future projections for the period of 2006 to 2019 as representative concentration pathways (rcps) 4.5 and rcp8.5 (meinshausen *et al*., 2011), encompassing the lower and upper range. However, in this work the historical period corresponds to 1981-2005, and future projections were generated for the common period spanning 2006-2095. Summarizing the future change, under rcp4.5 scenario, in temperatures and rainfall on three time-slices, f_1 (2006-39), f_2 (2040-69) and f_3 (2070-2095), and comparing with the baseline of 1981-2005, this analysis shows increase in maximum temperatures by 0.76°C, 1.56°C and 2.04°C and minimum temperatures by 0.78°C, 1.55°C and 2.01°C during f_1, f_2 and f_3 respectively, in 10 locations. Relatively, jashore region is predicted to be warmer than the other nine regions. On the other hand, under the same scenario, annual rainfall will likely increase by 228, 265 and 342 mm during f_1, f_2 and f_3 respectively, in the region. The effect will be more experienced in cox's bazar and less in jashore region. It is likely that such pattern of regional and seasonal variations in temperatures and rainfall will impact infestation of insect-pests and diseases on crops.
PI: Md Panna Ali, **PL:** Sheikh Shamiul Haque

STUDIES ON RICE INSECT PEST AND NATURAL ENEMY BIO-ECOLOGY

Impact of climate change on ecosystem services
Rice ecosystem harbors many kinds of arthropods such as insect pest and natural enemies. However, ongoing climate change affects the abundance of biocontrol agents in rice field especially in climate susceptible area. Comparatively higher number of insect pests and natural enemies were observed in Chattogram than Satkhira by analyzing collected data from 60 locations of two ecosystems including saline and non-saline (Fig. 5). Significant higher numbers of natural enemies including spiders, lady bird beetles, carabid beetles, dragon flies, damsel flies, green mirid bug and parasitoid wasps were observed in non-saline than saline ecosystem. No brown planthoppers (only 0.55) were observed in exposed area where eggs and adult BPH were released at the mid stage of rice growth in field. On the other hand, where BPH introduced area was covered by nylon mesh cage showed significant higher number of populations developed (180.89) and feed rice plant ($P < 0.001$). Statistically similar development trends were found in three locations as saline area ($P > 0.05$). Among the natural enemies, lady bird beetle, staphylinid beetle, carabid beetle and spiders were largely found both in exposed and non-exposed areas (Fig. 5). These indicate that natural enemies are available to destroy insect pests in rice field. Significant number of lady bird beetles (21), spiders (13), and staphylinid beetle (30) were recorded outside the cage in rice field. Higher number of lady bird beetle (31), spiders (18) and staphylinid beetle (46) was recorded in pest exposed area. Similarly, natural enemies were observed in non-saline area both in exposed and non-exposed pest area. Significant number of lady bird beetles (12), spiders (10), and staphylinid beetle (20) were recorded outside the cage in rice field. Higher number of lady bird beetle (18), spiders (14) and staphylinid beetle (26) were recorded in pest exposed area (Fig. 6). In non-exposed pest area, natural enemies including lady bird beetle, spiders and staphylinid beetles densely prevailed closed to cage where pest remained throughout the experimental period. More importantly, we quantified the yield reduction due to pest introduced in cage. Significant lower amount of rice yield observed

in non-exposed area (9 hills/cage, area: 0.36 m^2). Non-exposed area showed 206.52 g rice yield whereas exposed area showed 238.52 g yield. This result indicates that brown planthopper can reduce 13.41% rice yield if natural enemies are absent in the field.

PI: Md Panna Ali, **CI:** Md Saidur Rahman, **PL:** Sheikh Shamiul Haque

Impact of salinity on rice insect BPH and rice growth

The experiment was established in greenhouse of Entomology Division, BRRI, Gazipur. Five levels of salinity including 0 dS/m (control), 2 dS/m, 4 dS/m, 6 dS/m and 8 dS/m were used as treatment and BRRI dhan47 were sown in each earthen pot. The salinity has significant impact on the development of BPH (Fig. 7). Total number of BPH increased in control to 2 dS/m and thereafter declined with increasing salinity level. The highest population of BPH developed at 0 dS/m and 2 dS/m and the lowest was at 8 dS/m salinity. The reason behind the highest population of BPH was found at 0 dS/m and 2 dS/m might be due to growth and development of plants was better in control and lowest salinity level. Nymphal survival rate was also higher in 0 dS/m and the lowest in 8 dS/m. In higher salinity level, plant growth hampered so that BPH could not get sufficient food from the plant. This might be a cause for low survival rate in high salinity level.

PI: Farzana Nowrin **CI:** Md Panna Ali, **PL:** Sheikh Shamiul Haque

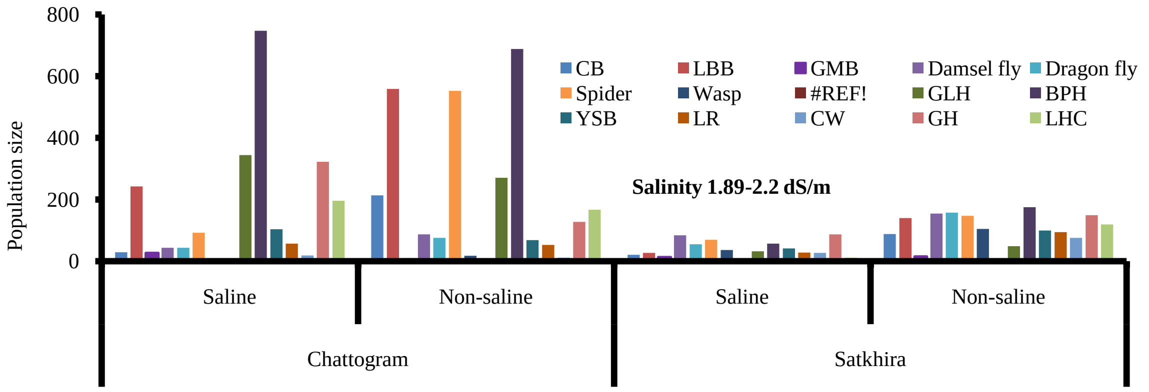


Fig. 5. Abundance of rice insects observed in Chattogram and Satkhira regions of Bangladesh. Data were collected using 20 complete sweep netting.

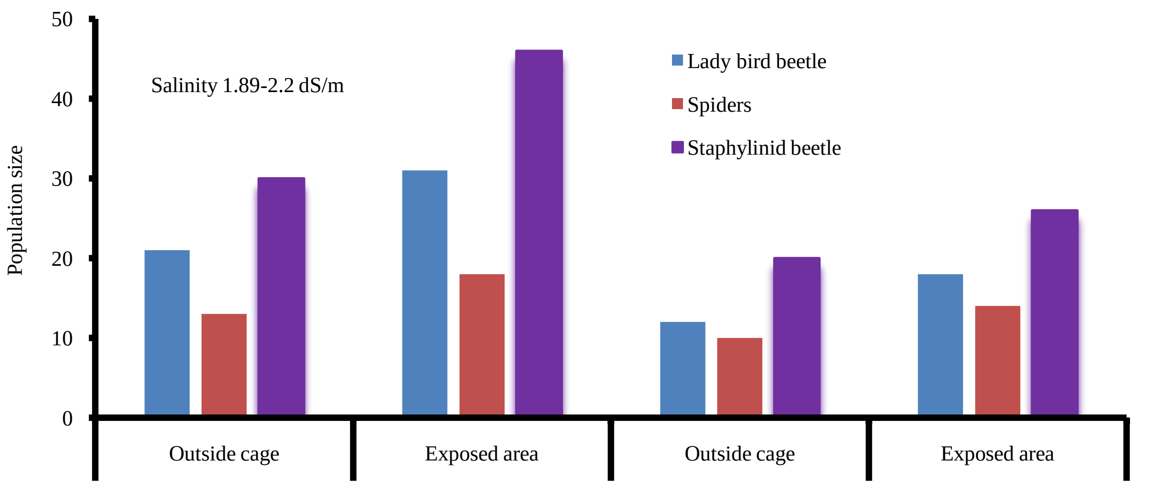


Fig. 6. Number of natural enemies observed in experimental plots both in BPH exposed and caging area at Boro 2018-19.

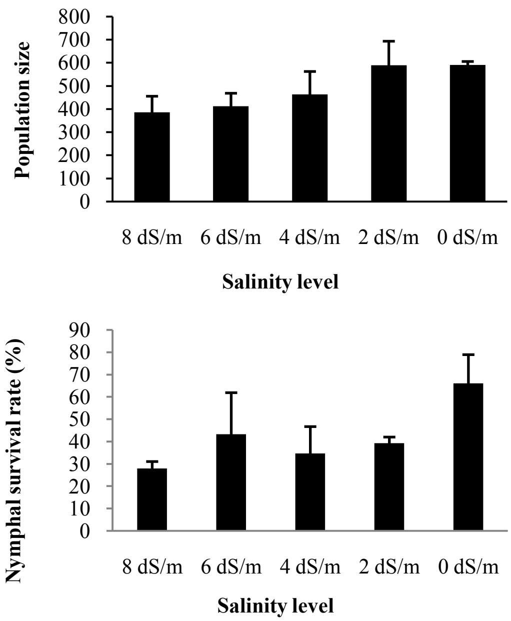


Fig. 7. Effect of salinity on population development and nymphal survival rate (%) of brown planthopper.

Rice variety influences the development of stored grain insect pest

When assessing the influence of rice weevil, *S. oryzae* on three rice varieties namely BRRI hybrid dhan3, BRRI dhan29 and Black rice in the laboratory of Entomology Division, BRRI comparatively higher number of eggs were laid on Hybrid rice followed by BRRI dhan29 and Black rice. Statistically similar survival rate of immature stage was observed among the tested varieties. Rice weevil infested significant higher number of Black rice grain than that of other two varieties. However, higher number adult weevil was developed from hybrid rice. It indicated that hybrid rice induces higher population development of the insect.

BIOLOGICAL CONTROL OF RICE INSECT PESTS

Conservation of natural enemies through ecological engineering approaches in rice ecosystem

Natural enemies of rice insect pests can be conserved in rice ecosystem through ecological engineering approach. The highest numbers of natural enemies were observed in rice field nearby nectar-rich flowering plants. Moreover, there was no yield reduction observed in rice field surrounded by flowering plants compared with insecticide application. So, farmers should avoid the toxic and hazardous insecticides to control the insect pests by growing nectar-rich flowering plants on the bunds of surrounding rice crops.

PI: Md Nazmul Bari, **CI:** Farzana Nowrin, **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 47 commercial formulations of insecticides were evaluated against brown planthopper (BPH). Forty-five out of 47 insecticides were found effective against BPH.

PI: Md Panna Ali, **CI:** Farzana Nowrin, Sadia Afrin and **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) 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 ranged from 54 to 91.11% and 84.20 to 92.12% in rice weevil and angoumois grain moth respectively (Fig. 8). The result of this study indicate that mahogany oil would be an effective product to control stored grain insect pests.

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

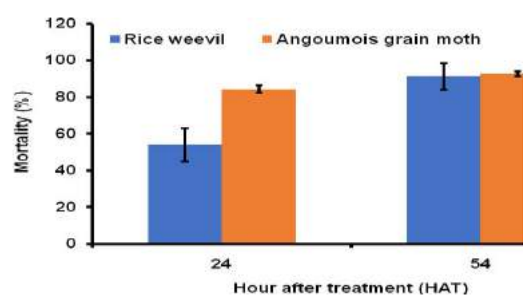


Fig. 8. Effect of fumigation action of mahogany oil against stored grain insect pests conducted in Entomology lab, BRRI, Gazipur.

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 2018-19. 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 its level was negligible. No significant differences were observed between the transgenic golden rice lines and non-transgenic BRRI dhan29 (Fig. 9). No unusual insect pest infestation was observed in transgenic lines.

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

Use of sex pheromone to control rice leafroller, *Cnaphalocrosis medinalis*

Pheromone lures were collected from China and used for field evaluation in Gazipur and Rangpur at T. Aman 2018 and Chuadanga, Jashore, and Gazipur in Aus 2019. The optimal blend of used pheromone was Z11-18:Ald, Z13-18:Ald, Z11-18:OH and Z13-18:OH at a ratio of 3 : 25 : 3 : 3. The optimal dosage is 500 µg Z13-18:Ald per poly-vinyl chloride (PVC) tubing lure. The trap was placed in rice field @ of 30 traps/ha. Significant number of insects that could cause damage to rice were caught in each trap at each location. Catches of leaffolder in trap varied and reached upto 571/trap within one week (Fig. 10). This result indicates that pheromone trap is very effective to caught leaffolder from rice field.

HOST PLANT RESISTANCE

Screening of advanced breeding lines against major insect pests of rice

A total of 207 advanced breeding lines/varieties/ INGER IRBPHN materials were evaluated at green house of Entomology Division to identify resistance sources against major insect pests of rice. Among 36 zinc enriched rice (ZER) breeding lines, one T. Aman line (IR 97641-35-2-2-8-P2) and one Boro line (IR99285-1-1-1-P2) was found moderately susceptible (score 5) against BPH and WBPH respectively (Table 1). Among rainfed lowland rice (RLR), one breeding line (IR11N202) was found moderately resistant (score 3) to GLH, four lines (IR 11L433, Latabalam, IR96321-1099-402-B-4-1-2, IR96321-1447-428-B-1-1-1) were moderately susceptible (score 5) to BPH, two lines were moderately susceptible against WBPH (BR8521-30-3-1, IR 11L433) and GLH (IR04A428, IR96321-1099-402-B-4-1-2) respectively (Table 1). Out of 27 advanced breeding lines of ALART and PVT, one ALART (Kalizira type) breeding line (BR 8850-10-12-2-3) was found moderately resistant (score 3) and another one ALART (Kalizira type) line (BR 8850-10-12-8-3-3) was found moderately susceptible against WBPH in T. Aman 2018. One Boro

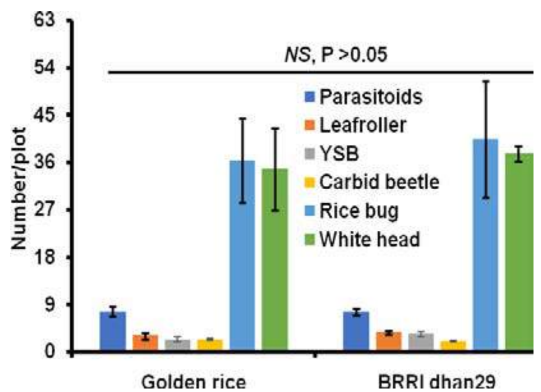


Fig. 9. Number of insects/damaged observed in golden rice and BRRI dhan29 field during Boro 2018-19. Bars bearing the same letter label are not significantly different at the 5% level. Error bar represents standard error.

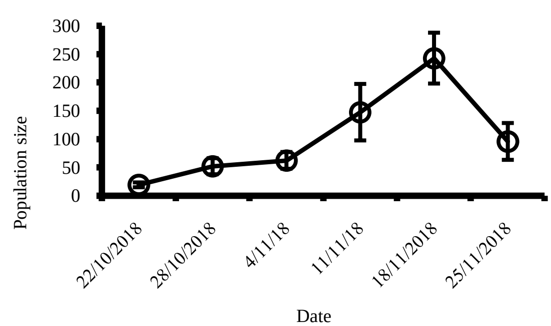


Fig. 10. Catches of rice leaffolder in pheromone trap at BRRI research HQ in Gazipur, T. Aman 2018. Insects caught in pheromone trap were collected after one-week interval and presented here.

ALART (Favourable Boro) line, BR (Bio) 9777-26-4-3 showed moderately susceptible reaction to WBPH (Table 1). Among 18 genotypes, RYT (FBR) BR9675-68-5-1, RYT (CTR) BR8562-11-2-6-1-1-1, BR8562-11-2-6-2-5-2 and BRRI dhan29-SC3-2816-10-6-HR6(Com)-HR1-(Gaz)-P8 (Hbj), and RYT(PQR) line BR8862-29-1-5-1-3, were found moderately susceptible (score 5) against WBPH (Table 1). Two IRBPHN genotypes out of 72, showed moderate resistance (Score 3) to moderate susceptible reaction (score 5) against BPH in T. Aman season 2018 season.

Susceptible check: BR 3 (for all), Resistant ck: T27A, IR64 and BR6 BPH, WBPH and GLH respectively. Scores were made according to SES. BPH= brown planthopper, WBPH= white-backed planthopper, GLH= green leafhopper, R= resistant (score 0-1), MR= moderately resistant (3), MS= moderately susceptible (5), S=susceptible (>7).

PI: Md Mosaddque Hossain, **PL:** Sheikh Shamiul Haque

Exploration of BRRI germplasm to identify Brown Plant Hopper (BPH) resistant rice accession

Out of fifty rice germplasm (received from GRS Division, BRRI) only one rice germplasm (Acc. no. 489) showed resistant reaction (score 3) against BPH when evaluated at BRRI Entomology Division green house.

PI: Sadia Afrin, **PL:** Sheikh Shamiul Haque

Table 1. Screening of rice advanced breeding lines against major rice insect pests, Entomology greenhouse during July 2018 to June 2019.

Seed source	Promising material	Score		
		BPH	WBPH	GLH
ZER, RYT-3, Aman 2018	IR 97641-35-2-2-8-P2	5	-	-
ZER, RYT, Boro 2018-19	IR99285-1-1-1-P2	-	5	-
RLR, RYT-1	BR8521-30-3-1	-	5	-
	IR 11L433	5	5	-
RLR, RYT-2	Latabalam	-	5	-
RLR, RYT-3	IR04A428	-	-	5
	IR11N202	-	-	3
	IR96321-1099-402-B-4-1-2	5	-	5
	IR96321-1447-428-B-1-1-1	5	-	-
ALART -1 (Kalizira type), Aman	BR 8850-10-12-2-3	-	3	-
	BR 8850-10-12-8-3-3	-	5	-
ALART (Favorable Boro), Boro	BR (Bio)9777-26-4-3	-	5	-
RYT (FBR)	BR8904-28-1-2-2-2	5	-	-
	KARJAT-5	5	-	-
	BR9675-68-5-1	3	5	-
RYT (CTR)	BR8562-11-2-6-1-1-1	-	5	-
	BR8562-11-2-6-2-5-2	-	5	-
	BRRI dhan29-SC3-2816-10-6-HR6(Com)-HR1-(Gaz)-P8 (Hbj)	-	5	5
RYT (PQR)	BR8862-29-1-5-1-3	-	5	-
IRBPHN, T. Aman 2018	SVIN036	3	-	-
	SVIN352	5	-	-

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 Standard Evaluation System (SES). In Rangpur at T. Aman 2018 season, average BB (incidence: 31.7% and severity: 5.07), Blast (incidence: 27% and severity: 3) sheath blight (ShB) (incidence: 24.5% and severity: 3.4) and false smut (incidence: 14.4% and severity: 1.6) were prevalent compared to brown spot, sheath rot and Narrow brown leaf spot. In Cumilla, average disease incidence of bacterial blight, sheath blight, neck blast, false smut, and brown spot were 5-70, 5-80, 2-90, 1-20 and 5-90% respectively during T. Aman 2018 season. Among the major diseases, Bacterial blight and sheath blight diseases were found all the surveyed areas in Cumilla region. Blast incidence was high in aromatic rice BRRI dhan34 in a location of Sadar Dakkhin only. In Barishal, T. Aman season 2018, prevalence of BB (25%), Blast (20%) and Brown spot (30%) disease incidences were higher in Barishal sadar, Babuganj and Wajirpur compared to other diseases. In Dumuria, Khulna, Brown spot disease incidence (90%) was higher compared to other diseases. Bacterial Blight (90%) and Sheath Blight (90%) diseases were higher in Kesobpur, Jeshore where false smut incidence (30%) was found lower in T. Aman.

In Boro 2018-19 season, average Sheath blight disease was widespread followed by brown spot, BB and blast in Rangpur. ShB (incidence: 32.5% and severity: 5.4) was extensive compared to brown spot, BB and blast in Rangpur district. In Habiganj, Brown spot disease incidence (15%) was higher compared to other diseases where Bacterial blight disease incidence was 9% in sayestaganj. The highest Blast incidence (50%) was recorded in Bahubol where sheath blight incidence was found lower (10%). Blast incidence was also higher (20%) in Chunarghat upazila where BB incidence (8%) was lower compared to other diseases. In Cumilla, the disease incidence of neck blast, bacterial blight, sheath blight, and brown spot were 2-100, 2-80, 5-70 and 5-80%, respectively. Neck blast disease was observed severe in aromatic rice in Aman and BRRI dhan28 in Boro season. This year neck blast disease was found so devastating in BRRI dhan28. In Sathkhira, Brown spot disease incidence (58%) was higher compared to other diseases in both Tala and Sadar Upazila where Bacterial leaf streak (BLS) disease incidence (31%) was second highest. Bacterial leaf blight (BLB) was found severe in Tala, 51% in Sadar, and 49% in Kalaroa) in all three upazilas. Blast incidence was found in Tala and Kalaroa upazila 4% and 5% respectively. In Boro, 2018-19, BB (20%) and Brown spot (50%) incidences were higher in Barishal sadar, Babuganj and Wajirpur compared to other diseases.

To improve the existing differential system for rice blast disease resistance, 110 blast infected samples were collected from 8 hot spots including 2 haors of Kishorganj and Netrokona districts of Bangladesh. The reaction of two isolates (CBD28-1 and CBD81-1) against differential varieties (DVs) showed different reaction pattern compared to the previous reaction. During 2010-14, late maturing variety like BRRI dhan29 was affected severely by neck blast. On the other hand, early maturing variety like BRRI dhan28 was escaped from neck blast infection. Due to early rain in 2015-17, early maturing variety like BRRI dhan28 affected more severely than late maturing variety like BRRI dhan29. The results of comparative studies of pathogenicity test between recently collected blast isolates to differential varieties and previously published data showed that there were distinct variations of reaction pattern between these two groups of isolates, especially with the *R* genes of chromosome 12.

A total of 350 bacterial blight infected samples were collected from the 26 different districts of Bangladesh. From the collected samples, 150 bacterial blight isolates were isolated & preserved. Among 50 isolates, 10 physiological races were identified based on the reaction pattern against BB resistant NILs. From this study *Xa21*, *xa13* and *Xa8* identified as effective gene for the development of bacterial blight resistance in Bangladesh. An experiment was conducted to know the relation between leaf blast and neck blast. Development of neck blast using infected leaves has explored under uniform blast nursery (UBN) in

different germplasm. There was huge source of blast inocula in rice seedlings in the UBN. Infected leaf was placed on the panicle neck and rapped with cotton plug. This was done when the panicle completely emerged. All the plants were placed in the UBN where sprinkler irrigation was given at each an hour automatically in 24 hour cycle. The results indicated that the same race of blast pathogen can cause both leaf and neck blast.

Increasing of sheath rot disease severity the panicle length exertion decline, which reduces number of filled grains/panicle that ultimately decreases the weight of filled grains/panicle and finally reduction of yield of rice/plant. The trend of increasing every unit of DS scale, the weight of filled grains decreasing 0.16 g/panicle. It was found that oat meal agar was the best media for sheath rot fungus mycelium growth and sporulation followed by potato sucrose agar + egg. From yield loss study of rice sheath blight disease, it was found that the panicle length, total number of grains and also number of filled grains decreased with the increase of disease severity. Among the tested plant products, neem extraction in ethanol, mehogoni extraction in ethanol and dodder plant extraction in ethanol completely (100%) inhibited the mycelial growth of the pathogen. Among the bio-control agents some bacteria and Trichoderma spp. performed excellently to manage bakanae disease (>90%) in net house condition.

Priming of *Trichoderma* isolate with seeds increased proline content and decreased Melon de-aldehyde (MDA), total phenolic content (TPC) and H_2O_2 content in drought tolerant varieties at stressed condition. It was also observed that proline, MDA and TPC was decreased in susceptible variety IR 64 at stressed condition when primed with *Trichoderma* isolate. 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 and BC_2F_2 to BC_2F_5 population were developed by using modified field RGA system.

To identify blast resistant gene using differential system and QTL analysis mapping population of BC1F2 family lines (US2/BRRI dhan33//US2) were developed and A total of 625 markers were surveyed for polymorphism studies between BRRI dhan33 and US2, a universal blast susceptible variety. Among 625 markers, 184 markers showed polymorphic. Blast resistant gene (*Pi9 and Pb1)* and bacterial blight resistant gene (*Xa21, Xa13*) were introgressed in the background of BRRI dhan28, BRRI dhan29 and BRRI dhan58. Introgression of *Pi9* and *Pita2* gene in the background of BRRI dhan28, BRRI dhan29 and BRRI dhan63 has been done. Progenies were selected from different backcross generations and advanced for the development of homozygous pre-breeding materials for further use. F_1 Seeds were produced from different crossings. *Pi9* and *Pita2* were detected using the primer NMSMPi9-1 and YL155/YL87 respectively. F_1 seeds produced in T Aman, 2018 were used for pyramiding *Pi9* and *Pita2* genes in the background of recurrent parents. F_1 seeds of *Pi9* and *Pita2* in the same background were crossed again and obtained F_1 seeds with both targeted genes in Boro 2018-19. For the development of pyramid line of bacterial blight resistance, resistant genes were introgressed in the background BRRI dhan49, BRRI dhan63 & BRRI dhan81 and F_1 generations were produced.

Seven BB resistant materials were evaluated along with the susceptible and standard check varieties for yield performance. Among the tested materials IR88903-8-1-1-3-HR(path)-7-70 gave the highest yield in 124 days period. The materials were advanced secondary yield trial (SYT). For the development 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) were carried out to produce different generation (BC3F4 and BC5F2). For the mapping of QTL in tungro resistant Kumragoir, hybridization was made between Kumragoir and BRRI dhan48 to produce BC2F2 generation. Primer survey was conducted to find 96 polymorphic markers between the Kumragoir and BRRI dhan48 for QTL mapping. Eight materials were tested against blast disease for identification of resistant materials. Only one material BR(path)-DA 21-PL13 was found resistant to blast. A total of 88 INGER materials were screened against three differential blast isolates. Among them, 39 materials were found resistant. A total of 165

INGER materials including susceptible and resistant checks, 21 and 26 materials were found resistant and moderately resistant, respectively against major bacterial blight isolates. In Boro 18-19, thirty six materials including checks were screened against bacterial blight disease to identify resistant material. Only one material named IR99285-1-1-1-P_1 found as moderately resistant against Bacterial blight disease.

A total of 347 rice germplasm along with checks were screened against bacterial blight pathogen. Among the 347 tested germplasm, 1, 1 and 2 entries found highly resistant, resistant and moderately resistant, respectively. Eighty five germplasm were collected from GRS Division and screened against bakanae disease. Among the tested materials, five accessions (ACC 630, 644, 549, 551, 553) were found resistant.

In T. Aman season, 2018, 10 demonstrations were conducted in Gazipur (5), Naogaon (3) and Cumilla (2) regions and in Boro season 82 demonstrations are conducting in Gazipur (30), Nilphamari (10), Khulna (20), Cumilla (10), Sherpur (6), Naogaon (3) and Dinajpur (3). Two field day on rice blast disease management were conducted. One in Cumilla region and other in Kapashia, Gazipur. Around 200 farmers, DAE personnel and BRRI scientists were attended in the field day. A total of 13 training program comprising 470 trainees including farmers, pesticides dealers and SAAOs were held in Gazipur (3), Rangpur (2), Cumilla (3), Sherpur (2), Khulna (3) regions. A Leaflet (10,000 copies) was published and distributed among the stakeholders.

Silver nanoparticles at 800 ppm showed a significant difference compared with the other concentrations of silver nanoparticles and silver nitrate. Only 1.77% and 3.23% leaf blast disease severity were found in preventive measure at 800 ppm concentration for Trooper 75 WP (standard dose of fungicide) and silver nanoparticles, respectively. Application of regent 3GR (10kg/ha, Fipronil based phenyl pyrazole Group) along with alternate wetting and drying significantly controlled the red eelworm. Among 18 fungicides, only four such as Positive 30 SE (Propiconazole 15% + Difeconazole 15%), Sunfighter 25 SC (Hexaconazole 3% + Tricyclazole 22%), Mtop-32.5 SC (Azoxystrobin + Difeconazole) and Limotar top 32.5 SC (Azoxystrobin + Difeconazole) were identified effective against sheath blight disease in Rajshahi farm.

There were six groups of fungicides namely Chlorothalonil (Deconil 500SC, Phenamarit (Phenam 25SC), Azoxystrobin+Difeconazole (Cropstar), Difeconazole+Pyraclostrobin (Safa 30SC), Azoxystrobin+Cyproconazole (Tipoff 28SC), and Hexaconazole (Hexol 10EC) along with control. The results showed that Phenam 25SC, Safa 30SC, Tipoff 28SC and Hexol 10EC completely inhibited the growth of sheath rot fungus. In case of blast, the Hexol was found as best to hinder the growth of fungus. Restructuring of Ankuri was done for the development of auto controlled system for temperature and humidity. It can also be used for disinfection through hot water seed treatment. For the management of sheath blight, recommended dose of fertilizers with Tricho-compost reduced % relative lesion height of sheath blight disease.

TRANSFERABLE TECHNOLOGY

Development of e-learning course on rice blast disease in MUKTOPAATH

An e-learning course on Rice Blast Disease was developed and uploaded in MUKTOPAATH. MUKTOPAATH is a platform of e-learning course governed by a2i. This course consisted of 5 topics such as identification of rice blast disease, congenial environment of blast disease, way of blast disease dispersal, control measure and list of recommended fungicides. Video clips and PDF documents are included in the course. This course will contribute a lot for rice blast disease management successfully as well as sustainable rice production in Bangladesh. This course is available in the folowing link:
http://www.muktopaath.gov.bd/#/elM2Portal/showCourseDetails?courseId=202&isPopulate=true

■ MAI Khan, MR Bhuiyan, MM Rashid and MA Latif

Restructuring of *Ankuri* seed germinator

Restructuring of Ankuri was done for the development of auto-controlled system for temperature and humidity (Fig. 1). This has done in such a way that it can also be used for disinfection through hot water seed treatment A plastic bucket having inside a steel frame, sensor and water heater controlled by an auto control box is used in Ankuri seed germinator. It is a vapor induced healthy seed germination technique in cold environment. Around 40-50 L water is taken in the bucket (60 L) first. Then loosely packed seeds in a sac are kept on the frame inside bucket water and covered with the lid. The temperature indicator is set at 30-32° C for 20-24 hours in the auto-control box and connected with electricity. When water temperature is adjusted to the set temperature, the heater disconnected and re-started-on automatically for heating water immediately after the set temperature goes down. The green light becomes on when the heater started for heating and becomes off when the heater goes off. After 20-24 hours, the bucket water is drained out at the level below the steel frame but must be considerably above the heater. Soaked seeds should be kept again as like previous on the steel frame in the bucket covered with its lid and connected with electricity. Vapor is generated from water and keeps inside the bucket environment with high humidity and expected set temperature. Under this environment seed can be germinated within 3 days. Care should be taken by disconnecting the electric connection whenever any operation is done inside the bucket. Seeds soaking outside the bucket can also be germinated using Ankuri.

■ TH Ansari, M Ahmed

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 2018-19 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.

T. Aman, 2018. In T. Aman 2018, survey was carried out in different locations of Rangpur, average BB (DI: 31.7% and DS: 5.07), Blast (DI: 27% and DS: 3), ShB (DI: 24.5% and DS: 3.4) and false smut (DI: 14.4% and DS: 1.6) were prevalent compared to brown spot, sheath rot and Narrow brown leaf spot. In Cumilla, average DI of BB, ShB, neck blast, false smut and brown spot were 5-70, 5-80, 2-90, 1-20 and 5-90% respectively. Among the major diseases, BB and ShB diseases were found all the surveyed plots in Cumilla region. Blast incidence was high in aromatic rice (BRRI dhan34) in one location of Sadar Dakkhin only. In Aman, 2018, DI of BB (25%), Blast (20%) and Brown spot (30%) were higher in Barishal sadar, Babuganj and Wajirpur compared to other diseases. In Jashore and Khulna region, during T. Aman, 2018, Brown spot disease incidence (90%) was higher compared to other diseases where Sheath Rot disease incidence (15%) was lower in Dumuria upazila. Additionally, BB (90%) and ShB (90%) were higher in Keshabpur where False smut incidence (30%) was found lower. ShB incidence also higher (90%) in Jeshore Sador upazila where false smut incidence (20%) was lower compared to other diseases.

Boro season 2018-19. In Boro 2018-19 season, average ShB was widespread followed by brown spot, BB and blast in Rangpur. ShB (DI: 32.5% and DS: 5.4) was extensive compared to brown spot, BB and blast in Rangpur district. In Habiganj, DI of Brown spot (15%) was higher compared to other diseases where BB disease incidence (9%) was lower in Sayestaganj. Additionally, Blast incidence (50%) was higher in Bahubol where ShB incidence (10%) was found lower. Blast incidence also higher (20%) in Chunarghat upazila where BB incidence (8%) was lower compared to other diseases. In Cumilla, the disease incidence of neck blast, BB, ShB and brown spot were 2-100, 2-80, 5-70 and 5-80%, respectively. Neck blast disease was observed severe in aromatic rice in Aman and BRRI dhan28 in Boro season. Neck blast disease was found so devastating in BRRI dhan28. In Sathkhira, Brown spot disease incidence (58%) was higher compared to other diseases in both Tala and Sadar Upazila where Bacterial leaf streak (BLS) disease incidence (31% and 55%) was second highest, respectively. BB was found severe (23% in Tala, 51% in Sadar, and 49% in Kalaroa) in all three upazilas. Blast incidence was found in Tala and Kalaroa upazila 4% and 5% correspondingly. There was ShB disease but incidence was found lower. In Boro, 2018-19, BB (20%) and Brown spot (50%) incidence were higher in Barishal sadar, Babuganj and Wajirpur compared to other diseases.

■ 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

Improvement of differential systems for rice blast disease in Bangladesh

To improve the existing differential system for rice blast disease resistance, 110 blast infected samples were collected from 8 hot spots including two haors of Kishoreganj and Netrakona districts of Bangladesh. We emphasized specially on BRRI dhan28, BRRI dhan29 and BRRI dhan81 infected plots during sample collection, because now a day's recurrent blast infection reported in these varieties. The specific objective of this study was to identify the evolution of new races of blast pathogen that may responsible for the recent blast outbreak in Bangladesh. The reaction pattern of two isolates (CBD28-1 and CBD81-1) against differential varieties (DVs) showed different reaction pattern from the previously published reaction pattern (Khan *et al.* 2016: Plant Disease). The changes were happened mostly in the blast resistance genes situated on chromosome 1 and 12. One of these two isolates may include in the existing differential system as a new differential isolate for blast resistance studies in Bangladesh.

■ MAI Khan, MR Bhuiyan, MM Rashid and MA Latif

Factors affecting recent blast outbreak in Bangladesh

To find out the reasons of recent rice blast outbreak in Bangladesh, a systematic study was conducted based on Disease Triangle. There were two types of factors (biotic and abiotic) responsible for blast outbreak. Among biotic factors, we considered blast resistant *R* gene distribution in popular variety and evolution of new races of blast pathogen. In abiotic factors, we considered mostly the changing pattern of weather parameters such as rainfall, relative humidity and temperature. Results showed that during 2010-2014, late maturing variety like BRRI dhan29 affected severely by neck blast. On the other hand, early maturing variety like BRRI dhan28 escaped neck blast infestation. But in 2015-2017, happened opposite situation. The weekly average rainfall, relative humidity and temperature pattern of 2010-2014 were totally different from the average of 2015-2017 (Fig. 1). Due to early rain in 2015-2017, early maturing variety like BRRI dhan28 affected more severely than late maturing variety like BRRI dhan29 by neck blast disease. The results of comparative studies of pathogenicity test between recently collected blast isolates to differential varieties and previously published data (Khan *et al.* 2016: Plant Disease) showed that there was a distinct variation of reaction pattern between these two groups of isolates, especially with the *R* genes of chromosome 12 (Fig. 2).

■ MAI Khan, SAI Nihad, MR Bhuiyan, MM Rashid and MA Latif

PATHOGEN POPULATION STRUCTURES AND BIOLOGY

Identification of physiological races of bacterial blight and its distribution patterns (NATP-2)

A total of 350 bacterial blight infected samples were collected from the 26 different districts of Bangladesh. From the collected samples 150 bacterial blight isolates were isolated, purified and preserved. To identify the physiological races, pathogenicity tests of 50 BB isolates were done on

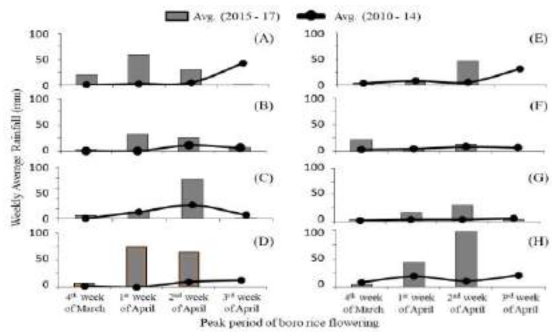


Fig. 1. Average rainfall pattern of the peak period of boro rice flowering at different rice growing regions of Bangladesh: Rangpur (A), Bogura (B), Rajshahi (C), Gazipur (D), Barishal (E), Jeshore (F), Khulna (G) and Cumilla (H). Bar graph indicated average rainfall pattern of 2015-2017 and line graph indicated average of 2010-2014.

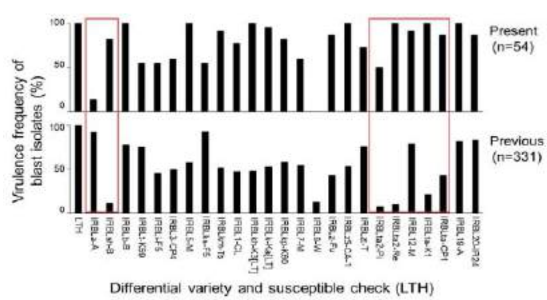


Fig. 2: Evolution of new races of blast pathogen in Bangladesh.

NILs and pyramid lines of Bacterial blight resistance. In total, 10 races were identified according to the reaction pattern of the BB isolates against BB resistant NILs. From this study *Xa21*, *xa13* & *Xa8* have been identified as effective genes for the development of bacterial blight resistance in Bangladesh. But this needs further experiment to conclude the result.

■ MA Latif, MAI Hasan, T Ferdous, MM Rashid and MAI Khan

Development of neck blast using infected leaf

The experiment was conducted to know the relation between leaf blast and neck blast. Development of neck blast using infected leaves have explored under uniform blast nursery (UBN) in different germplasm. There was a huge source of blast inocula in rice seedlings in the UBN. Infected leaf was placed on the panicle neck and rapped with cotton plug. This was done when the panicle completely emerged. All the plants were placed in the UBN where sprinkler irrigation was given at each an hour automatically in 24 hour cycle. The results indicated that all the inoculated panicle developed neck blast in susceptible US2. The tested germplasm showed the neck blast development in a varied range from no infection to 100% panicle infection of the inoculated panicles. In some cases, panicles were also infected with blast even without artificial infection.

■ TH Ansari

Development of inoculation technique for false smut disease

To develop an effective inoculation technique for rice false smut (RFSm) disease the experiment was carried out in the inoculation chamber (established for rice false smut screening). Firstly, isolation was done from freshly collected yellow smut balls on PSA media. Germination of chlamydospores was observed after 48 hours of incubation. Then it was transferred on to fresh media to obtain pure culture. After 4 days, inoculums were prepared by scraping the pure culture from PSA plate using distilled water. Rice plants were inoculated in the inoculation chamber by injecting the inoculums suspension into the boot when they were at booting stage. Very few symptoms were developed 21 days after inoculation. It needs to be confirmed again in greenhouse.

Development of an algorithm between sheath rot disease severity and yield reduction in rice

The study investigated the relationship between sheath rot disease severity (DS) and yield reduction in rice. The results showed that with increasing of sheath rot disease severity the panicle length exertion decline, which reduces the number of filled grains/panicle that ultimately decreases the weight of filled grains/panicle and finally reduction of yield of rice/plant (Fig. 3). The trend of increasing every unit of DS scale, the weight of filled grains decreasing 0.16 g/panicle (Fig. 3). The results need to verify again to make a conclusion.

■ T Khatun

Cultural variation of rice sheath rot pathogen under different synthetic media

The objective of this study was to find out the best medium for sheath rot fungus culture and sporulation. Four synthetic media were used to culture the fungus namely oat meal agar (OMA), potato sucrose agar (PSA), potato sucrose agar (PSA) + egg, and potato sucrose agar (PSA) + N. It was found that oat meal agar was the best media for sheath rot fungus mycelium growth and sporulation followed by potato sucrose agar + egg. Although it was established that overdose use of nitrogen fertilizer generally increases the growth of fungus and increase the expression of disease symptom in rice plant. However, our preliminary study contradicts with this finding. We noticed with the addition of nitrogen source gradually decrease the mycelium growth and reducing the sporulation of sheath rot fungus in PSA+N medium.

■ B Nessa

Yield loss study of rice sheath blight disease

From yield loss study of rice sheath blight disease, it was found that the panicle length of infected tiller decreases with the increases of disease severity (Fig. 4). If disease severity increases the total number of grains and also number of filled grains decreases. Weight of filled grains remains unaffected up to disease severity scale 5, drastic reduction in weight of filled grains occurs after that.

■ B Nessa

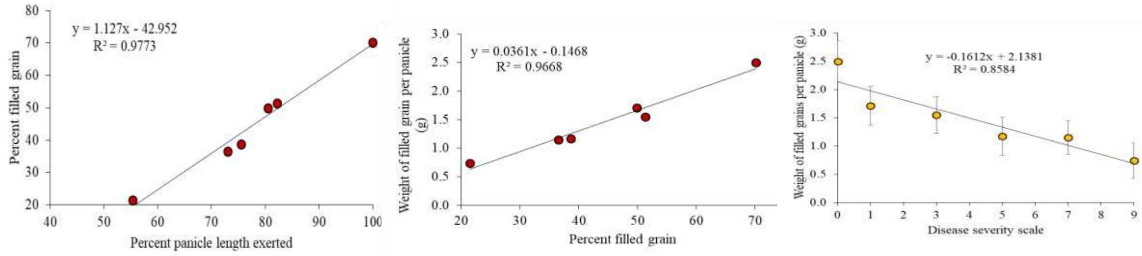


Fig. 3: Relationship between percent panicle length exertion and percent filled grain (Left side); relationship between percent panicle filled grain and weight of filled grain per panicle (middle); and relationship between weight of filled grains/panicle and disease severity scale (Right side).

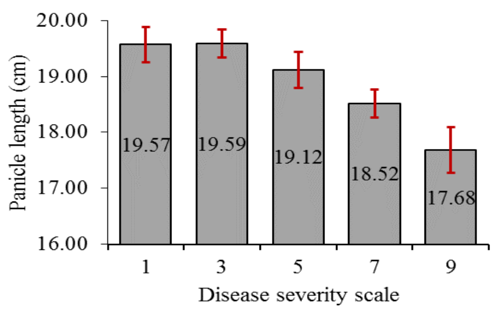


Fig. 4: Relationship between panicle length and disease severity scale

Identification of potential bio-control agents and formulations of bio-pesticides against bakanae disease

Forty (40) biocontrolling bacteria, six *Trichoderma* spp., and four plant active ingredients (neem seed extraction in ethanol, neem leaf extraction in ethanol, mehogoni extraction in ethanol and dodder plant extraction in ethanol) have been identified to inhibit mycelial growth of bakanae causing pathogen. Among the tested plant products, neem extraction in ethanol, mehogoni extraction in ethanol and dodder plant extraction in ethanol completely (100%) inhibited the mycelia growth of the pathogen. Identified biocontrolling agents will be confirmed following molecular method for documentation and future use. Further, isolated active ingredient materials from plant products will be tested singly or in combination with biocontrolling agents to find out effectiveness against bakanae disease in field condition. Thus, effective plant active ingredient will be used to formulate biopesticide single or in accordance with the effective biocontrolling agent/s. In addition, it is worth to replace chemicals gradually with biopesticide/s which are safe to human and non-target to other beneficial organisms and cheaper than the chemicals. Among the biocontrolling agents bacteria (9-4) and *Trichoderma* (T3) performed excellently to manage bakanae disease (>90%) in net house condition.

■ 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) and one drought susceptible check variety IR64 were used in T. aman, 2017. At the same time, two *Trichoderma* isolates (T_3 and T_5) were found to have good drought tolerant activity when inoculated with rice seeds in 2018. Assessment of biochemical (Proline, malondialdehyde and total phenolics content) responses of rice plants inoculated or primed with *Trichoderma* T_3 and untreated rice plants against drought stress were carried out. Seeds of each variety were surface sterilized and primed separately with identified drought tolerant *Trichoderma* T_3 @ 10g/kg of seeds. For control-1, instead of inoculation with *Trichoderma* T3 (-T), rice seeds were dipped in distilled water only and tested in drought condition. For control-2 (C), seeds were primed with *Trichoderma* T3 and tested in irrigated condition. All biochemical parameters were taken on the fifth day of drought application and drought stress was induced at flowering stage. Proline was highly increased when primed (inoculated) with *Trichoderma* at stressed condition compared to non-stressed (irrigated) condition for all three varieties. Moreover, more proline was accumulated in drought tolerant varieties compared to susceptible varieties at stressed and *Trichoderma* primed condition. MDA content was lower in drought tolerant varieties compared to susceptible variety IR64 in all conditions. On the other hand, *Trichoderma* inoculation decreased MDA content in non-stressed condition compared to stressed condition for susceptible as well as drought tolerant varieties. Highest TFC was measured at stressed condition but non inoculated with *Trichoderma* for all varieties. Total Phenolic content was decreased at stressed condition when primed with *Trichoderma* for susceptible as well as drought tolerant varieties. Moreover, it was observed that, TFC accumulation was increased in drought tolerant varieties compared to susceptible IR 64 for all conditions. From the findings it can be summarized that *Trichoderma* primining increased proline content and decreased MDA, TFC and H_2O_2 content in drought tolerant varieties at stressed condition. It was also observed that, proline, MDA and TFC was decreased in susceptible variety IR 64 at stressed condition when primed with *Trichoderma* T3. Thus, it is assumed that *Trichoderma* T3 has ability to increase drought tolerant activity at stressed condition. However, more research needs to carry out for confirmation the result.

■ QSA Jahan and MA Latif

DISEASE RESISTANCE AND MARKER ASSISTED SELECTION STUDIES

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 400 plants from each combination of BC_2F_2 population were selected by foreground selection using linked markers. The selected materials have already advanced from BC_2F_2 to BC_2F_5 in BRRI field by modified field RGA system (Table 1). In the next Boro 2019-2020, around 6000 individuals of 15 combinations of BC_2F_5 derived lines will be cultivated as LST and desire lines will be selected from these population with the collaboration of Plant Breeding Division, BRRI.

■ MAI Khan, SAI Nihad, MR Bhuiyan, MM Rashid and MA Latif

Studies on the genetic mechanism of rice blast resistance in BRRI dhan33

BRRI dhan33, a short duration popular variety, is being used as a blast resistant check in Plant Pathology Division, BRRI from a long time. To know the genetic mechanism of blast resistance of this variety, a programme was undertaken on blast resistant gene estimation using differential system and QTL analysis using segregating population (BC1F2 family lines). The mapping population of BC1F2 family lines (US2/BRRI dhan33//US2) were developed in Plant Pathology Division, BRRI. Results of gene estimation using differential system showed that BRRI dhan33 harbored *Pia, Pish, Pib,*

Table 1. List of the materials advanced from BC2F2 to BC2F5 in BRRI field by modified field RGA.

Cross combination	Target gene	Present Generation	No. of population
NILpi21/BRRI dhan28// BRRI dhan28	*pi21*	BC1F5	400
NILPb-1/ BRRI dhan28/2* BRRI dhan28	*Pb-1*	BC2F5	400
BRRI dhan28/NILPiz-t-T/2* BRRI dhan28	*Piz-t*	BC2F5	400
BRRI dhan28/NILPi9-M/2* BRRI dhan28	*Pi9*	BC2F5	400
BRRI dhan29/ NILpi21/2* BRRI dhan29	*pi21*	BC2F5	400
BRRI dhan29/ NILPb1/2* BRRI dhan29	*Pb-1*	BC2F5	400
BRRI dhan29/ NILPish-S/2* BRRI dhan29	*Pish*	BC2F5	400
BRRI dhan63/ NILpi21/2* BRRI dhan63	*pi21*	BC2F5	400
BRRI dhan63/ NILPb1/2* BRRI dhan63	*Pb-1*	BC2F5	400
IRBLzt-T/ BRRI dhan63/2* BRRI dhan63	*Piz-t*	BC2F5	400
IRBL9-M/ BRRI dhan63/2* BRRI dhan63	*Pi9*	BC2F5	400
NILpi21/BD64// BRRI dhan64	*pi21*	BC1F5	400
NILPb-1/ BRRI dhan64/2* BRRI dhan64	*Pb-1*	BC2F5	400
BRRI dhan64/NILPiz-t-T/2* BRRI dhan64	*Piz-t*	BC2F5	400
BRRI dhan64/NILPi9-M/2* BRRI dhan64	*Pi9*	BC2F5	400

Pit, one of *Pii* allele, one of *Pik* allele, one of *Piz* allele, one of *Pita* allele gene and also unknown genes in their genetic background. A total of 625 markers were surveyed for polymorphism studies between BRRI dhan33 and US2, a universal blast susceptible variety. Among 625 markers, 184 markers showed polymorphic. The phenotyping and also genotyping of 300 BC1F2 family lines will be done in next year.

■ MAI Khan, SAI Nihad, MR Bhuiyan, MM Rashid and MA Latif

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 2018 and Boro 2018-19 (Table 2 and Table 3). Four set of parents with 7 days interval were grown for the synchronization of flowering among the parents. Seeding was starting from 14th July, 2018 in Aman season and for Boro season it was starting from 17th December 2018. In Aman 2018 four crosses, one backcross and three inter crosses were made to obtain BB and blast resistant genes among the parents; whereas in Boro season six backcrosses and two selfing were made to obtain seeds of BC_3F_1, BC_2F_1, BC_1F_1 and BC_1F_2 generation. Heterozygosity of the populations was confirmed through using respective marker.

■ MA Latif, AI Hasan, SAI Nihad, MAI Khan

Pyramiding of Bacterial Blight and Blast Resistance Genes into the Genetic Background of BRRI dhan29 (BAS project)

To introgress bacterial blight (BB) and blast resistant genes in high yielding variety; parent materials were grown during Aman 2018 and Boro 2018-19. Four set of parents with 7 days interval were grown for the synchronization of flowering among the parents. Seeding was started from 9th July, 2018 in Aman season and for Boro season it was started from 22nd December, 2018. In Aman'18 four backcrosses were made to obtain BC2F1 seeds and one inter crosses for two blast resistant genes were made to obtain BC1F1 seeds whereas in Boro season three backcrosses and one intercrosses were made to obtain BB and blast resistant genes among the parents (Table 4 and Table 5). Heterozygosity of the populations was confirmed through using the respective marker. After confirmation crossing was done to make next generation.

■ A KM S Islam, MA Latif, AH Khan

Table 2. List of crosses and number of seeds for respective cross, Aman 2018.

Generation	Cross	No. of seeds
BC_2F_1	BRRI dhan28*IRBB58	56
F_1	BRRI dhan28/*Pi9* (IR64)	44
F_1	BRRI dhan28**Pi9* (IR74)	22
BC_1F_1	BRRI dhan28/*Pb1** BRRI dhan28/*Pi9* (IR64)	35
F_1	BRRI dhan28/*Pb1*	16
F_1	BRRI dhan58* *Pi9* (IR64)	22
BC_1F_1	BRRI dhan58* *Pb1*/ BRRI dhan58* *Pi9* (IR64)	32
BC_1F_1	BRRI dhan58* *Pb1*/ BRRI dhan58* *Pi9* (IR64)	18

Table 3. List of backcrosses and number of seeds for respective cross, Boro 2017-18.

Generation	Cross	No. of seeds
BC_3F_1	BRRI dhan28*IRBB58	44
BC_1F_1	BRRI dhan28/*Pi9* (IR64)	83
BC_1F_1	BRRI dhan28**Pi9* (IR74)	4
BC_1F_1	BRRI dhan28/*Pb1*	45
BC_2F_1	BRRI dhan28/*Pb1** BRRI dhan28/*Pi9* (IR64)	9
BC_1F_1	BRRI dhan58* *Pi9* (IR64)	34
BC_2F_1	BRRI dhan58* *Pb1*/ BRRI dhan58* *Pi9* (IR64)	65
BC_2F_1	BRRI dhan58* *Pb1*/ BRRI dhan58* *Pi9* (IR64)	20

Table 4. List of backcrosses and number of seeds for respective cross (Aman 2018).

Generation	Cross	No. of seeds
BC_1F_1	BRRI dhan29*IRBB58	102
BC_1F_1	BRRI dhan29**Pi9* (US)	114
BC_1F_1	BRRI dhan29**Pi9* (IR64)	33
BC_1F_1	BRRI dhan29* *Pb1* (US2)	77
BC_1F_1	[BRRI dhan29**Pi9* (US)* BRRI dhan29* *Pb1* (US2)]	141

Table 5. List of backcrosses and number of seeds for the respective cross (Boro 2018-19).

Generation	Cross	No. of seeds
BC_2F_1	BRRI dhan29*IRBB58	78
BC_2F_1	BRRI dhan29**Pi9* (IR64)	62
BC_2F_1	[BRRI dhan29**Pi9* (US)* *Pb1* (US2)]	59
BC_2F_1	[BRRI dhan29*IRBB58*{BRRI dhan29**Pi9* (US)* *Pb1* (US2)}]	65

Introgression of blast resistant gene(s) into Boro Rice

Introgression of *Pi9* and *Pita2* gene in the background of BRRI dhan28, BRRI dhan29 and BRRI dhan63 has been done. Progenies were selected from different backcross generations and advanced for the development of homozygous pre-breeding materials for further use. The number of lines selected from different backcross generations during T. Aman and Boro are listed in Table 6 and Table 7, respectively. Progenies were confirmed through Marker Assisted Selection in different generations.

■ TH Ansari

Pyramiding blast resistant genes into Boro rice

Introgression of monogenic resistant gene *Pi9* and *Pita2* was done in the background of BRRI dhan28, BRRI dhan29 and BRRI dhan63 during T. Aman 2018. are mentioned in Table 8 mentions the seeds produced in different crossings. Confirmation of the crosses was done through marker assisted selection. *Pi9* and *Pita2* were detected using the primer NMSMPi9-1 and YL155/YL87 respectively.

■ TH Ansari

Table 6. Advance generations of different backcross progenies in T. Aman 2018.

Parental cross	Generation	No. of lines selected	Comment
BR28XPi9	BC_6F_2	29	
	BC_5F_3	69	
	BC_4F_4	43	
	BC_3F_5	178	OT
BR29XPi9	BC_2F_3	5+25	
	BC_3F_1	17	
BR63XPita2	BC_6F_2	3	
	BC_5F_3	20	
	BC_4F_4	37	
	BC_3F_4	106	

Table 7. Advance generations of different backcross progenies in Boro 2018-19.

Parental cross	Generation	No. of lines selected	Comment
BR28XPi9	BC_6F_3	21	
	BC_5F_4	20	
	BC_4F_5	6+4	
	BC_3F_6	178	OT
BR29XPi9	BC_1F_4	44	
	BC_3F_2	4+22	

Table 8. Number of F_1 seeds produced from crossing between different parents in T. Aman 2018.

Recurrent parent	Target gene	Progeny	No. of seed
BRRI dhan28	*Pi9*	F_1	65
	Pita2	F_1	34
BRRI dhan29	*Pi9*	F_1	60
	Pita2	F_1	44
BRRI dhan63	*Pi9*	F_1	35
	Pita2	F_1	33

F_1 seeds produced in T. Aman, 2018 were used for pyramiding Pi9 and Pita2 genes in the background of recurrent parents mentioned above. F_1 seeds of Pi9 and Pita2 in the same background were crossed again and obtained F_1 seeds with both targeted genes in Boro 2018-19 (Table 9).

Gene Pyramiding of Bacterial Blight Resistance Genes into the Genetic Background of BRRI dhan49, BRRI dhan63 & BRRI dhan81 (NATP-2)

To introgress bacterial blight (BB) resistant genes in high yielding variety, parent materials were grown during Aman 2018 and Boro 2018-19. Four set of parents with 7 days interval were grown for the synchronization of flowering among the parents. Seeding was started from 12 July, 2018 in Aman season and for Boro season it was started from 19th December, 2018. In Aman'18 four crosses were made to obtain F1 seeds whereas in Boro season, two crosses & four backcrosses were made among the parents (Table 10 and Table 11). Heterozygosity of the populations was confirmed through using respective molecular marker. After confirmation of F1, crossing was done to make next generation.

■ M A Latif, MAI Hasan, MM Rashid and MAI Khan

Table 9. Number of F1 seeds produced for pyramiding Pi9 and Pita2 in Boro 2018-19.

Recurrent parent (RP)	Gene pyramiding (crossing of F_1s)	Progeny	No. of seed
BRRI dhan28	*Pi9* × *Pita2*	F1	447
	Pita2 × *Pi9*	F1	304
BRRI dhan29	*Pi9* × *Pita2*	F1	547
	Pita2 × *Pi9*	F1	681
BRRI dhan63	*Pi9* × *Pita2*	F1	208
	Pita2 × *Pi9*	F1	168

Table 10. List of crosses and the number of seeds for respective cross combinations (Aman 2018).

Generation	Cross combination	No. of seeds
F_1	BRRI dhan49*IRBB60	22
F_1	BRRI dhan63-Pb1*IRBB58	33
F_1	BRRI dhan81*IRBB60	42
F_1	BRRI dhan81*IRBB58	23

Table 11. List of backcrosses and number of seeds for respective cross (Boro 2018-19).

Generation	Cross combination	No. of seeds
BC_1F_1	BRRI dhan49*IRBB60	40
BC_1F_1	BRRI dhan63-Pb1*IRBB58	75
BC_1F_1	BRRI dhan81*IRBB60	42
BC_1F_1	BRRI dhan81*IRBB58	50
F_1	BRRI dhan63-Pb1*IRBB60	90
F_1	BRRI dhan49*IRBB58	189

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. Result is presented in Table 12. 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.

■ MA Latif, MK Hassan, AI Hasan, SAI NIHAD, MAI Khan

Bacterial blight resistance and primary yield trial (PYT) of advanced pure lines, T. Aman 2018.

Seven BB resistant materials were evaluated along with the susceptible and standard check varieties for yield performance. Among the tested materials IR88903-8-1-1-3-HR(path)-7-70 gave the highest yield in 124 days period (Table 13). The growth duration of other tested materials ranged from 120-126 days with the yield range from 4.5-5.6 t/ha. BRRI dhan49 produced 4.8 t/ha with 137 growth duration. The materials advanced secondary yield trial.

■ TH Ansari

Table 12. 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	IRBB58	*Xa4, xa13, Xa21*	29 seeds of BC_2F_1
CN6	IRBB60	*Xa4, xa5, xa13, Xa21*	24 seeds of BC_3F_1
BRRI dhan28	IRBB57	*Xa4, xa5, Xa21*	135 seeds of BC_2F_1
BRRI dhan28	IRBB60	*Xa4, xa5, xa13, Xa21*	22 seeds of BC_2F_1
BRRI dhan28	IRBB58	*Xa4, xa13, Xa21*	9 seeds of BC_1F_1
BRRI dhan28	ST3	*xa13, Xa2, Xa23*	15 seeds of BC_1F_1
BRRI dhan29	ST4	*xa13, Xa2, Xa23*	54 seeds of BC_1F_1
BRRI dhan58	ST3	*xa13, Xa2, Xa23*	55 seeds of BC_1F_1

Table 13. Yield performance of BB resistant advanced lines in PYT in T. Aman 2018.

Advanced line/check	GD (day)	Yield (t ha^{-1})	BB Resistance
IR88903-8-1-1-3-HR(path)-7-70	124	6.37	R
IR88903-8-1-1-3-HR(path)-7-72	124	5.62	R
IR88903-8-1-1-3-HR(path)-7-82	126	5.58	R
IR88903-8-1-1-3-HR(path)-3-58	124	4.98	R
IR88903-8-1-1-3-HR(path)-8-78	120	4.56	R
IR88903-8-1-1-3-HR(path)-5-1	124	4.52	R
IR88903-8-1-1-3-HR(path)-9-17	124	4.86	S
Purbachi (Sus. check)	104	4.33	S
BRRI dhan49	137	4.81	

GD: Growth duration, R: Resistant, S: Susceptible, BB: Bacterial blight.

Development of pre-breeding materials of tungro resistance

To introgress tungro resistant gene in high yielding variety; parent materials were grown during Aman, 2018 and Boro season of 2018-19. Five set of parents with 7 days interval were grown for the synchronization of flowering among the parents. Seeding was starting from 14th July, 2018 in Aman season and for Boro season it was starting from 6th December, 2018-19. In Aman'18 six crosses (Table 14) and in Boro season six crosses (Table 15) were made among the parents. Heterozygosity of the populations was confirmed through using the respective marker. After confirmation crossing was done to make next generation.

■ 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 7 days interval for flowering synchronization for hybridization. After successful crosses, BC2F1 and consecutively BC2F2 seeds were produced (Table 16 & Table 17). A total of 400 SSR primers were surveyed and 98 primers (Fig. 5) were found polymorphic between two parents. GLH was collected from the rice field of BRRI and reared in a cage (80 cm × 45 cm × 45cm) for virus acquisition and transmission. Tungro virus particles (RTBV and RTSV) were detected by using molecular marker.

■ MA Latif, SAI Nihad and MA Rahman

Table 14. List of crosses and the number of seeds for the respective cross (Aman, 2018).

Generation	Cross combination	No. of seeds
BC_5F_1	BRRI dhan48*IR69705-1-1-1-4-2	27
BC_5F_1	BRRI dhan48*Matatag-1	38
BC_3F_2	BRRI dhan48*IR69705-1-1-1-4-2	Seed harvested from 29 plants
BC_3F_2	BRRI dhan71*TW-16	Seed harvested from 33 plants
BC_3F_2	BRRI dhan48*Matatag-1	Seed harvested from 22 plants
BC_1F_1	BRRI dhan71*Sonahidmota	25

Table 15. List of crosses and the number of seeds for the respective cross (Boro, 2018-2019).

Generation	Cross combination	No. of seeds
BC_5F_2	BRRI dhan48*IR69705-1-1-1-4-2	Seed harvested from 11 plants
BC_5F_2	BRRI dhan48*Matatag-1	Seed harvested from 9 plants
BC_3F_4	BRRI dhan71*TW-16	Seed harvested from 250 plants
BC_3F_4	BRRI dhan48*IR69705-1-1-1-4-2	Seed harvested from 150 plants
BC_3F_4	BRRI dhan48*Matatag-1	Seed harvested from 85 plants
BC_2F_1	BRRI dhan71*Shadamota	45

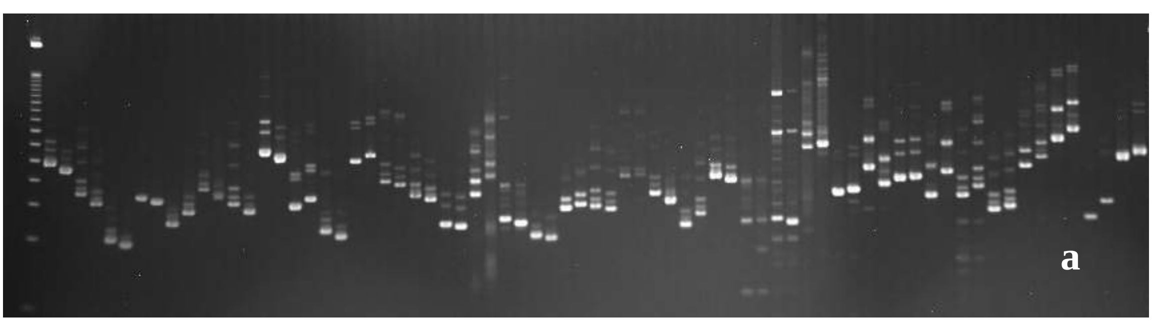


Fig. 5. Primer survey for finding polymorphic primers between Kumragoir and BRRI dhan48.

Screening of blast resistance of BR(path)-DA materials in uniform blast nursery (UBN)

Eight materials were tested against blast disease for identification of resistant materials to rice blast. Only one material BR(path)-DA 21-PL13 was identified as resistant.

■ TH Ansari

Screening of INGER materials against blast disease

A total of 88 INGER materials were screened against three differential blast isolates. Among them, 39 materials were found resistant. These materials are needed to confirm again in blast nursery where natural blast infection occurs regularly.

■ MAI Khan and MA Latif

Screening of INGER materials obtained from IRRI against bacterial blight disease of rice, Boro 18-19

A total of 165 materials including susceptible and resistant checks, 21 materials such as SVIN310, SVIN288, SVIN323, SVIN314, SVIN318, SVIN309, SVIN324, SVIN313, SVIN316, SVIN317, SVIN317, SVIN017, SVIN324, SVIN316, SVIN313, SVIN315, SVIN314, SVIN038, SVIN307, SVIN302 and SVIN304 were found as resistant and 26 (SVIN048, SVIN312, SVIN044, SVIN005, SVIN322, SVIN308, SVIN297, SVIN044, SVIN026, SVIN305, SVIN315, SVIN307, SVIN321, SVIN050, SVIN291, SVIN017, SVIN309, SVIN046, SVIN045, SVIN305, SVIN039, SVIN018, SVIN312, SVIN318, SVIN046 and SVIN311) as moderately resistant against major Bacterial blight isolates.

■ A Ara and MA Latif

Screening of advanced breeding line against BB disease

In Boro 18-19, thirty-six materials including checks were screened against bacterial blight disease to identify resistant material. Only one material named IR99285-1-1-1-P_1 found as moderately resistant against Bacterial blight disease. No resistant material was found.

■ A Ara

Screening of rice germplasm against bacterial blight (BB) disease during T. Aman 2018 (NATP-2)

A total of 347 rice germplasm along with checks were screened against bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) pathogen. The experiment was conducted under field conditions using artificial inoculation during T. Aman 2018 season. Among the 347 tested germplasm, only a single entry (Ghunsi) found highly resistant (HR), 1 (Voratain) found resistant(R) and 2 (Chine Kanai & Parbat Jira) found moderately resistant (MR). 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 program.

■ MA Latif, MM Rashid, MAI Hasan, T Ferdous and MAI Khan

Screening of rice germplasm against bakanae disease

Germplasms were collected from GRS division. The seeds were surface sterilized with 70% ethanol, washed with sterilized distilled water and then soaked overnight in sterilized distilled water. The water drained out and seeds were further soaked in spore suspension (10^6 conidia/ml) of the virulent isolate for 48 h. The seeds were then planted in sterilized soil in trays (2 kg soil/tray) and were arranged in a completely randomized design with 3 replications (15 seeds/replication). Pre-soaked seeds for the control treatment (susceptible variety BR1 and resistant check variety BR3) were soaked further in sterile distilled water for 48 h before sowing. All trays were placed in a glasshouse at room temperature, and were watered once daily with a hand sprinkler. 85 germplasms were screened out and five (ACC 630, 644, 549, 551, 553) were found resistant.

■ QSA Jahan

Smart deployment of resistance genes and ecological engineering to prevent rice yield loss and reduce pesticide dependency (BMZ Project)

Two on farm trials were conducted in two hotspots of Bangladesh viz. Gazipur and Cumilla for the evaluation of 98 Near Isogenic Lines of BLB, Blast and Tungro including checks against three major rice diseases. A total of 12 entries found resistant against BLB, six found resistant against blast and one found resistant against tungro. Fifty-three lines including three checks were screened against tungro in greenhouse through artificial inoculation technique. Among them 10 lines were found resistant, six were moderately resistant. Rest of the materials were susceptible to Tungro. A total of 40 blast isolates were purified and phenotyped on near isogenic lines. Where, *Pish*, *Pi9* genes were found resistant and *Pita* genes became susceptible against 40 isolates of blast in the present study. Seven major races of *Xanthomomas oryzae* pv. *oryzae* were purified and sent for sequencing.

■ A Ara, MM Rashid, M Salim Miah, MAI Khan and MA Latif

Regional yield trial (RYT) of blast resistant materials

A total of 13 materials including susceptible checks BRRI dhan28, BRRI dhan29 and BRRI dhan58 were evaluated in six locations of Bangladesh with the collaboration of Plant Breeding Division, BRRI. The locations were selected based on their previous blast occurrence history. Some promising blast resistant high yielding lines were found from these trials. The detail results will be found in the report of Plant Breeding Division.

■ MA Latif, M Khatun, T H Ansari, Scientist of Regional Stations and MAI Khan

DISEASE MANAGEMENT

Efficacy of silver nanoparticles against rice blast disease

Rice blast caused by *Magnaporthe grisea* is one of the major and recurrent threats for sustainable rice production in Bangladesh. To mitigate this problem, the current study was aimed to investigate the efficacy of silver nanoparticles against rice blast disease. *In vitro* assays indicated that silver nanoparticles had a significant inhibitory effect on the mycelial growth of rice blast pathogen. Silver nanoparticles and silver nitrate successfully controlled mycelial growth and showed significant differences compared with the other nanoparticles. Only silver nanoparticlse at 800 ppm showed a significant difference compared with the other silver nanoparticles and silver nitrate. Effective concentration of the silver nanoparticles inhibiting mycelial growth by 50% (EC_{50}) up to 9 days after incubation was 308.1 ppm. However, the inhibitory effect on mycelial growth significantly diminished at 12 days of incubation. To measure leaf blast disease severity, three concentrations (200, 400 and 800 ppm) of silver nanoparticles and a popularly used blast control fungicide Trooper 75WP were sprayed on rice seedlings that were 20-25-day old, 3 days before inoculation for preventive and 3 days after inoculation with spore suspension (10^5 conidia/ml+0.01% Tween 20) for curative measure. Only 1.77% and 3.23% leaf blast disease severity were found in preventive measure at 800 ppm concentration for Trooper 75 WP (standard dose of fungicide) and silver nanoparticles, respectively. Whereas untreated control plot exhibited more than 70.0% disease severity. In greenhouse assay, silver nanoparticles were highly effective in preventative application rather than curative application.

■ R Akter, MA Latif and MAI Khan

Identification of crop damage phenomenon by red eelworm and their management

Trials were set up in Boro 2018-19 at three replicated sites for management perspectives. Six treatments were used including, T1= Insecticide (regent 3GR 10kg/ha, Fipronil based phenyl pyrazole Group); T2= regent+AWD; T3= alternate waiting drying (AWD); T4= Nematicide (Furadan 5G, 20Kg/ha), T5= Furadan+AWD and T6= Farmers practice (control). The treatments were applied as soon as the eel worm was reported by farmers at the seedling stage and each treatment was replicated thrice following RCB design. All other cultural management practices including weeding, fertilizer and water management were followed as BRRI recommended guidelines. In control treatment farmers used own (traditional) practice. Hybrid variety was used for the trial. Among the treatments used, T1, T2 and T3 performed similar result and no significant difference was observed among the treatments. However, T2 (Regent + AWD) gave highest yield (7.5 t/ha) compared to T1 and T3. Yield was increased up to 13.7% compared to control treatment (0.06 t/ha) by managing red eel worm. In addition, Farmers' practice produced lower yield.

■ QSA Jahan and MA Latif

Effect of different doses of fungicide against Neck Blast disease, T. Aman 2018

In T Aman 2019, Six different doses of nativo (6g, 8g, 10g/5 decimel) and trooper (8 g, 10g, 12 g/5 decimel) were considered to reconfirm the exact dose of fungicides to control neck blast disease. From this investigation, it was found that, less infected panicles with less severity were observed in trooper 8g per decimel compared to other doses of fungicides. Maximum filled grain also observed at that dose.

■ A Ara

Evaluation of new chemicals against sheath blight disease of rice in Rajshahi, T. Aman 2018

Among 18 fungicides, only four such as Positive 30 SE (Propiconazole 15% + Difeconazole 15%), Sunfighter 25 SC (Hexaconazole 3% + Tricyclazole 22%), Mtop-32.5 SC (Azoxystrobin + Difeconazole) and Limotar top 32.5 SC (Azoxystrobin + Difeconazole) were identified against sheath blight disease successfully in Rajshahi farm.

■ A Ara and MA Latif

In-vitro screening of fungicides against sheath rot and blast fungus of rice

The experiments were carried out in laboratory to find out effective fungicide/s against sheath rot and blast fungus. There were six groups of fungicides namely Chlorothalonil (Deconil 500SC, Phenamarit (Phenam 25SC), Azoxystrobin+Difeconazole (Cropstar), Difeconazole+Pyraclostrobin (Safa 30SC), Azoxystrobin+Cyproconazole (Tipoff 28SC), and Hexaconazole (Hexol 10 EC) along with control. The treatments used were: T1: Half of the recommended doses; T2: The recommended doses; and T3: The 1.5 times of recommended doses. The results showed that Phenam 25SC, Safa 30SC, Tipoff 28SC and Hexol 10 EC completely inhibit the growth of sheath rot fungus at 21 days after transformation, while Deconil 500SC and Cropstar didn't work. In case of blast, the Hexol was found as best to hinder the growth of fungus, whereas Deconil 500SC was ineffective to control it at 12 days after transformation. The other fungicides namely Phenam 25SC, Cropstar, Safa 30SC, and Tipoff 28SC were observed to work some extent but fail to inhibit the complete growth of fungus. It needs to conduct the experiment in field condition to recommend the fungicides.

■ T Khatun

Management of sheath blight disease utilizing *Trichoderma harzianum*

Compost was prepared in T. Aus season, 2018 in net house; Plant Pathology Division, BRRI, Gazipur. Culture of *Trichoderma spp* was grown in broken corn seeds in laboratory condition. The composting materials were placed in layers in a pit (1m x 1m x1m) in ratio of water hyacinth: Cow dung: *Trichoderma inoculum:* 3: 1: 0.25. Urea solution (10%) was used for rapid decomposing. The compost was prepared within 6-7 weeks. After compost preparation, it was used in farmers' fields in variety BRRI dhan70 and BRRI dhan75 to find the efficacy of this compost in reducing sheath blight disease. A total of six trials were set up at the same time adjacent to the compost trial for comparison. All six practices 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 T1 (RDF-Rational dose of fertilizers with Trichocompost) positively reduced % RLH (115%) whereas T2 (T2=75% RDF +25% vermicompost) and T5 (RDF with DAP) reduced to some extent and T4 (75% RDF+ 25% poultry manure) increased % RLH in BRRI dhan70. In BRRI dhan75, T1 and T2 showed similar results as BRRI dhan70, whereas, T3 (RDF), T4 and T5 increased % RLH.

In T. Aus season it was observed that DSI was lowest in T3 (Compost + Nativo -1 spray) and T1 (Compost 2t/h) and T5 (Nativo -2 spray) reduced highest sheath blight DSI which was comparable to T7 (Healthy control). On the other hand, yield was increased higher in T1 and T3 compared to T5.

Again, in T. Aman, highest RLH reduction was observed in T3 followed by T5 and T4 compared to other treatments. Considering yield, the highest yield was observed in T3 followed by T1 and T5. Flag leaf length and width were also found higher in T1 and T3. This flag leaf length, width and yield increase might be due to the extra nutrition added from the tricho-compost.

■ QSA Jahan

Management of blast disease for enhancing rice production in relation to climate change (GOB Project)

In T. Aman season, 2018, 10 demonstrations on rice blast disease management were conducted in Gazipur (5), Naogaon (3) and Cumilla (2) regions and in Boro season 82 demonstrations are conducting in Gazipur (30), Nilphamari (10), Khulna (20), Cumilla (10), Sherpur (6), Naogaon (3) and Dinajpur (3), and two field day were also conducted. One in Cumilla region and other in Kapashia, Gazipur. Around 200 farmers, DAE personnel and BRRI scientists were attended in the field day. A total of 13 training program comprising 470 trainees including famers, pesticides dealers and SAAOs were held in Gazipur (3), Rangpur (2), Cumilla (3), Sherpur (2), Khulna (3) regions. A Leaflet (10,000 copies) was published and distributed among the stakeholders. During T. Aman 2018 season, Neck blast disease was obtained severe 44-82% in BRRI dhan34 at farmers practice compared at BRRI practices (1-7%) in the demonstration areas. The disease incidence was nearly zero in the BRRI practice due to following the technology developed by plant pathology division, BRRI in all the locations. Rice yield was saved upto 57% by managing neck blast disease. During Boro 2018-19 season, highest neck blast disease (80%) was recorded in farmers practice but neck blast lowest incidence was obtained in the BRRI managed plots ranged from 0.1-5%. Yield was saved up to 63% by following BRRI developed blast management technology.

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Rice Farming Systems Division

SUMMARY

In the mini pond, aroid and Telapia fish were cultivated as mixed crops in different stocking density of Telapia. Vegetables and fruits were grown on the bank of the pond. The highest stem and stolon yield of aroid was obtained from Aroid+Fish (Stocking density: 02 piece/m^2) system which gave a gross margin of Tk 20,500/- from 105 m^2 area. Production of sweet gourd (Tk 4,625) and bottle gourd (Tk 3,725) gave better result among the tested vegetables on the bank of the pond.

An experiment was conducted to evaluate short duration T. Aman varieties under supplemental irrigation in Boro-F-T. Aman cropping pattern to find out the best varietal combination of Boro and T. Aman varieties. In T. Aman season 2017-18, BRRI dhan71 produced the highest yield (5.83 t/ha). In Boro season there was no significant difference between BRRI dhan58 (6.70 t/ha) and BRRI dhan63 (6.67 t/ha). In the year of 2018-19, in T. Aman season the same variety BRRI dhan71 gave the highest yield (5.91 t/ha). In the Boro season, similar result of previous year was found where BRRI dhan58 and BRRI dhan63 yielded 6.40 t/ha and 5.70 t/ha respectively.

In four crop cropping pattern trial, the highest rice equivalent yield (26.03 t/ha) was obtained from Field pea- Mungbean-T. Aus-T. Aman cropping pattern (T_1) followed by Potato/Pumpkin (Relay)-T. Aus-T. Aman cropping pattern (T_2) (25.83 t/ha).

Effect of establishment methods was evaluated in Mustard-Boro-T. Aman cropping pattern. No significant difference was found among the treatments in Boro rice yield. The highest yield (4.78 t ha^{-1}) was obtained from Conventional Boro rice-Single pass unpuddled Aman rice-Mustard system.

DEVELOPMENT OF VEGETABLES, FISH AND FRUIT SYSTEM IN MINI POND

An experiment was conducted on mini pond system to increase total production of the system at BRRI Experimental Farm, Gazipur during 2018-19. In the pond aroid and Telapia fish were cultivated as mixture crops. The treatments consisted of four combinations viz T_1= Aroid+Fish (Stocking density: 02 piece/m^2) in the pond and vegetable and fruit on the bank of the pond, T_2= Aroid+Fish (Stocking density: 01 piece/m^2) in the pond and vegetable and fruit on the bank of the pond, T_3= Aroid in the pond and vegetable and fruit on the bank of the pond and T_4= Fish in the pond (Stocking density: 01 piece/m^2) and vegetable and fruit on the bank of the pond. The Aroid variety was BARI panikachu-3 and fish species was monosex Tilapia.

The results showed that the aroid stem yield of T_1, T_2 and T_3 was 1200, 1125 and 1012 kg/105 m^2 respectively (Table 1). The highest stem yield was observed in T_1 followed by T_2 and the lowest was in T_3 treatment. The stolon yield ranged from 92 to 106 kg/105 m^2 and the highest stolon was obtained from T_1 treatment (106 kg). The highest fish yield was obtained from T_4 treatment (45 kg) where T_1 and T_2 produced 26 and 14 kg fish respectively. Economic analysis of different treatment showed that T_1, T_2 and T_3 gave gross margin of Tk 20,500/-, 17800/- and 15,500/105 m^2 respectively where T_4 (only fish) gave Tk 2950/- from the same unit plot. However, mixed farming near the homestead was found to be an effective combination accommodating vegetable, fruit and fish in a system. There is scope of substantial improvement of the productivity of the system with the inclusion of diversified vegetables and fruit. Year-round papaya gave Tk 350/- per 0.06 ha. Different vegetables like snake gourd, bitter gourd, ash gourd, ridge gourd, bottle gourd, sweet gourd, country bean and yard long bean gave Tk 350/-, 1250/-, 825/-, 3150/-, 275/-, 3725/-, 4625/-, 975/- and 375/- per 0.06 ha respectively (Table 2). Among the vegetables the highest gross margin was found from sweet gourd followed by bottle gourd while ridge gourd produced the lowest gross margin compared to others.

IDENTIFICATION OF RICE VARIETY IN BORO-FALLOW-T. AMAN CROPPING SYSTEM FOR SUSTAINABLE PRODUCTIVITY

An experiment was conducted to evaluate suitable T. Aman and Boro varieties for sustaining the productivity of Boro-Fallow-T. Aman cropping pattern and evaluate the performance of short duration T. Aman variety with supplemental irrigation at East Byde, BRRI, Gazipur in 2018-19.

Table 1. Yield and profitability of aroid and Tilapia fish in mixed culture, BRRI HQ, Gazipur, 2018-19.

Treatment	Yield (kg/105m^2)			Gross margin ('000Tk/105m^2)
	Aroid		Fish	
	Stem	Stolon		
T_1= Aroid+Fish (stocking density: 02 piece/m^2)	1200	106	26	20.5
T_2= Aroid+Fish (stocking density: 01 piece/m^2)	1125	98	14	17.8
T_3= Only aroid in the pond	1012	92	-	15.5
T_4= Only fish (stocking density: 01 piece/m^2)	-	-	45	2.95

Price (Tk/kg): Aroid stem=15/-, Stolon= 20/-, Fish=110/-.

Table 2. Yield and economics of different vegetables and fruits on pond bank, BRRI, Gazipur, 2018-19.

Vegetable/fruit	Yield on bank (kg/0.06 ha)	TVC (Tk/0.06 ha)	Gross margin (Tk/0.06 ha)
Papaya	60	850	350
Snake gourd	70	500	1250
Bitter gourd	51	450	825
Ash gourd	150	600	3150
Ridge gourd	33	550	275
Bottle gourd	175	650	3725
Sweet gourd	270	775	4625
Country bean	55	400	975
Yard long bean	35	500	375

Price (Tk/kg): Papaya= 20/-, Snake gourd= 25/-, Bitter gourd= 25/-, Ash gourd= 25/-, Ridge gourd= 25/-, Bottle gourd= 25/-, Sweet gourd= 20/-, Country bean= 25/-, Yard long bean= 25/-.

B J Shirazy, A B M J Islam and M Nasim

The experiment was carried out in a randomized complete block design (RCBD) with three replications. There were ten treatments in the experiment with supplemental irrigation (SI) viz, (1) BRRI dhan49 with SI (2-3)-BRRI dhan63, (2) BRRI dhan49 with SI (2-3)-BRRI dhan58, (3) BRRI dhan49-BRRI dhan63, (4) BRRI dhan49-BRRI dhan58, (5) BRRI dhan71 with SI (2-3)-BRRI dhan63, (6) BRRI dhan71 with SI (2-3)-BRRI dhan58, (7) BRRI dhan71-BRRI dhan63, (8) BRRI dhan71-BRRI dhan58, (9) BRRI dhan57-BRRI dhan63 and (10) BRRI dhan57-BRRI dhan58.

The results illustrate that in Aman season there was a significant yield difference among the varieties where BRRI dhan71 produced the highest yield (5.91 t/ha) and the lowest yield was produced by BRRI dhan57 (2.53 t/ha) (Table 3). In Boro season there was no significant difference between the yield of BRRI dhan58 and BRRI dhan63. In Aman season this year, no supplemental irrigation was needed due to abundant rainfall. From that point of view, it can be concluded that farmers can choose BRRI dhan71 in Aman season with any of the two Boro varieties for maximum yield.

Table 3. Yield of different Aman and Boro rice varieties in Boro-F-T. Aman cropping pattern, BRRI HQ, Gazipur, 2018-19.

Varietal combination + supplemental irrigation	T. Aman yield (t ha^{-1})	Boro yield (t ha^{-1})
BRRI dhan49 + SI (2-3)-BRRI dhan63	5.49	5.56
BRRI dhan49 + SI (2-3)-BRRI dhan58	5.51	6.11
BRRI dhan49-BRRI dhan63	5.38	5.25
BRRI dhan49-BRRI dhan58	4.98	6.40
BRRI dhan71 + SI (2-3)-BRRI dhan63	5.67	5.23
BRRI dhan71 + SI (2-3)-BRRI dhan58	5.50	6.37
BRRI dhan71-BRRI dhan63	5.91	5.37
BRRI dhan71-BRRI dhan58	5.50	6.14
BRRI dhan57-BRRI dhan63	2.76	5.70
BRRI dhan57-BRRI dhan58	2.53	6.27
CV (%)	8.15	-
$LSD_{(0.05)}$	1.17	-
Significant level (5%)	**	ns

B J Shirazy, L Khatun and M Nasim

DEVELOPMENT OF FOUR-CROP CROPPING PATTERNS FOR FAVOURABLE IRRIGATED ECOSYSTEM IN MEDIUM HIGHLAND

The experiment was conducted during 2018-19 at BRRI experimental farm, Gazipur to increase total productivity of unit area per year by increasing cropping intensity. The tested cropping patterns were, CP_1= Field pea-Mungben-T. Aus-T. Aman, CP_2= Potato/Pumpkin (Relay)-T. Aus-T. Aman, CP_3= Mustard-Boro-Jute-T. Aman, CP_4= Wheat-T. Aus-T. Aman (Ck_1) CP_5= Mustard-Mungbean-T. Aus-T. Aman (Ck_2) and CP_6= Potato-Mungbean-T. Aus-T. Aman (ck_3). The experiment was conducted in a RCB design with three replications. Initial soil sample was collected at the beginning of the experiment. BRRI dhan28 was used in Boro season in CP_3. BRRI dhan48 was used in T. Aus and BRRI dhan49, BRRI dhan57, BRRI dhan71, and BRRI dhan75 were used in CP_4, CP_6, $CP_{1,2,3}$ and CP_5 respectively for T. Aman season. Potato, field pea, wheat, pumpkin and mustard varieties were Asterix, BARI Motor-3, BARI Gom-30, Lalteer and BARI Sarisha-14, respectively. The yield of each crop was converted to rice equivalent yield (REY) for comparing the system productivity.

The initial soil status of the experimental plot has been presented in Table 4. Soil pH of the field was slightly acidic. Organic matter status in most cases was low to medium. All the plots of the experimental field were rich in phosphorus. On the other hand, zinc content was medium. Nitrogen, potassium, sulphur and boron were limiting in most of the plots.

Table 5 presents individual crop yield and rice equivalent yield (REY) of respective crops and cropping pattern. Mustard were cultivated under zero tillage condition and yielded 0.84 and 0.96 t/ha. Yield of field pea was 5.0 t/ha. Wheat and sweet gourd yielded 3.4 t/ha and 11.7 t/ha, respectively under respective cropping patterns. Yield of Boro rice was 5.5 t/ha under Mustard-Boro-Jute-T. Aman cropping pattern. Yield of T. Aus (BRRI dhan48) and different T. Aman rice were from 4.7-4.9 and 3.95-5.38 t/ha, respectively in different cropping patterns. Among the tested cropping patterns, the highest rice equivalent yield (26.03 t/ha) was obtained from Field pea-Mungbean-T. Aus-T. Aman cropping pattern (T_1) which is statistically similar to that of Potato/Pumpkin (Relay)-T. Aus-T. Aman cropping pattern (T_2) (25.83 t/ha). Treatment T_3, T_4, T_5 and T_6 produced statistically similar yield which were significantly lower than that of T_1 and T_2. Among the tested crops jute was not possible to establish. Considering rice equivalent yield, Field pea-Mungbean-T. Aus-T. Aman was the best performer followed by Potato/Pumpkin (Relay)-T. Aus-T. Aman cropping pattern.

Table 4. Initial soil status of the experimental plots, BRRI Gazipur, 2017.

Treatment	Soil properties (0-15 cm depth)							
	pH	% OM	N (%)	P (µg/g)	K (meq/100g^{-1})	S (µg/g)	Zn (µg/g)	B (µg/g)
T_1	6.22	1.70	0.091	32.83	0.051	10.25	1.063	0.152
T_2	6.55	1.52	0.084	29.12	0.050	10.16	1.073	0.155
T_3	6.39	1.66	0.089	34.49	0.064	9.55	1.119	0.161
T_4	6.35	1.62	0.088	36.35	0.064	11.29	1.141	0.153
T_5	6.10	1.78	0.095	34.49	0.057	8.95	1.121	0.156
T_6	6.44	1.68	0.091	31.71	0.053	9.38	1.133	0.149
Critical limit*			0.12	10.00	0.12	10.00	0.60	0.20
Interpretation	Slightly acidic	L-M	VL-L	High	Very low	Low	Medium	VL-L

*Fertilizer recommendation guide 2012; VL= Very low, L= Low and M= Medium.

Table 5. Yield of different crops under four crop experiment, BRRI Gazipur 2018-19 .

Treatment	Grain/Tuber/Pod yield (t ha^{-1})									REY (t ha^{-1})
	Mustard	Field pea	Potato	Wheat	Boro	M. bean	S. gourd	T. Aus	T. Aman	
T_1		5.0				0.92		4.90	5.25	26.03
T_2			14.4				11.7	4.72	5.38	25.83
T_3	0.84				5.6			-	5.31	13.22
T_4				3.4				4.88	4.47	13.52
T_5	0.96					0.77		4.78	5.29	15.53
T_6			14.9			0.67		4.91	3.95	19.56

Price (taka per kg): Mustard= 50/-, Field pea= 45, Potato= 10, Wheat= 22, Rice= 18, Mungbean= 65, Sweet gourd= 12.

From the economic analysis, the highest gross margin was obtained from T_1 (Tk 215,300) followed by T_2 (Tk 140,600). Treatment T_5, T_6 and T_3 gave the gross margin of Tk 59,100, 50,800 and 44,500 per hectare, respectively. The lowest gross margin (Tk 44,000 per ha) was obtained from the T_4 (Table 6).

Table 6. Economic performance of different cropping patterns, BRRI HQ, Gazipur, 2018-19.

Cropping pattern	TVC ('000 Tk/ha)	GR (000 Tk/ha)	GM (000 Tk/ha)
Field pea-MB-T. Aus-T. Aman (T_1)	253.2	468.5	215.3
Potato\Pumpkin-T. Aus-T. Aman (T_2)	324.3	464.9	140.6
Mustard-Boro-Jute-T. Aman (CP_3)	193.5	238.0	44.5
Wheat-T. Aus-T. Aman (CP_4)	199.4	243.4	44.0
Mustard-MB-T. Aus-T. Aman (CP_5)	220.4	279.5	59.1
Potato-MB-T. Aus-T. Aman (CP_6)	301.3	352.1	50.8

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EVALUATION OF CROP ESTABLISHMENT METHODS IN MUSTARD-BORO-T. AMAN CROPPING PATTERN IN MEDIUM HIGHLAND ECOSYSTEM

An experiment was conducted during 2018-19 at BRRI experimental farm, 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 was transplanted using transplanter machine and 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 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 hand transplanting. For hand transplanting 30-day-old seedlings were used in 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 for initial fertility status by collecting samples at 0-15 cm depth.

There were no significant differences among the treatments in Boro rice yield (Table 7). The highest yield (4.78 t/ha) was obtained from T_2 treatment (Conventional Boro rice-Single pass unpuddled Aman rice-Mustard) followed by T_3 treatment (4.74 t/ha). The cropping pattern cycle need to be completed to find out the effects of the treatments on the crop establishment and the economics of the respective patterns. Hence the experiment will be repeated in the next years.

Table 7. Yield of Boro under different establishment methods in Mustard-Boro-T. Aman cropping pattern, BRRI, Gazipur, 2018-19.

Establishment method	Boro yield (t ha^{-1})
Single pass unpuddled Boro rice-Conventional Aman rice-Mustard (T_1)	4.67
Conventional Boro rice-Single pass unpuddled Aman rice-Mustard (T_2)	4.78
Single pass unpuddled Boro -Single pass unpuddled Aman -Mustard (T_3)	4.74
Conventional Boro rice-Conventional Aman rice-Mustard (check) (T_4)	4.71
CV (%)	8.56
LSD	NS

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FARMING SYSTEM RESEARCH AND DEVELOPMENT ACTIVITIES AT SREEPUR FSRD SITE

A project has been running for the improvement of holistic farming systems research funded by National Agricultural Technology Program Phase-II (NATP-II). The study area for BRRI component is in Sreepur, Gazipur under Madhupur Tract agro-ecological region (AEZ 28). Major crops grown in this area are rice, wheat, jute, pulses and oil seed. Major cropping patterns of the region are Boro-Fallow-T. Aman, Boro-Fallow-Fallow, Fallow-Fallow-T. Aman, Fallow-Vegetable-T. Aman etc.

BRRI and BARI have already developed improved cropping pattern with management practices involving 3 or 4 crops. Besides, BFRI and BLRI also developed improved technologies on calf rearing, poultry rearing and high value fish culture. Verification of new technologies, integration of different farming components for livelihood improvement and dissemination of proven technologies developed by NARS institutes on crops, cropping pattern, climate resilient options, resource conservation technologies, plantation crops, homestead production systems, fish, livestock and poultry production as well as other income generating activities have been included in this project under plain land ecosystem.

Year round vegetables production in homestead

BARI developed Goyeshpur model was used in vegetables production systems in the homesteads of

12 farmers. Seeds of different vegetables were distributed among the farmers during August 2018-February 2019 to produce high value vegetables in fallow land of homestead with a view to increase income. Goyeshpur model includes nine production units as follows:

For implementing Goyeshpur model, three beds were prepared by each farmer. Intercultural operation and management practices were done by the farmers following recommended practices. During Kharif season sweet gourd, bottle gourd, bitter gourd, red amaranth and stem amaranth were sown in bed. On the other hand, in Rabi season spinach, country bean, cucumber, red amaranth, radish, tomato and *pat shak* were distributed among 12 farmers. Cost-return analysis was done for six months (August 2018 to January 2019). The highest yield was obtained from spinach (435 kg) followed by tomato (299 kg), stem amaranth, country bean, bottle gourd, red amaranth and radish. Total land area of 12 farmers under vegetables production was 84 decimal. Total production of vegetables in six months was 2,117 kg. Among the produced vegetables, 663 kg, 251 kg and 1203 kg were sold, distributed and consumed respectively by 12 farmers.

Homestead vegetable production as well as consumption, distribution and selling increased after intervention. Consumption, distribution and selling of vegetables increased 29%, 50% and 34% respectively in six months (Table 8). Women specially showed interest in homestead vegetable production and willingly took part in its cultural operations.

The year round vegetable patterns under the nine production niches were divided into three cropping seasons per year including Rabi, Kharif-1 and Kharif-2. Some vegetables under each production niche were grown only in one season; some were grown in two seasons. Radish and tomato were grown only in Rabi season under the open sunny space. On the other hand, papaya was grown in the boundary, bottle gourd, country bean in the trellis, bitter gourd in the fence, spinach, chilli, red amaranth, *pat shak* under the open sunny space. After intervention vegetables production and income increased in different niches (Table 9).

After intervention year round vegetables production and utilization was increased. Total production was 2,117 kg from 84 decimal lands of 12 farmers. Total cost of production upto six months was Tk 18,733 and gross return from homestead vegetables production was Tk 42,340 (Table 10).

Table 11 shows the family labour utilization pattern in homestead vegetable production. Contribution of male for land preparation and marketing were 80% and 90% respectively. On the other hand, in cooking woman contributed maximum (90%) percentage of work. But in seeding, sowing, intercultural operations and harvesting both man and woman did more or less same percentage of work whereas their children worked (10%) with them as a helping hand.

Space	Cropping pattern	
	a.	Radish - Stem Amaranth - Indian spinach
Open land	b.	Cauliflower - Brinjal - Red Amaranth
	c.	Tomato - Spinach - Okra
Roof	a.	Bottle gourd - Wax gourd
Trelli	a.	Bottle gourd - Sweet gourd
	a.	Bitter gourd - Ribbed gourd - Sponge gourd
Tree support	b.	Snake gourd - Potato yam
	c.	Country bean - Yard long bean
	a.	Elephant foot yam
Partial shady area	b.	Leaf aroid (Moulavi kachu)
	c.	Turmeric
	d.	Perennial chilli
Marshy land	a.	Panikachu (Latiraj)
Fence	a.	Bitter gourd - Yard long bean - Bitter gourd
	a.	Papaya (3-5 plants)
Homestead boundary	b.	Guava (1-2 plants)
	c.	Lemon (1-2 plants)
Back yard/waste land	a.	Sazna (1-2 trees)
	b	Banana

Table 8. Year round vegetables and fruits production and utilization pattern up to six months (Average of 12 farmers), 2018-19, Tengra, Sreepur.

Description	Before intervention (2017-18)		Six months after intervention (2018-19)	
	Vegetable (kg)	Fruits (kg)	Vegetable (kg)	Fruits (kg)
Consumption	77	32	100	-
Distribution	14	5	21	-
Selling	41	22	55	-
Total	132	59	176	-

Table 9. Year round vegetable production from different niches (Average of 12 farmers), 2018-19, Tengra, Sreepur.

Niche	Before intervention		Six months after intervention	
	Production (kg)	Income (Tk)	Production (kg)	Income (Tk)
Open sunny place	40	800	87	1760
Roof top	0	0	0	0
Trellis	35	700	40	800
Shady place	12	240	10	200
Marshy place	0	0	0	0
Unproductive place	10	200	10	200
Fence	20	400	12	240
Backyard	0	0	5	100
House boundary	15	300	12	240
Total	132	2640	176	3520
Fruit (other places)				

Table 10. Year round vegetables production and utilization pattern (Total of 12 farmers), 2018-19, Tengra, Sreepur.

Total production (kg)	Vegetable utilization (kg)			Cash income (Tk)	Total income (Tk)	Total cost (Tk)	Gross margin
	Consumption	Distribution	Selling				
2117	1203	251	663	13,260	42,340	18,733	23,607

Table 11. Family labour utilization pattern for homestead vegetables production.

Work area	Men (%)	Women (%)	Children (%)
Land preparation	80	10	10
Seed/seedling	60	40	0
sowing/planting	40	60	0
Intercultural operations	50	40	10
Harvesting	30	60	10
Marketing	90	0	10
Cooking	0	90	10

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Farmers' participatory turmeric and ginger production under perennial trees

The activity was conducted at FSR and D site Tengra, Sreepur, Gazipur during 2018-19 to utilize the fallow land under orchard and to increase the total productivity of orchard. The size of the selected area under orchard was 20 m × 20 m. Total area was divided into two plots for turmeric and ginger cultivation. After preparing land sowing was done on 12th May 2018 by maintaining 50 × 25 cm and 60 × 25 cm spacing for ginger and turmeric respectively. About 40-50 days after ginger sowing "Pilaitola" (harvesting of mother ginger) was done. About 100 kg ginger was harvested and the yield of turmeric was about 210 kg from 200 m^2 area. Total cost for the production of ginger and turmeric was Tk 7,300 and 3,600 respectively (Table 12). Gross margin from ginger and turmeric were Tk 7,700 and 21,600 respectively (Table 13) from 200 m^2.

Table 12. Cost of production of ginger and turmeric at 200 m^2 area, Tengra, Sreepur, Gazipur, 2018-19.

Element	Ginger	Turmeric
Seed purchase	4800	1200
Land preparation	400	400
Fertilizer	500	400
Pesticide/Insecticide	100	100
Labour	1500	1500
Total	7300	3600

Table 13. Yield and economic output of ginger and turmeric, Tengra, Sreepur, Gazipur, 2018-19.

Crop	Yield (200 m^2)	Total cost (Tk)	Total income (Tk)	Gross margin
Ginger	100	7,300	15,000	7,700
Turmeric	210	3,600	25,200	21,600

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On-farm trial of newly released BRRI varieties in T. Aman season

The experiment was conducted at Tengra, Sreepur, Gazipur during Aman 2018 to increase total productivity of land by replacing local rice variety with high yielding variety and to determine the field performance of newly BRRI released Aman varieties in this region. Five newly released BRRI varieties for Aman season viz, BRRI dhan57, BRRI dhan71, BRRI dhan72, BRRI dhan75 and BRRI dhan80 were used as test variety. On contrary, BRRI dhan51 and Swarna were used as check variety. Three farmers with an average of 35 decimal lands were selected and all the five varieties randomly distributed to each farmers field for the trial. Two check varieties (BRRI dhan51, Swarna) were cultivated in three farmers field with an average of 30 decimal lands under their regular practices. The tested varieties differed in respect to number of tillers per m^2, number of panicles per m^2, filled grains per panicle, thousand grain weight and yield. Among the varieties BRRI dhan71 produced the highest yield (5.27 t/ha) followed by BRRI dhan75 (5.21 t/ha) and BRRI dhan80 (4.83 t/ha) which were higher than the check varieties BRRI dhan51 (3.68 t/ha) and Swarna (3.44 t/ha) (Table 16). On the other hand BRRI dhan57 and BRRI dhan72 yielded more or less similar to the check varieties.

Table 14. Yield of different crops under existing and improved cropping patterns, Tengra, Sreepur, Gazipur, 2018-19.

Cropping pattern	T. Aus (t ha^{-1})	T. Aman (t ha^{-1})	Mustard (t ha^{-1})	Mungbean (t ha^{-1})	Boro (t ha^{-1})	REY (t ha^{-1})
		Existing pattern				
Boro - Fallow - T. Aman	-	4.16	-			
		Improved pattern				
1: Mustard-Boro-T. Aman	-	5.12	1.31			
2: Mustard-Mungbean-T. Aus-T. Aman	4.62	4.86	1.22		-	
3: Boro-Sesame -T. Aman	-	5.27				

Table 15. Yield and yield contributing characters of Aus rice varieties, Tengra, Sreepur, Gazipur, 2018.

Treatment	Tiller m^2	Panicle m^2	1000 grain wt (g)	Filled grain panicle	Yield (t ha^{-1})
T_1= BRRI dhan27	282 c	259 de	21.21 cd	40 c	2.19 b
T_2= BRRI dhan43	320 b	304 bc	20.24 d	44 bc	2.78 b
T_3= BRRI dhan48	359 a	320 b	23.32 b	78 a	5.51 a
T_4= BRRI dhan65	300 bc	278 cd	22.21 bc	49 b	3.03 b
T_5= BRRI dhan82	381 a	367 a	26.77 a	52 b	4.95 a
T_6= BRRI dhan83	270 c	232 e	28.24 a	81 a	5.01 a
CV (%)	3.96	4.61	2.89	4.81	10.68

Table 16. Yield and yield contributing characters of Aman rice varieties, Tengra, Sreepur, Gazipur, 2018.

Variety	Tiller/m^2	panicle/m^2	Filled grain/pan	TGW (gm)	Yield (t/ha)
BRRI dhan57	378	265	70	20.8	3.76
BRRI dhan71	395	388	77	19.0	5.27
BRRI dhan72	363	245	66	22.0	3.44
BRRI dhan75	438	403	78	21.1	5.21
BRRI dhan80	435	405	81	19.0	4.83
BRRI dhan51 (Ck)	373	333	64	20.2	3.68
Swarna (Ck)	360	315	62	18.6	3.42

TGW = 1000 grain weight.

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Turkey rearing under scavenging system

Turkey rearing activity was conducted at Tengra, Sreepur, Gazipur during 2018-19 to check the feasibility of Turkey rearing under rural condition and to increase household income through empowering rural women. A lady farmer was selected and 50 Turkey chickens were given to her maintaining a ratio of 3:7 male and female. The routine works of vaccination were followed regularly and natural feeds (grass, Gimakolmi shak, rice grain, jackfruits etc) were fed. After 5-6 months of age female birds started laying eggs. Egg production and body weight gained was monitored regularly. About 7-8 months duration turkey birds gained marketable weight for sale. Technical supports (feeding, vaccination, incubator etc) and advices were also given to the farmer. Eggs were hatched using the incubator. Necessary treatment was also given as per requirement. By hatching eggs 70 Turkey chickens were given to seven new farmers at FSR and D site, Tengra, Sreepur, Gazipur.

The average initial weight of a single chicken was 85 g. At nine months of rearing average body weight became 7.5 kg (Table 17). The egg consumption rate was increased among family members as well as nutritional intake was also increased. Farmers sold and hatched egg on an average 35% and 45% respectively. About 15% eggs were damaged during hatching. By hatching eggs about 650 chicks were sold in the market. Farmers earned money from selling of eggs, chicks and adult birds. Maximum income obtained from selling Turkey chicks was Tk 195,000 followed by adult birds (Tk 106,650) and eggs (Tk 60,000). Net income from turkey rearing was Tk 269,650 at nine months of rearing (Table 17).

Success story of Nazma Akter encouraged many farmers about turkey rearing at FSR and D site. Seventy turkey chickens were distributed among seven farmers at the FSR and D site, Sreepur, Gazipur during September 2018. Necessary treatments and management are maintaining as per requirements. At four months of rearing average 4.4 kg body weight gained. The market value of the birds at four months rearing is about Tk 13,500 and total cost is about Tk 8000 (Table 18). These results indicate that turkey production is highly profitable.

Table 17. Average performances of Turkey at farmers' level up to nine months of rearing, Tengra, Sreepur, Gazipur, 2018-19.

Item	Result
No. of farmers	1
No. of birds supplied	50
Date of chick supplied	23-04-2018
Initial wt/bird (g)	80-90
Initial value/bird (Tk)	370
Date of delivery egg	27-09-2018
Feed supplements/bird (g)/day	150
Feed supplements cost/bird (Tk)	810
No. of egg/bird	36
Total value of egg/bird (Tk)	1,800
Present wt/bird (kg) (after 9 months)	7.5
Weight gained/bird (kg)	7.4
Cost/farmer in Tk (Feed cost/farm)	92,000/-
Total variable cost (Tk)	63,500/-
Total return/farmer in Tk (Market value of Egg + Bird +Meat)	361,650/-
Gross margin (Tk)	269,650/-

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Small scale Sonali chicken rearing in the farmer's household under scavenging system

The activity was conducted at Tengra, Sreepur, Gazipur during 2018-19 to check the feasibility of Sonali chicken rearing under rural condition and to increase household income through empowering rural women. Twenty Sonali chickens were given to each of 12 selected farmers at FSR and D site, Sreepur, Gazipur. The routine works of vaccination were being followed and natural feeds were fed. Technical supports (feeding, vaccination etc) and advices were also given.

Average initial weight of a single chicken was 65 g. The growth rate was slow. They also face some disease problems. At four months rearing average body weight was 2 kg (Table 19). The average body weight gained 1.93 kg over the initial weight. Farmers consumed and sold chicken on average 35%, and 65% respectively. Farmers earned money from selling chickens and the average net return was found Tk 2,000/- per farmer.

DEVELOPMENT OF HOMESTEAD AGROFORESTRY SYSTEM

The canopy structure of date palm is of eco-friendly type, which marginally affects the growth and yield of field crops. Integrated gardening of date palm with different field crops may enhance the total productivity of the land. Some crops are well-grown under the partial shade of tree plants. Some may be cultivated in marginal and less fertile land. Several crops can tolerate a wide range of stresses. Because of dryness at Mujibnagar, the area is characterized by the abundance of goat farming, which generated a high demand of fodder. Considering the aforesaid dimensions, some cropping sequences have been designed for the agro-forestry systems in the exotic date palm orchard. For the selection of suitable crops and cropping sequences several treatments were designed under agro-forestry approach (Table 20).

Table 18. Average performances of Turkey at farmers' level up to four months of rearing, Tengra, Sreepur, Gazipur, 2018-19.

Item	Result
Number of farmers	7
No. of birds supplied	70 (10 per farmer)
Date of supplied period	7-9-2018
Initial wt/bird (g)	80-90
Initial value/bird (Tk)	350
Date of delivery egg	Not started yet
Feed supplements/bird (g)/day	150
Feed supplements cost/ bird (Tk)	430
No. of egg/bird	Not yet started
Total value of egg/bird (Tk)	-
Present wt/bird (kg) (after 4 months)	4.5
Weight gained/bird (kg)	4.4
Cost/farmer in Tk (Feed cost/farm)	4300/-
Total variable cost (Tk)	8000/-
Total return/farmer in Tk (market value of bird)	13500/-
Gross margin (Tk)	5500/-

Table 19. Average performances of Sonali (Cock) breed at farmers' level up to four months of rearing.

Item	Result
Number of farmers	12
No. of birds supplied	240
Date of supplied period	30-10-2018
Initial wt/bird (g)	60-70
Initial value/bird (Tk)	15
Feed supplements/ bird (g)/day	20
Feed supplements cost/ bird (Tk)	50
Present wt/bird (kg)	2
Weight gained/bird (kg)	1.9
Cost/farmer in Tk (feed cost/farm)	1000/-
Total variable cost/farmer (Tk)	1500/-
Total return/farmer in Tk (market value of meat)	3500/-
Gross margin/farmer (Tk)	2000/-

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Among the cropping patterns single turmeric cultivation under exotic date palm gave the highest gross return of 198.75 thousand taka per hectare (Table 21). The second highest return was from the pattern of year-round vegetables (Carrot-Red amaranth-Okra). The lowest levels of gross returns were achieved from year-round cover crops of leguminous family (Grasspea-Mungbean-Blackgram) and year-round fodder crops (Triticale-Gama). This comparison of profitability was calculated only on the basis of gross return. This is the result of first year experiment. Fine tuning of the experiments is going on. Details of cost analyses will be incorporated in the next progressive years.

Table 20. Description of the treatments (cropping sequences) for the agro-forestry system with *Phoenix dactylifera*, Mujibnagar, Meherpur, 2017-18.

Cropping pattern (intercropping with exotic date palm)	Planting date of the crops			Field duration of the crops (day)			Total field duration (day)
	1st	2nd	3rd	1st	2nd	3rd	
T_1=Chilli-T. Aman (BR71)	01.11	01.07	-	180	105	-	285
T_2=Pumpkin-Aus (BR83)-Blackgram	01.02	16.05	30.08	105	100	70	285
T_3=Barley-Turmeric	01.11	10.04	-	105	220	-	325
T_4=Fallow-Turmeric	-	10.04	-	-	290	-	290
T_5=Triticale (fodder)-Gama (fodder)	01.11	01.04	-	140	180	-	320
T_6=Carrot-Red Amaranth-Okra	15.10	01.02	01.04	100	45	160	205
T_7=Grasspea-Mungbean-Blackgram	01.11	10.03	30.08	120	70	70	260
T_8=Sole (no crop with date palm)	-	-	-	-	-	-	-

Table 21. Productivity and gross return of different cropping patterns under date palm agro-forestry systems, Mujibnagar, Meherpur, 2017-18.

Cropping pattern (intercropping with date palm)	Economic yield of crops (t/ha)			Gross return of the pattern ('000Tk ha^{-1})
	1st	2nd	3rd	
T_1=Chilli-T. Aman (BR71)	5.50	2.05	-	174.40
T_2=Pumpkin-Aus (BR83)-Blackgram	11.24	1.95	0.89	108.14
T_3=Barley-Turmeric	1.25	9.85	-	166.50
T_4=Fallow-Turmeric	-	13.25	-	198.75
T_5=Triticale (fodder)-Gama (fodder)	19.50	22.15	-	104.13
T_6=Carrot-Red Amaranth-Okra	7.56	6.47	8.35	179.04
T_7=Grasspea-Mungbean-Blackgram	1.16	1.05	0.95	103.20
T_8=Sole (no crop with date palm)	-	-	-	-

Price of the product (Tk/kg): Rice= 18.00; Chilli= 25.00; Pumpkin= 6.00; Blackgram= 40.00; Barley= 15.00; Turmeric= 15.00; Fodder= 2.50; Carrot= 8.00; Red amaranth= 8.00; Okra= 8.00; Grasspea= 20.00; Mungbean= 40.00.

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SUMMARY

In Aus season, overall adoption of modern rice varieties was 84.95% of which BRRI varieties' coverage was about 70.28%. BRRI dhan48 ranked the top position (31.50%) in terms of area coverage followed by BRRI dhan28 (11.19%). In T. Aman season, though overall adoption of BRRI varieties seemed apparently low (52.53%); but adoption in some regions namely Khulna, Faridpur, Cumilla, Barishal, Sylhet, it was substantially high (61-77%). BRRI dhan49 (15.03%) and BR11 (5.33%) were the mostly adopted BRRI varieties in T. Aman season. Adoption of Indian varieties in this season was 19.39%. Overall adoption of modern varieties in Boro season was about 100%, of which coverage of BRRI varieties was 67.04%. BRRI dhan28 and BRRI dhan29 were the most dominant varieties covering 50% areas in Boro season. BRRI dhan48 produced the highest yield (4.00 ton/ha) in Aus season whereas in T. Aman season, BRRI dhan49 was the top yielder (4.87 ton/ha), followed by BRRI dhan52 (4.57 ton/ha). BRRI dhan29 was the top yielder (6.26 ton/ha) followed by BRRI dhan58 (5.62 ton/ha) and BRRI dhan63 (5.60 ton/ha) in Boro season. Average yield of hybrids was 7.09 ton/ha whereas BRRI developed hybrids yielded 7.05 ton/ha in Boro season.

Per hectare gross margin of MV T. Aman rice (Tk 34,645) was higher followed by MV T. Aus rice (Tk 16,289) and MV Boro rice (Tk 9,058). Similarly, per hectare net returns for T. Aman (Tk 3,954) was higher followed by T. Aus rice (Tk -13,976) and Boro rice (Tk -23,657).In Boro season, yield was comparatively 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.

BRRI dhan76 and BRRI dhan77 were the most preferred variety to farmers in Dacope and Amtali respectively because of suitability for planting in fields with stagnant water, matured for harvesting after drainage out stagnant, better yield performance, less or no disease infestation and long panicle with large number of grain. BBRI dhan73 was least preferred variety both in Dacope and Amtali mainly because poor yield performance and matured for harvesting in the fields with stagnant water. The findings of this study indicate that environmental compatibility of a variety, especially at maturity and transplanting stage is the most crucial consideration to farmers about selecting a new variety for adoption along with high yield potential, taller plants, strong stem, tillers per hills, panicle length and grain size. The breed and extension personnel should consider the traits for developing and disseminating rice cultivars in different ecosystems.

In Bogura district, adoption of Indian cultivars was 45% of total area in Boro season, of which Miniket and Zirasail were 20% and 15% respectively. At the same time, dominant Indian variety Zirasail alone covered 70% areas in Naogaon during 1918-19. Apparently Zirasail and Miniket are same cultivar but named differently in different locations. The key adoption drivers of Indian cultivars are resistance to biotic stress, better yield performance and grain quality, higher market demand and price compared to BRRI varieties.

It revealed that BRRI released wet (Aman) season rice technology has a robust and positive effect on small farmers' welfare in Bangladesh as measured by the level of increases in per capita real household income, increases in real rice income, and also increases in yield, and decreases both in poverty gap and squared poverty gap over the time. On the other hand, the marginal and near landless farmers have not gained significantly through adopting BRRI released modern rice technology over non-adopter in terms of all the indicators except rice yield. However, only yield of BRRI released wet season rice technology has positive and significant impact for the marginal and near landless farmers. So, BRRI rice technology adoption seemed to be conducive in increasing the yield level of marginal and near-landless farms but it hardly helps them to overcome the poverty line, unless other equity-enhancing policy measures. Overall, there was large scope for enhancing adoption of BRRI released rice technology in order to reduce the poverty level in rural areas. Thus, it is necessary to develop rice technology targeting to increase the income level as well as reduce the poverty of the resource poor marginal and near landless farmers.

It was found from the study that total cost of production of *Tulshimala* an aromatic rice variety was Tk 92,821/ha which was almost similar to other MVs (Tk 98,346/ha) in T. Aman season but benefit cost ratio (BCR) was 1.40 and 1.94 on full cost and cash cost basis, respectively which was obviously higher (1.04 and 1.54 for other MVs), indicating that *Tulshimala* growers obtained higher benefit from cultivating this variety. Share of net profit earned by miller was 42.75% which was highest among all other actors of value chain and side by side, it was also observed that marketing costs was also higher for millers. Producer's share was 63.53% of consumer's paid price, which seemed not sufficient compared to other actors of the value chain.

Hilly area, which is very important for the economy of Bangladesh, covers almost 10% area of the country. Like other areas of the country, hilly peoples' staple food is rice as well. Rice is being cultivated both in *Jhum* and valley of the hill. About 16% *Jhum* area is covered by rice where in valley, about 45%, 32% and 7% areas were occupied by T. Aman, Boro and Aus rice respectively. Per hectare return from *Jhum* is Tk 2,76,887 where costs incurred Tk 1,00,879, indicating *Jhum* cultivation is profitable (Tk 1,76,008/ha.) in the hilly areas.

FARM LEVEL ADOPTION AND EVALUATION OF MODERN RICE CULTIVATION

Rice, as the staple food in Bangladesh, 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. BRRI has developed 91 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;
- 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 upazila 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 set objectives.

Season-wise adoption of modern rice varieties Aus season. The overall adoption rate of modern rice varieties in Aus season was about 85% of which the coverage of BRRI developed varieties was about 72%. Among all BRRI varieties, BRRI dhan48 ranked the top position (31.5%) in terms of area coverage followed by BRRI dhan28 (11%) and BR26 (5.24%). In Aus season, coverage of other MVs, Indian and hybrids were about 7.36, 0.44 and 5% respectively. Results also revealed that, area coverage of traditional varieties was about 11% in this season (Table 1).

T. Aman season. Although, overall adoption of BRRI varieties was apparently low (53% of total areas) in T. Aman season, their adoption rate was substantially higher (ranges between 61-77% of total area) in some regions (region 6, 8, and 9-14). Although, overall adoption of BRRI dhan49 was higher about 15% of total area; its adoption some regions, such as Bogura (22%), Mymensinghh (33%), Dhaka (46%) and Sylhet (26%) was notable. Similarly, overall adoption of BR11 was only about 5% of total T. Aman area but the variety is still a very popular one in Rangamati (21%) and Sylhet (14%) region. Besides, overall adoption of BRRI dhan34 was about 3% of total T. Aman area; however; the variety occupied considerable area in Dinajpur (17%) and Bogura (5%). Likewise, an overall adoption of Indian rice varieties was about 19.39% of total areas and adoption of those varieties was very high (35-58% of total areas) in Rangpur, Dinajpur, Bogura, Rajshahi and R5= Jashore region. Overall adoption of modern varieties (MVs) in T. Aman season was about 81%. This result indicates that there is still some room of increasing rice production through increasing adoption of MVs in T. Aman season (Table 2).

Table 1. Adoption (%) of different Aus rice varieties by agricultural regions of Bangladesh, 2018-19.

Variety	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	BD
BR21	0.00	0.00	6.63	4.80	1.88	0.00	0.60	0.00	0.08	0.00	1.91	0.45	0.28	3.00	2.01
BR26	0.58	0.69	4.74	3.69	7.40	8.02	0.98	4.96	15.21	7.11	5.30	0.83	9.69	9.26	5.24
BRRI dhan28	33.68	48.85	17.62	15.23	4.08	2.75	0.54	2.98	8.50	16.23	6.43	0.55	9.64	17.47	11.19
BRRI dhan48	33.91	25.95	0.00	36.15	39.28	21.17	19.15	11.69	61.39	39.40	19.71	8.11	63.40	47.53	31.50
Other BRRI	6.48	2.44	18.80	6.19	6.83	17.43	42.51	7.46	7.44	22.57	38.62	10.74	7.31	18.39	20.34
BRRI total	74.64	77.92	47.80	66.06	59.47	49.38	63.78	27.09	92.63	85.31	71.96	20.68	90.33	95.66	70.28
All hybrids	22.90	15.24	1.20	1.75	15.86	5.05	0.06	0.30	0.20	9.25	4.83	4.88	0.14	0.19	4.96
All Indian	0.00	0.00	4.46	0.00	1.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.44
Other HYVs	0.29	3.05	3.78	1.42	19.29	11.11	14.63	0.31	1.43	3.09	10.28	0.10	0.31	1.41	7.36
Nerika	1.22	3.06	1.72	0.59	0.52	2.45	0.49	0.44	4.19	1.84	0.00	2.77	2.89	0.90	1.00
Parija	0.02	0.64	8.14	12.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.23
Local	1.00	0.10	11.20	3.81	3.16	32.01	21.06	71.95	2.23	0.50	13.60	73.95	6.64	1.92	10.92
All MVs	76.18	84.66	89.12	96.01	81.10	62.94	78.90	27.83	98.24	90.24	82.24	23.56	93.54	97.97	84.59
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 Mymensingh, R10= Cumilla, R11= Chattogram, R12= Rnagamati, R13= Dhaka, R14 = Sylhet and BD=Bangladesh, Source: Field survey 2018-19

Table 2. Adoption (%) of different T. Aman rice varieties by agricultural regions of Bangladesh, 2018-19.

Variety	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	BD
BR11	12.57	0.17	2.10	0.19	0.61	5.60	7.05	1.34	3.18	2.18	6.02	21.63	7.09	13.59	5.33
BR22	0.00	0.00	2.47	0.00	0.85	1.04	3.11	0.00	4.24	35.27	9.28	1.64	1.05	7.78	3.98
BR23	0.05	0.00	0.02	0.03	0.82	17.71	6.24	0.02	0.47	5.75	6.46	0.00	0.42	2.28	3.02
BRRI dhan32	0.10	0.03	0.37	0.02	0.00	0.00	0.30	0.42	6.98	6.81	1.72	0.96	0.44	5.16	1.73
BRRI dhan34	1.54	17.16	5.30	6.78	0.11	0.10	0.07	0.19	3.03	0.38	0.01	0.29	0.58	1.11	2.95
BRRI dhan39	0.63	0.00	3.21	2.07	9.48	1.99	0.09	25.73	0.48	1.95	1.87	7.46	0.47	1.79	2.48
BRRI dhan49	5.20	4.66	22.90	13.59	15.02	10.15	1.13	7.93	33.82	17.95	13.96	19.06	46.35	26.27	15.09
BRRI dhan51	4.02	5.83	3.35	10.87	5.17	1.29	1.09	2.34	2.77	0.49	1.83	1.66	3.98	4.70	3.55
BRRI dhan52	9.69	1.95	1.82	1.77	1.51	3.09	8.72	4.34	4.97	1.55	8.27	2.98	1.98	5.06	5.02
Other BRRI	2.96	1.68	2.26	3.78	10.85	20.29	17.22	24.63	2.93	11.97	16.68	21.74	2.73	9.08	9.38
BRRI total	36.76	31.48	43.80	39.09	44.42	61.28	45.03	66.93	62.88	84.29	66.11	77.42	65.11	76.82	52.53
All hybrid	7.19	6.26	2.51	0.40	5.18	3.27	4.44	4.64	6.71	4.57	1.04	1.45	0.32	0.00	4.48
All Indian	48.60	57.68	37.40	41.62	35.24	4.89	2.91	0.68	1.09	1.26	5.63	1.87	1.94	2.19	19.39
Local	4.64	0.95	2.46	8.64	1.04	22.80	42.86	13.60	16.42	7.05	17.13	4.97	14.75	15.86	15.07
Other MVs	2.80	3.82	14.74	10.26	14.13	7.76	4.76	14.14	12.90	2.83	10.10	14.28	17.88	5.13	8.60
All MVs	88.17	92.98	95.94	90.96	93.79	73.93	52.69	81.75	76.87	88.38	81.84	93.57	84.93	84.14	80.52
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 Mymensingh, R10= Cumilla, R11= Chattogram, R12= Rnagamati, R13= Dhaka, R14 = Sylhet and BD=Bangladesh, Source: Field survey 2018-19

Boro season. The adoption of modern rice varieties (MVs) was about 80% of total Boro areas, of which 67% was BRRI varieties. BRRI dhan28 and BRRI dhan29 were the most dominant Boro varieties, covered about 50% of Boro areas in 2018-19. Among the recently released BRRI varieties, BRRI dhan50 has become a popular variety (15% of total areas) in particular in region 5. Besides, adoption of BRRI dhan58 was notable in region 10 (15% of total areas), region 2 (12% of total areas) and region 1and 9 (11% of total). On the other hand, overall adoption of hybrids and Indian varieties was 19.66% and 8.25% respectively. Nevertheless, adoption of Indian varieties was very location specific, for example, adoption of Indian variety 'Zira' was higher in region 4 (57%), followed by region 2 (11%). Moreover, adoption of Indian variety locally known as 'Miniket' was higher in region 3 and 5 (12% of total area) (Table 3).

Yield of modern rice varieties

Tables 4, 5 and 6 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 (4.0 ton/ha) and BRRI dhan28 and, BRRI dhan55 ranked the second and third position with an average yield of 3.97 ton/ha and 4.03 ton/ha respectively. The yield of hybrid was also higher (4.70 ton/ha) compared to Indian varieties (4.15 ton/ha) in this season. Average yield of all MVs in Aus season was 4.0 ton/ha (Table 4).

Table 3. Adoption (%) of different Boro rice varieties by agricultural regions of Bangladesh, 2018-19.

Variety	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	BD
BRRI dhan28	21.99	18.68	18.72	18.83	23.60	28.62	9.80	13.50	26.31	29.00	21.44	22.39	28.50	31.84	23.82
BRRI dhan29	18.62	27.48	26.71	8.94	2.44	1.12	11.59	42.01	31.12	34.65	10.97	9.81	56.60	33.06	26.09
BRRI dhan50	0.83	0.84	0.59	0.54	14.92	2.86	0.58	1.93	0.14	0.00	0.56	0.85	0.74	0.54	1.81
BRRI dhan58	11.60	12.45	8.95	2.88	8.36	3.23	0.35	6.63	11.25	14.42	4.12	8.40	5.49	6.54	8.09
Other BRRI	7.19	6.35	3.50	4.51	9.85	5.97	30.05	3.11	5.17	9.86	22.46	13.99	1.54	6.61	7.22
All BRRI	60.23	65.80	58.47	35.71	59.17	41.81	52.37	67.18	74.00	87.93	59.55	55.45	92.88	78.57	67.04
All hybrid	38.23	15.20	8.07	4.22	11.33	50.46	25.27	28.87	25.12	11.58	33.21	41.34	6.49	18.34	19.66
All Indian	0.56	11.46	22.73	56.75	13.28	1.83	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	8.25
Other MVs	0.58	7.55	10.10	3.32	16.22	5.66	18.60	2.08	0.75	0.40	6.74	3.21	0.04	0.40	4.37
Local	0.41	0.00	0.62	0.00	0.00	0.25	3.77	1.84	0.14	0.09	0.50	0.00	0.59	2.69	0.67
Zira	0.07	4.98	10.69	56.75	1.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.68
Miniket	0.49	6.48	12.04	0.00	12.07	1.02	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	2.54
All MVs	61.36	84.80	91.31	95.78	88.67	49.30	70.97	69.29	74.74	88.33	66.29	58.66	92.92	78.97	79.66
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 Mymensingh, R10= Cumilla, R11= Chattogram, R12= Rnagamati, R13= Dhaka, R14 = Sylhet and BD=Bangladesh, Source: Field survey 2018-19

Table 4. Yield (t ha^{-1}) of different Aus rice varieties by agricultural regions of Bangladesh, 2018-19.

Variety	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	BD
BR21	0.00	0.00	4.58	4.11	3.83	0.00	3.65	0.00	3.39	0.00	3.17	3.89	2.95	3.10	3.66
BR26	3.83	4.19	4.16	4.07	4.21	3.83	3.38	3.45	3.82	3.75	3.87	3.74	3.47	3.71	3.79
BR27	0.00	0.00	4.13	3.24	4.42	3.91	3.53	3.55	4.06	4.22	3.79	3.69	3.54	3.53	3.71
BRRI dhan28	4.11	4.29	4.50	4.62	4.07	4.08	3.83	3.53	3.96	3.90	3.92	4.01	3.49	3.74	3.97
BRRI dhan48	4.31	4.17	0.00	4.73	4.05	4.11	3.49	3.57	4.23	4.14	4.12	4.37	3.53	3.95	4.00
Other BRRI	4.10	4.35	3.87	4.24	4.11	3.81	3.48	3.69	4.00	3.88	3.77	3.77	3.77	3.54	3.84
BRRI varieties	4.02	4.17	4.20	4.22	4.20	3.92	5.54	3.56	3.76	3.91	3.76	3.88	3.54	3.64	4.02
All hybrid	4.87	4.87	4.81	4.71	4.66	4.67	4.83	4.42	4.30	4.71	4.42	4.59	4.89	4.07	4.70
All Indian	0.00	0.00	4.13	0.00	3.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.99	0.00	4.15
Local	2.02	1.92	1.92	2.00	1.84	1.76	2.08	1.90	1.99	2.09	1.89	2.07	1.59	2.00	1.96
Other HYV	4.17	4.07	4.04	4.15	3.93	3.94	3.40	3.58	3.99	3.75	4.04	4.20	3.44	3.46	3.84
All MVs	4.02	4.12	4.14	4.18	4.15	3.91	5.27	3.53	3.79	3.90	3.78	3.88	3.63	3.64	4.00
Average	4.38	4.30	3.92	3.94	4.09	3.63	3.30	2.73	3.44	3.91	3.40	3.05	3.35	3.23	3.62

Note: R = Region, R1= Rangpur, R2= Dinajpur, R3= Bogura, R4 = Rajshahi, R5= Jashore, R6= Khulna, R7= Barishal, R8= Faridpur, R9 Mymensingh, R10= Cumilla, R11= Chattogram, R12= Rnagamati, R13= Dhaka, R14 = Sylhet and BD=Bangladesh, Source: Field survey 2018-19

T. Aman season: Among BRRI varieties, BRRI dhan49 was the top yielder (4.87 t ha^{-1}), followed by BRRI dhan52 (4.57 t ha^{-1}) and BR11 (4.49 t ha^{-1}) in T. Aman season whereas average yield of hybrid was 5.75 t ha^{-1}. The productivity of Indian variety was 4.20 t ha^{-1}. Average yield of BRRI varieties was 4.33 t ha^{-1} and the overall yield of modern varieties (MVs) in this season was 4.30 t ha^{-1} (Table 5).

Table 5. Yield (t ha^{-1}) of different *T.* Aman rice varieties by agricultural regions of Bangladesh, 2018-19.

Variety	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	BD
BR11	4.39	4.92	4.69	4.67	5.04	4.31	4.52	4.36	4.34	4.34	4.46	4.42	4.21	4.36	4.49
BR22	0.00	0.00	3.94	0.00	4.48	4.10	4.61	0.00	4.18	4.21	4.47	4.26	4.06	4.13	4.52
BR23	4.28	0.00	4.03	4.64	4.33	4.54	4.52	4.18	4.11	4.12	4.52	0.00	3.91	4.19	4.28
BRRI dhan33	3.76	4.35	4.45	4.78	4.49	4.01	4.21	4.67	3.78	4.45	4.47	4.26	4.62	3.91	4.28
BRRI dhan34	3.69	3.59	3.87	3.39	4.06	3.96	3.77	3.78	3.67	3.48	4.05	4.11	3.69	3.38	3.72
BRRI dhan49	4.34	4.62	4.75	4.89	4.70	4.45	7.48	4.83	4.64	4.66	4.60	4.41	4.47	4.47	4.87
BRRI dhan51	4.26	4.77	4.68	4.99	4.71	4.23	4.55	4.70	4.52	4.13	4.49	4.15	4.34	4.14	4.49
BRRI dhan52	4.32	4.84	4.88	4.66	4.73	4.37	4.62	4.73	4.59	4.38	4.69	4.37	4.46	4.19	4.57
Other BRRI	4.31	4.56	4.68	4.61	4.58	4.23	5.53	4.75	4.24	4.46	4.40	4.24	4.30	4.15	4.62
BRRI varieties	4.14	4.41	4.45	4.47	4.57	4.21	4.57	4.40	4.20	4.19	4.40	4.21	4.16	4.07	4.33
BRRI hybrid	0.00	0.00	0.00	0.00	0.00	5.15	0.00	5.33	0.00	0.00	0.00	0.00	0.00	0.00	5.29
All hybrid	6.67	6.27	5.49	6.02	5.36	5.16	6.87	5.55	5.45	5.18	9.29	6.20	5.49	0.00	5.75
All indian	4.36	5.04	4.69	4.79	4.17	4.03	3.69	4.16	3.90	2.33	4.36	4.16	3.23	3.92	4.20
Local	2.36	3.12	2.47	2.54	2.39	2.57	2.68	2.54	2.58	2.17	2.46	2.55	2.34	2.51	2.54
Other MVs	4.36	4.33	4.17	4.65	4.43	3.99	4.66	0.00	4.33	0.00	4.34	4.86	4.32	0.00	4.45
All MVs	4.15	4.50	4.42	4.48	4.51	4.22	4.49	4.36	4.15	4.10	4.37	4.23	4.04	4.04	4.30
Average	4.58	4.98	4.34	4.39	4.49	3.77	4.33	4.02	3.86	3.78	4.15	4.13	3.58	3.54	4.15

Note: R = Region, R1= Rangpur, R2= Dinajpur, R3= Bogura, R4 = Rajshahi, R5= Jashore, R6= Khulna, R7= Barishal, R8= Faridpur, R9 Mymensingh, R10= Cumilla, R11= Chattogram, R12= Rnagamati, R13= Dhaka, R14 = Sylhet and BD=Bangladesh, Source: Field survey 2018-19

In **Boro season**, among all BRRI varieties, BRRIdhan29 was the top yielder (6.26 t ha^{-1}) followed by BRRI dhan58 (6.10 t ha^{-1}) and BRRI dhan63 (5.60 t ha^{-1}). Average yield of hybrid was 7.09 t ha^{-1} whereas BRRI hybrids yielded 7.05 t ha^{-1} in this season (Table 6). Average yield of Indian varieties was 5.60 t ha^{-1} and the overall yield of modern varieties in Boro season was about 5.71 t ha^{-1}.

Table 6. Yield (t ha^{-1}) of different Boro rice varieties by agricultural regions of Bangladesh, 2018-19.

Variety	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	BD
BRRI dhan28	5.40	5.79	5.84	6.09	6.07	5.84	5.71	6.09	5.33	5.42	5.46	5.28	5.43	5.34	5.62
BRRI dhan29	6.62	6.32	6.67	6.84	6.87	5.96	6.35	6.74	6.26	6.11	6.00	5.67	6.14	6.10	6.26
BRRI dhan50	5.08	5.50	6.07	5.85	6.26	5.62	5.64	6.29	5.33	0.00	5.28	5.43	5.82	5.67	5.63
BRRI dhan58	5.88	6.26	6.36	6.53	6.48	6.04	5.57	6.97	5.84	6.00	5.75	6.05	5.97	5.54	6.10
BRRI dhan63	5.2	5.3	5.5	5.6	5.7	5.3	4.5	5.6	6.0	6.3	6.1	5.1	5.9	7.7	5.6
Other BRRI	3.95	3.97	3.59	3.78	3.06	4.44	3.38	3.15	5.19	4.67	4.43	4.27	4.72	2.84	5.77
All BRRI	5.38	5.57	5.71	5.82	5.75	5.58	5.33	5.85	5.59	4.44	5.38	5.34	5.62	5.10	5.88
BRRI hybrid	7.12	7.08	0.00	0.00	7.44	7.03	0.00	0.00	0.00	0.00	7.05	6.86	0.00	7.08	7.05
All hybrid	6.97	5.73	6.36	6.23	5.96	7.05	7.20	6.65	7.11	7.17	5.78	5.49	6.90	6.98	7.09
All Indian	3.44	3.62	4.11	1.99	3.97	3.85	0.00	1.47	0.00	0.00	0.00	0.00	1.18	0.00	5.60
Other MVs	4.93	5.79	5.79	5.81	6.00	5.22	5.10	6.74	5.66	5.10	5.33	4.56	0.00	5.16	5.53
All MVs	4.58	4.02	4.26	3.26	4.29	4.48	4.45	4.69	4.34	3.99	4.33	3.86	3.96	4.19	5.71
Average	6.45	6.52	6.67	6.62	6.70	6.49	6.30	7.07	6.14	5.96	6.07	6.16	5.70	5.48	6.32

Note: R = Region, R1= Rangpur, R2= Dinajpur, R3= Bogura, R4 = Rajshahi, R5= Jashore, R6= Khulna, R7= Barishal, R8= Faridpur, R9 Mymensingh, R10= Cumilla, R11= Chattogram, R12= Rnagamati, R13= Dhaka, R14 = Sylhet and BD=Bangladesh, Source: Field survey 2018-19

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ESTIMATION OF COSTS AND RETURN OF MV RICE CULTIVATION AT 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 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 inputs level used in MV Aus, MV T. Aman and MV Boro rice cultivation;
- Estimate the cost of MV rice cultivation in different seasons;
- 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, inputs and outputs prices 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 analyze the data and tabular technique was used to present the results.

Cultivation costs

Per hectare costs of hired labour were Tk 33,813, Tk 35,514 and Tk 42,980 for MV Aus, MV T. Aman and MV Boro rice cultivation respectively. Fertilizer cost of Boro (Tk 12,925/ha) was higher than that of Aus rice (Tk 6,591/ha) and T. Aman (Tk 8,385/ha) rice cultivation. Irrigation cost was much higher (Tk 12,746/ha) for MV Boro rice cultivation than that of MV Aus (Tk 3,978/ha) and MV T. Aman (Tk 3,604/ha) (Table 8). Per hectare variable costs was Tk 63,071, Tk 67,656 and Tk 90,635 for MV Aus, MV T. Aman and MV Boro rice cultivation respectively (Table 9).

Profitability Per hectare yield of Boro rice (6,136 kg) was higher followed by T. Aman rice (5,207kg) and T. Aus rice (4,477 kg). Despite higher yield per hectare, gross margin of MV Boro rice (Tk 9,058) was lower than that of MV T. Aman rice (Tk 34,645) and MV T. Aus rice (Tk 16,289) (Table 8). BCR on cash cost basis of T. Aman was higher (1.5) followed by T. Aus (1.3) and Boro (1.12) (Table 9).

Table 7. Per hectare input used for MV rice cultivation in different seasons of Bangladesh, 2018-19.

Item	Aus	Aman	Boro
Human labour	101	103	121
Hired	47	41	45
Family	16	17	18
Hired contract (transplanting and harvesting)	40	48	59
Seed (kg/ha)	35	35	40
Urea	163	182	245
TSP	77	88	110
MoP	58	71	130
DAP	23	9	25
Gypsum	26	37	48
ZnSo4	5	8	8
Mg	0	3	6
Theovit	3	3	4

Table 8. Per hectare cost of MV rice cultivation in different season of Bangladesh, 2018-19.

Input-wise cost (BDT/ha)	Aus	Aman	Boro
Seedling development	2,280	2,614	2,508
Seed	1,662	1,624	2,099
Tillage	7,033	6,929	7,634
Human labour	39,620	41,701	49,412
Hired	16,692	14,338	16,425
Family	5,807	6,075	6,950
Hired contract (transplanting and harvesting)	17,121	21,176	26,555
Fertilizer cost	6,591	8,385	12,925
Irrigation	3,978	3,604	12,746
Herbicide	628	460	692
Pesticides	3,407	3,956	4,373
Power thresher	2,879	2,795	3,398
Total variable cost	63,071	67,656	90,635
Interest on operating capital	1,206	1446	1,890
Rental change of own land	24,052	24,832	25,837
Total fixed cost	30,114	30,562	32,724
Total cost	93,337	98,346	123,515

Table 9. Per hectare cost and return of MV rice cultivation in different seasons in Bangladesh, 2018-19.

Item	Aus	Aman	Boro
Total costs (BDT/ha)	93,337	98,346	123,515
Total variable costs (BDT/ha)	63,071	67,656	90,800
Total fixed cost (BDT/ha)	30,114	25,762	32,724
Yield (kg/ha)	4,477	5,207	6,136
Market value of paddy (BDT/ha)	75,394	92,951	95,270
Market value of straw (BDT/ha)	3,966	9,349	4,588
Gross benefit (BDT/ha)	79,360	102,300	99,858
Gross margin (BDT/ha)	16,289	34,645	9,058
Net return (BDT/ha)	-13,976	3,954	-23,657
Unit price of grain (BDT/kg)	16.86	17.92	15.57
Unit cost of production (BDT/kg)	20.86	18.91	20.12
BCR (cash cost basis) (Undiscounted)	1.30	1.54	1.12
BCR (full cost basis) (Undiscounted)	0.86	1.04	0.81

PREFERENCE ANALYSIS OF T. AMAN RICE VARIETIES IN THE COASTAL AREAS

The preference polls were conducted on 14 December 2018 in Pankhali, Dacope and 13 December 2018 in Kallyanpur, Amtali to identify the most preferred rice varieties among farmers. Female farmers voted first, followed by male farmers and the researchers, the last. Votes were tallied and the preference scores were computed in front of all the participants. Two most preferred and two least preferred varieties were announced as one of the check varieties was voted top in both the villages. Correlation analysis was performed to test if there are significant correlations between the preference scores of male and female farmers as well as the preference scores of farmers and breeders.

BRRI dhan76 was the most preferred variety to farmers in Dacope followed by check variety BR23. BRRI dhan73 was the most preferred variety in 2018 but the variety was least preferred among the potential one in the current year. Main reasons of vote for BRRI dhan76 were taller seedling height, long panicle with large number of glossy colour medium bold grain, higher yield (5.9 t/ha) than local check BR23 (5.5 t/ha) and Shadamota (3.2 t ha^{-1}). Besides, matured for harvesting 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, no infestation of other insects and diseases despite no pesticides application; and rat was unable to cut the panicle due to taller plant height. And these were the important criteria of preferring BRRI dhan76. Farmers reported drawbacks about BRRI dhan76 were 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 (Table 10).

Table 11 shows that there is a very strong significant correlation on the preference scores between male and female farmers as well as between farmers and scientists/researchers in Pankhali.

Table 10. Preference score for T. Aman rice varieties in Pankhali, Dacope 2018.

Variety	Preference score			
	Male	Female	Scientist	Total
BR11	-0.04	-0.07	0.05	-0.05
BRRI dhan73	-0.23	-0.21	-0.15	-0.21
BRRI dhan76	0.20	0.14	0.05	0.16
BRRI dhan77	-0.02	-0.03	0.20	0.00
BR23	0.11	0.16	-0.05	0.12
Sadamota	-0.02	0.02	-0.10	-0.01

Table 11. Correlation analysis of preference scores for Pankhali, Dacope 2018.

Item	Male vs. female	Famers vs. scientists
Correlation coefficient (r)	0.84	0.66
P-value	0.001	0.04
Sig.	***	**

*** Significant at the 1% level and ** Significant at the 5% level

BRRI dhan77 was the most preferred variety at Amtali followed by BRRI dhan76. Similarly, BBRI dhan73 ranked as least preferred variety in Amtali (Table 12). Farmers voted for BRRI dhan77 mainly because of its environmental suitability in particular 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 grains and consequently 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 in both the locations were fewer tillers per hill, a smaller number of grains per panicle resulting in low yield and for shorter growth duration it matured for harvesting before drained out the stagnant water in the fields. Farmers gave negative vote for BRRI dhan77 in Dacope mainly because of less tillering ability, resulting from expected low yield. Additionally, taller plant height also considered as negative trait in apprehension of lodging susceptibility because rain with ghastly wind is usual phenomenon in November in the coastal areas of Bangladesh.

Table 13 shows that there is a very strong significant correlation on the preference scores between male and female farmers as well as between farmers and scientists/researchers in Kallyanpur.

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Table 12. Preference score for wet season rice varieties in Kallyanpur, Amtali 2018.

Variety	Preference score			
	Male	Female	Scientist	Total
BRRI dhan77	0.21	0.18	0.14	0.19
BRRI dhan66	-0.18	-0.16	-0.18	-0.17
Swarnamoshuri	-0.13	-0.08	-0.07	-0.09
BR23	0.13	0.20	0.11	0.17
BRRI dhan73	-0.05	-0.08	-0.11	-0.08
Vojon	0.00	-0.07	-0.29	-0.08
BR11	-0.02	-0.05	0.00	-0.04
BRRI dhan76	0.04	0.04	0.11	0.05
Sornogota	0.00	-0.02	-0.29	-0.05

Source: Authors' calculation

Table 13. Correlation analysis results of preference scores in Kallyanpur, Amtali 2018.

Items	Male Vs. Female	Famers vs. Scientists
Correlation coefficient (r)	0.84	0.67
P-value	0.006	0.029
Significant	***	**

*** Significant at the 1% level ** Significant at the 5% level

STATUS AND ADOPTION DRIVERS OF INDIAN VARIETIES IN BORO SEASON IN NORTH-WEST BANGLADESH: A CASE OF BOGURA AND NAOGAON DISTRICT

BRRI has so far developed 94 high yielding inbred and six hybrid rice cultivars for ensuring rice grain security in Bangladesh. On average adoption of BRRI developed cultivars in Boro season was 70% of total areas of the season in the country. However, adoption of BRRI cultivars in some of the north-west frontier regions was low. Thus, the study assesses adoption status and adoption drivers of Indian cultivars in Bogura and Naogaon district in Bangladesh.

Adoption status

Adoption of Indian varieties was about 72% of total area of Boro rice in Nougoan district of which adoption of Zirasail was about 70% of total Boro areas of the district. Besides, adoption of Indian varieties was about 45% of total Boro areas in Bogura district, of which adoption of Zirasail and Miniket were respectively about 15% and 20% of total Boro area in the District. Farmers and traders in the group discussion said that apparently Zirasail and Miniket are the same cultivar named as different in the different locations. The key driver of dominance of the cultivars in the locations is that the Indian cultivars are more profitable due to higher price and demand in the market was ensured because of better grain quality. However, increased post-harvest loss due to proneness of the cultivar to lodging and increased infestation of stem borer were the constraints of adoption of the cultivars. Additionally, performance of the cultivars significantly varied between the different soil types. Therefore, its adoption is still location specific (Table 14).

Table 14. Adoption (%) and yield of Boro rice in Bogura and Naogaon District in 2018-19.

Varieties name	Noogoan		Bogura	
	Adoption (%)	Yield (t ha^{-1})	Adoption (%)	Yield (t ha^{-1})
BRRI	23.1	6.2	42.9	6.1
BRRI dhan28	13.0	5.7	21.2	5.7
BRRI dhan29	4.5	6.4	8.1	6.4
BRRI dhan58	1.0	6.2	8.9	6.2
Other BRRI	4.5	6.3	4.8	5.9
Hybrid	4.7	7.1	7.4	7.4
Indian	72.2	5.8	45.6	5.7
Zirasail	70.0	5.7	14.9	5.8
Miniket	-	-	19.6	5.5
Sampa katari	1.3	6.2	-	-
Other Indian	1.0	5.4	11.0	5.7
Local	-	-	0.6	
Other MVs	0.1	5.9	3.5	
Total	100		100	

Adoption drivers of Indian cultivars

The key adoption drivers of Indian cultivars are as follows:

Profitability. Farmers in the group discussion said that Boro rice is an important commercial crop as on average about 80-90% of total farm produce of households, including small farm type is marketable surplus in the study locations. Therefore, potentiality to give higher return per unit area was the most important driver of large-scale adoption of Miniket/Zirasail variety in the study locations, reported by 95-100% of total respondents. The variety gave higher return due to higher market price than the variety it has replaced (e.g., BRRI dhan28) (Fig. 1).

Access to market. The key informant said that the second most important driver of adoption of the variety is the demand of the cultivar at local market is ensured due to better grain quality and similar milling outturn as BRRI dhan28. It was reported that both the paddy and husked rice of the cultivar is the first choice to the traders and consumers respectively so that access to market of the cultivar is secured.

Compatibility with cropping system. Farmers in the group discussion said that suitability of the cultivar with local cropping system is also an important driver for large scale dissemination of the variety. It was reported that due to medium growth duration (90-100 days field duration depending on seedling age 45-50 days) so that the cultivar is compatible for both the two (rice-rice) and three (rice-mustard or potatoes-rice) crops cropping system. It was also the case that flexibility in planting dates i.e., no variation in yield despite early and/or delay transplanting after harvesting dry season crops (mustard or potatoes) make the cultivar compatible for the crops system. The key informant reported that due to flexibility in the transplanting dates, they can easily reap the benefit of cultivating other short duration crop, for instance mustard and/or potatoes in between T. Aman and Boro rice. Additionally, life cycle of the cultivar is 7-15 days shorter than Shampa katari and BRRI dhan29 so that chances of affected by extreme weather events at maturity stage is certainly lower than other cultivars.

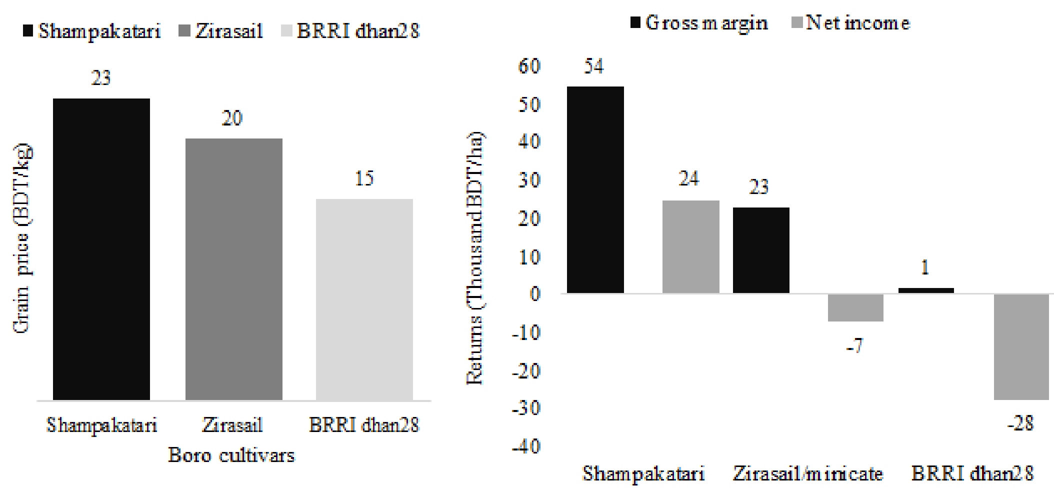

Fig. 1. Comparative price and profitability of major Boro cultivars in Naogaon and Bogura.

Grain quality. Framers in the group discussion said that better grain quality i.e., medium slender type grain and taste good to eat and non-sticky rice is another important driver of large-scale adoption of the variety. It was reported that Zira is more slender but shorter in length than BRRI dhan28

Biophysical performance. Performance of the crops under typical seasonal condition is nearly at per with BRRI dhan28; however, the variety is free from severe infestation of blast under both the early and late transplanting dates. Additionally, it has few unfilled grains in the panicles and higher number of effective tillers (85-90% of total) per hill. Furthermore, Zirasail's ability to recover from transplanting and cold stress is higher than BRRI dhan28, Zirasail takes shorter time to recover from transplanting shock, BRRI dhan28 needs some gap filling for cold stress at transplanting time. However, Zirasail do not need gap filling despite transplanting at the same time.

Drivers and constraints of Shampa katari

Shampa katari is a recently adopted exogenous rice cultivar. Farmers have been cultivating the variety since 2015 and 2013 in Naogaon and Bogura respectively. Although, current adoption rate of the variety is largely lower than Zirasail/Minikit; however, farmers in the group discussion reported that adoption of the cultivar might be increased largely in the future as the cultivar is not only potential to give higher yield (5.9 t/ha) than Zirasail (5.3 t/ha) but also price of the paddy rice (BDT 25/kg) is largely higher than Zirasail (BDT 20/kg). In addition, the cultivar is highly lodging resistant while both the Zirasail and even BRRI dhan28 are lodging prone. Furthermore, quality of the grain of the cultivar is finer and smaller than Zirasail. Its cooked rice is delicious to eat and non-sticky. The variety is practiced in both the wet season and dry season but it has no aroma even growing in the wet season (Table 16).

Table 15. Adoption drivers of Minikit /Zirasail cultivars.

Adoption driver	Respondent (%)
Economic	
Produced higher return due to potentiality to give good yield (5.3 -5.5 t/ha) and higher market price (Per kg Tk 28, Tk 25, Tk 18 in 2017, 2018 and 2019 respectively)	100
Demand for both the paddy and husked rice is ensured even at local market	100
About 80-90% of total produce is marketable surplus	70
Agronomic	
Medium growth duration (90-100 days field duration depending on 45-50- day-old seedling) so that compatible for three (rice/mustard/potatoes/rice) crops-based system.	100
Not only less susceptible to major diseases (e.g., sheath rot, sheath blight, BLB and blast) and insects (BpH) but also it has higher potentiality to recover from stress	80
Emerge panicle at a time, and height of the plants is similar so that look so attractive.	78
Longer panicle with higher number of grains per panicle (180-200 grain/panicle)	70
Higher tillers per hill (18-20 tillers/hills), and most (90-95%) of them are effective	68
Less bushy so that less or no infestation of BPH	60
Early transplanting rice can easily escape from stem borer infestation	50
Medium plant height so that harvesting cost is low and threshing is easy	45
Social	
Finer and medium slender grain	100
Good taste, soft and non-sticky so that about 100% of total farmers cultivate and consume the rice for family subsistence for about six months	100
Most farmers (99%) consume the rice for about 6-7 months in a year	80

Table 16. Adoption drivers of Shampa katari cultivars.

Adoption driver	Respondent (%)
Produced higher yield (best- 6.6 t/ha, typical-5.9 t/ha and worst-5.0 t/ha) than Zira (Best- 6.4 t/ha, typical-5.4 t/ha and worst-4.7 t/ha) despite household seeds	100
Higher price (BDT 25/kg) than Zirasail (BDT 20/kg) and ensured demand in the market so that they mainly cultivate for commercial purpose	100
No lodging despite even strong wind at reproductive stage so that suitable for cultivating in the nutrient enriched soil, in particular in the fields after harvesting potatoes	90
Better grain quality (finer and smaller) than Zirasail/Miniket	80
Cooked rice is delicious to eat, non-sticky	78
Suitable for cultivating in both the wet and dry seasons but potential to give higher yield in dry season (5.9 t/ha) than wet season (4.8 t/ha)	70
Wider leaves and remain green despite matured for harvesting	65
Higher number of effective tillers per hill (22-23)	60
Less disease and pest susceptible, only one dose of pesticides need to apply	55

Adoption constraints of BRRI cultivars

BRRI dhan28 has been mostly replaced gradually by the Zirasail/Miniket and Shampa katari over the last 5-10 years mainly because of Zirasail/Miniket and Shampa Katari produced higher return than BRRI dhan28. Besides, severe sensitivity to neck blast is also an important reason of decreasing adoption of the cultivar in the locations. Farmers in the group discussion reported that BRRI dhan81 as a highly potential cultivar for the dry season in the areas mainly due to its potentiality to give higher grain (5.5-6 t/ha) and straw yield than Zirasail (5.3-5.5 t/ha). Additionally, quality of the grain is even better than Zirasail so that its demand in the market is ensured. Furthermore, post-harvest loss of the cultivar is largely lower than Zirishile as the cultivar is not lodging prone. However, sensitivity of the cultivar to neck blast disease is identified as a major constraint for up-scaling BRRI dhan81.

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VALUE CHAIN ANALYSIS OF AROMATIC RICE (*TULSHIMALA*) IN BANGLADESH

Bangladesh has about 54 aromatic and fine grain rice varieties that are being grown in different parts of the country. The area coverage under aromatic rice is 12.5% in Aman season (Islam et al. 2018) and the yield of clean rice is about 2.0 t/ha (Rashid et al. 2017). Among the aromatic rice varieties, *Tulshimala* is a famous local variety which mostly cultivated in Sherpur and Netrakona districts. The yield performance of *Tulshimala* is little bit higher than the average yield. With low production cost and geo-environmental facilities, Bangladesh could enjoy a good opportunity to export aromatic and fine grain rice. So, the present study was undertaken to explore the value chain of *Tulshimala* rice with the following objectives to:

- Map the supply chain networks of *Tulshimala* rice and the process of value addition along the chain;
- Determine cost, margin and price spread of supply chain of *Tulshimala* rice; and,
- Identify constraints and opportunities of production and marketing of *Tulshimala* rice and recommend policy measures

Primary data were collected following survey method during March to April of 209 from Sherpur and Netrakona districts, which are highly concentrated with *Tulshimala* cultivation and marketing. The sample size of the study was about 100 different actors of rice value chain including 30 farmers, 20 paddy traders, 20 rice millers and 30 clean rice traders. Both tabular and descriptive statistics were employed to analyze the data.

Benefit cost ratio (BCR) of *Tulshimala* rice was 1.40 and 1.94 respectively on full cost and cash cost basis, indicating that current return on investment in *Tulshimala* rice production is 194 percent. Unit cost of production and return from grain of *Tulshimala* rice were 34.00 and 42.00 Tk/kg, respectively indicating farmers are getting benefit of 8.50 Tk/kg by producing *Tulshimala* rice.

Supply chain of *Tulshimala* rice

i. Farmer > Faria > Paddy arathder > Miller > Arathder (rice) > Wholesaler > Retailer > Consumer
ii. Farmer > Bepari > Paddy arathder > Miller > Arathder (rice) > Wholesaler > Retailer > Consumer
iii. Farmer > Bepari > Paddy arathder > Miller > Arathder (Pran, ACI, Chashi) > Dealer > Retailer > Consumer
iv. Farmer > Bepari > Paddy arathder > Miller > Companies (Pran, ACI, Chashi) > Foreign country

Marketing cost and margin of different actors of *Tulshimala* rice value chain

It is revealed that the miller shared highest cost (64.55%) and captured highest percentage of total net profit (42.75%) amongst the traders. The second highest cost was incurred by wholesaler (8.10%) and earned 11.33 percent of the total net margin. The rice retailer captured 17.92 percent of total net marketing margin by incurring 6.40 percent of the total marketing cost. The *aratdar* earned 11.02 percent of the net marketing margin by incurring only 6.23 percent of the total marketing cost. Share of net profit earned by the paddy *aratdar* and *bepari* were 9.42 and 7.56 percent respectively.

Problems faced by the producers

Major constraints pertaining to cultivation of aromatic rice were heavy infestation of neck blast and sheath rot diseases. Ninety five percent of the respondent farmers reported these as the most vulnerable constraints. The other most exposed constraints were labour crisis on transplanting and harvesting period (85 percent), high price of pesticide and insecticide (80.66 per cent) etc. Lack of storage, rational price and capital formation were the considerable constraints of *Tulshimala* rice production in the study area.

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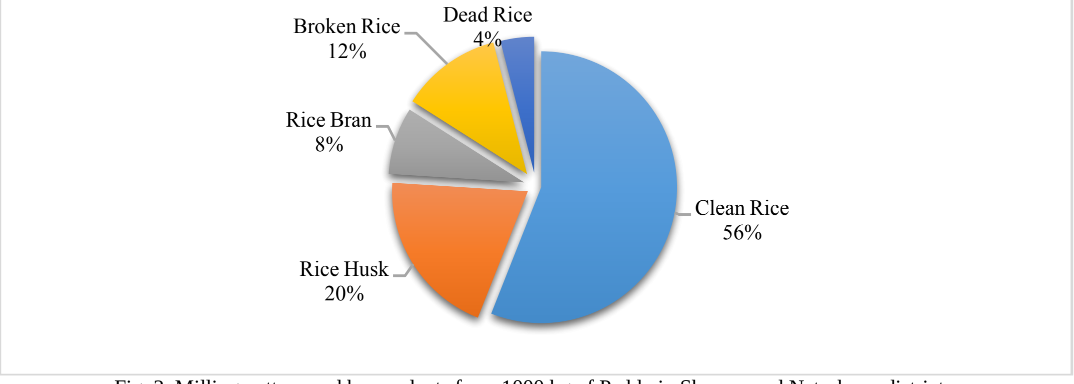

Fig. 2. Milling outturn and by-products from 1000 kg of Paddy in Sherpur and Netrokona districts.

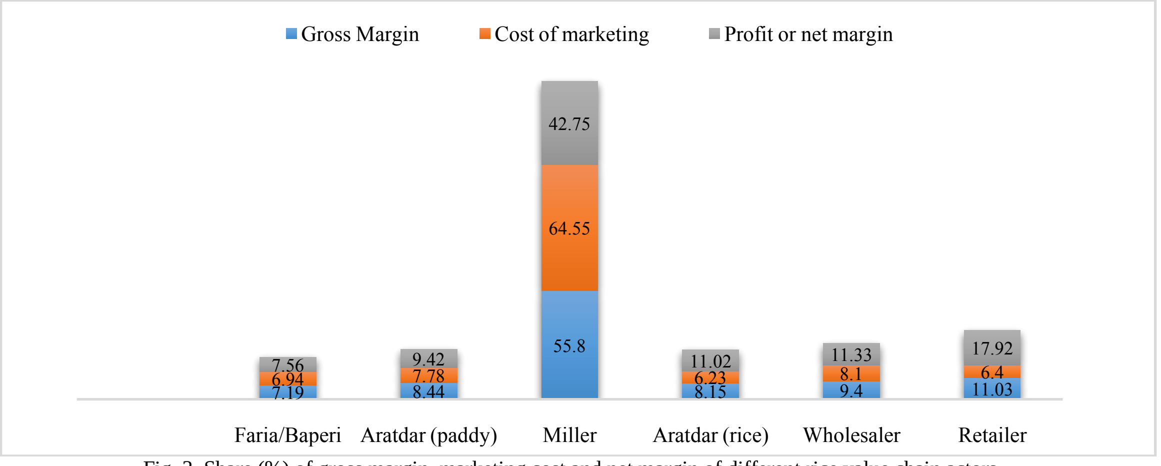

Fig. 3. Share (%) of gross margin, marketing cost and net margin of different rice value chain actors.

ASSESSING THE IMPACT OF BRRI RELEASED MODERN WET SEASON RICE TECHNOLOGY ADOPTION ON FARMERS' WELL-BEING IN BANGLADESH

For this study, two period panel data were obtained from the Bangladesh Integrated Household Survey (BIHS). The International Food Policy Research Institute (IFPRI) conducted two nationwide survey covering 6,500 nationally representative sample rural households in different divisions of Bangladesh during 2011-12 and 2015. From 6,500 rural households, there are 1,542 wet (T. Aman) season rice growing rural households and from 5,447 rural households, there are 1,522 wet season rice growing households in two different periods. The study did not consider 955 households from 1,542 and 935 households from 1,522 those have adopted both modern and traditional rice varieties. Finally, 587 rural households (same for both periods) were selected on the basis of adoption and non-adoption of improved rice technology. This study used unbalanced panel data (because approximately 79% of same arable land have been cultivated to follow-up period from the base period) for DID-treatment effect model. In this study, real income was calculated using rural general consumer price index (CPI) for better understanding. All income data were converted to 2016-17 financial year as a base. Although rice production in Bangladesh is carried out in three distinct seasons (namely, *Aus*/pre-monsoon season, Aman/wet season, and Boro/dry season), however, this study used data of rice growing households only in the wet season, to achieve the set objectives. The definition of DID treatment effects is based on the existence of a pair of before-and-after periods, namely, one baseline ($t = 0$) and one follow-up ($t = 1$). The basic DID framework is dependent on the availability of two groups of units i, including a treated group to which the treatment is delivered ($Z_i = 1$) and a control group to which the treatment is not delivered ($Z_i = 0$). The treatment indicator in the DID setting requires absence of any intervention in the baseline for either group ($D_{i,t=0} = 0|Z_i = 1, 0$), and it requires the intervention to be positive for the treated group in the follow-up ($D_{i,t=1} = 1|Z_i = 1$). For a given outcome variable, Y_{it}, the population DID treatment effect is given by the difference in the outcome variable for treated and control units before and after the intervention. The single DID setting is given by

$$DID = \{E(Y_{it=1}|D_{it=1} = 1, Z_i = 1) - E(Y_{it=1}|D_{it=1} = 0, Zi = 0)\} - \{E(Y_{it=0}|D_{it=0} = 0, Z_i = 1) - E(Y_{it=0}|D_{it=0} = 0, Z_i = 0)\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (1)$$

This single DID can be combined with other non-experimental evaluation methods. Additional control covariates are important when observed heterogeneity may confound the identification strategy. Given the features of DID estimation, observed covariates should be exempt from the effects of the treatment. Thus, if observable covariates (X_i) are available, they can be added into the analysis.

$$DID = \{E(Y_{it=1}|D_{it=1} = 1, Z_i = 1, X_i) - E(Y_{it=1}|D_{it=1} = 0, Z_i = 0, X_i)\} - \{E(Y_{it=0}|D_{it=0} = 0, Z_i = 1, X_i) - E(Y_{it=0}|D_{it=0} = 0, Z_i = 0, X_i)\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (2)$$

In the context of measuring poverty in a population the indices in Foster *et al.* (1984) are commonly used which is expressed as:

$$P_{\propto} = \frac{1}{N}\sum_{i=1}^{N}\left[\frac{Z-y_i}{Z}\right]^{\propto} (\alpha > 0) \; and \; (y_i < Z) \ldots\ldots\ldots\ldots\ldots \; (3)$$

where Z is the agreed-upon poverty line (US$ 1.25/capita/day) converted to Bangladeshi Taka, N is the total household population, y_i is consumption expenditure per capita for the i[th] person, and$\propto$ is a poverty aversion (sensitivity) parameter. When $\propto$ = 1, it is a measure of the poverty gap. When $\propto$ = 2, P equals the squared poverty gap, which is used as a measure of the severity of poverty. The study used the international poverty line of US$ 1.25/capita/day for round 1 (2011-12: base period) and US$ 1.90/capita/day (adjusted from US$ 1.25) (WBG, 2016) for round 2, which is converted to taka per capita per year using official exchange rate.

Descriptive statistics

Table 17 depicts the level of differences in yield and other relevant economic parameters of the sample farms in the study areas. As for the welfare impact of modern rice technology, a straightforward comparison between both per capita total household real income of adopters and non-adopters was considered. While per capita total household real income indicates the ability of the household to purchase its basic needs of livelihood, and thus it provides information on the food security status of households. The result indicates that there is a difference between the per capita total household real income of adopters and non-adopters over time. The mean differences in per capita real income from rice production in the wet season, and the yield the of wet season rice (kg/ha) of the adopters and non-adopters indicate that adopters of improved rice technology are better off than the non-adopters over time.

As evident in Table 17, the incidence of poverty was lower among adopters (35.02%) than non-adopters (39.56%) in the base period. On the other hand, incidence of poverty decreased in case both adopters (25.34%) and non-adopter (33.32%) in the follow-up period. The level of poverty in case of adopters decreasing more compared to that of non-adopter. The depth of poverty was lower among adopters (14.87%) than non-adopters (20.59%) in the base period. On the other hand, depth of poverty decreased in case of both adopter (8.46%) and non-adopter (15.69%) in the follow-up period, and the trend or rate in decrease of poverty was higher in case of the MV adopters. In addition, severity of poverty was also lower (7.51%) among adopters as compared to the non-adopters (11.24%) in the base period. Similarly, the severity of poverty was also lower (4.42%) among adopters as compared to the non-adopters (8.71%) in the follow-up period.

Table 18 presents the level of rice technology adoption by farm size categories over time. In the base period (2011/12), adoption of BRRI released MV rice was higher (76.03%) among marginal and near landless farms, compared to that of medium and large farms (74.51%) and small farms (70.77%) respectively. However, in the follow-up period (2015), adoption of BRRI released MVs by marginal and near landless farms and small size farms increased compared to the level of LV adoption in wet season over time. However, in the case of modern rice (MVs) varieties adoption medium and large farms also the level of adoption of MVs was higher.

Table 17. Differences in rice yield and other economic parameters of the sample households by adoption category in two periods.

Item	2011-12 (base period)			2015 (follow up period)		
	Adopter	Non-adopter	T-test	Adopter	Non-adopter	T-test
Rice yield (t ha^{-1})	3180.27	1969.13	1211.14**	3959.92	2243.03	1716.89***
Per capita wet (*aman*) season real income (tk/year)	7501.51	5536.66	1964.85**	7166.43	3520.28	3646.15***
Per capita household real income (tk/year)	92737.04	85099.87	7637.17**	107871.8	76148.69	31723.11***
Head count ratio (HCR) (%)	35.02	39.56	4.54**	25.34	33.32	7.98***
Poverty gap index (PGI) (%)	14.87	20.59	5.72**	8.46	15.69	7.23***
Squared poverty gap index (SPGI) (%)	7.51	11.24	3.73*	4.42	8.71	4.29**
Sample size	425	162	-	452	135	-

Note: Real income based calculation (using rural general consumer price index (CPI): base year 2016-17), Data source: IFPRI, BIHS: 2011-12 and BIHS: 2015 data. Official exchange rate: 2016-17: US$ 1= 79.1192 Bangladeshi Taka. ***p < 0.01, **p < 0.05, *p < 0.10.

Table 18. Rice technology adoption, by farm size categories in wet (*T. Aman*) season in Bangladesh.

Farm categories	2011/12 (base period)			2015 (follow-up period)		
	BRRI MVs	LVs	Total	BRRI MVs	LVs	Total
Marginal and near landless farms (<0.21 ha) (% of farms)	111 (76.03)	35 (23.97)	146 (100)	97 (80.17)	24 (19.83)	121 (100)
Small farms (0.21 ha –1.01 ha) (% of farms)	276 (70.77)	114 (29.23)	390 (100)	320 (78.04)	90 (21.96)	410 (100)
Medium and large farms[1] (> 1.01 ha) (% of farms)	38 (74.51)	13 (25.49)	51 (100)	35 (62.50)	21 (37.50)	56 (100)
Total (% of farms)	425 (72.40)	162 (27.60)	587 (100)	452 (77.00)	135 (23.00)	587 (100)

Notes: 1. Due to few sample large farms (2 for 2011-12 and 5 for 2015), they are included in the same category as medium farms

Based on the availability of unbalance panel data, the welfare impact of the adoption of modern rice technology (BRRI varieties) in wet season on comparatively resource-poor rural households were assessed. Specifically, the focus was on the underlying causal effect of 'direct' impact of modern rice technology adoption. For measuring the impact of modern rice technology adoption on household welfare, the DID treatment effect model (DID-PSM) was employed.

The study did not apply DID-PSM model in case of large and medium farms, since in this case the sample size was small. For the small farms, causal effect of wet season BRRI modern rice technology adoption on per capita household annual real income (Tk/year) appeared positive and statistically significant. The increase in real income by the MV adopting farms was 67.80% higher than non-adopter over the period (Table 19). Furthermore, wet season per capita real rice income (Tk/year) was positive and statistically significant and the effect of adopting MV rice was 88.50% higher than non-adopters over the period. The results further imply that difference in rice yield in wet season was statistically significant and the effect of adopting BRRI MVs was 30.10% higher than non-adopter over the years. Moreover, poverty gap index and squared poverty index appeared positive and statistically significant. The decrease in poverty gap index and squared poverty index by the MV adopting farms was 12.90% and 6.10%, higher respectively than non-adopter over the period. However, per capita household real income, wet season per capita real rice income, and yield obtained by the MV adopters under DID-kernel 1st, 2nd and 3rd quantile farmers have increased significantly compared to that of non-adopter over the period (Table 19).

On the contrary, marginal and near landless farmers did not gain significantly through adopting BRRI released wet season rice technology vis-à-vis non-adopter for the case of per capita real income, and wet season real rice income, poverty gap index and squared poverty index over time (Table 18). However, on average, difference of yield of rice (kg/ha) in wet season was positive and statistically significant and effect of adopting BRRI MVs was 18.5% higher than non-adopter over the period. It implies that dissemination of new rice technology contributes to food availability though it does not impact on the welfare of the marginal and near landless farmers (Table 18). However, per capita household real income, wet season per capita real rice income, and yield obtained by the MV adopters under DID-kernel 1st, 2nd and 3rd quartile farmers did not increase significantly compared to that of non-adopter (Table 20).

Table 19. Results of DID treatment effect analysis for BRRI released modern rice growing households in T. Aman season in Bangladesh (Small farm size).

Indicator	DID kernel (bw=0.03)	Quantile regression		
		DID kernel (bw=0.03) Quantile(0.25)	DID kernel (bw=0.03) Quantile (0.50)	DID kernel (bw=0.03) Quantile (0.75)
Ln rice yield (t/ha)	30.10**(0.130)	15.0**(0.071)	20.30**(0.081)	13.81**(0.064)
Ln per capita wet (*aman*) season real income (Tk/year)	88.50**(0.359)	106.80***(0.194)	129.50***(0.186)	94.70***(0.450)
Ln per capita household real income (Tk/year)	67.80***(0.188)	41.60***(0.124)	38.10***(0.114)	46.90***(0.133)
Poverty gap index (PGI) (%)	-12.90**(0.071)	-	-	-
Square poverty gap index (SPGI) (%)	-6.1*(0.036)	-	-	-
Balancing property satisfied	yes	yes	yes	yes
Common support imposed	yes	yes	yes	yes
Sample size	410	410	410	410

Notes: 1. Parentheses indicate bootstrap standard error with 100 replications, Ln=Log, 2. ***p < 0.01, **p < 0.05, *p < 0.10.

Table 20. Results of DID treatment effect analysis for BRRI released modern rice growing households in T. Aman season in Bangladesh (Marginal and near to landless farm size).

Indicator	DID Kernel (bw=0.03)	Quantile regression		
		DID Kernel (bw=0.03) Quantile(0.25)	DID Kernel (bw=0.03) Quantile (0.50)	DID Kernel (bw=0.03) Quantile (0.75)
Ln rice yield (t/ha)	18.5*(0.105)	14.39*(0.077)	16.70**(0.071)	15.3**(0.061)
Ln per capita wet (*aman*) season real income (Tk/year)	49.60^{NS}(0.585)	70.90^{NS}(0.669)	98.40^{NS}(0.605)	85.10^{NS}(0.802)
Ln per capita household real income (Tk/year)	45.00^{NS}(0.390)	21.0^{NS}(0.453)	14.6^{NS}(0.246)	37.01^{NS}(0.235)
Poverty gap index (PGI) (%)	-21.2^{NS}(0.201)	-	-	-
Square poverty gap index (SPGI) (%)	-12.7^{NS}(0.108)	-	-	-
Balancing property satisfied	yes	yes	yes	yes
Common support imposed	yes	yes	yes	yes
Sample size	146	146	146	146

Notes: 1. Parentheses indicate bootstrap standard error with 100 replications, Ln=Log, 2. ***p < 0.01, **p < 0.05, *p < 0.10. NS = Not significant

Table 21. Results of DID treatment effect analysis for BRRI released modern rice growing households in the T. Aman season in Bangladesh (Pool farm size).

Indicator	DID kernel (bw=0.03)	Quantile regression		
		DID kernel (bw=0.03) Quantile(0.25)	DID kernel (bw=0.03) Quantile (0.50)	DID kernel (bw=0.03) Quantile (0.75)
Ln rice yield (t/ha)	25.4**(0.117)	11.0**(0.053)	19.4***(0.063)	11.8**(0.053)
Ln per capita wet (*aman*) season real income (Tk/year)	82.2**(0.326)	99.3***(0.184)	132.5***(0.228)	33.6^{NS}(0.306)
Ln per capita household real income (Tk/year)	48.8***(0.133)	22.8**(0.095)	28.2***(0.084)	36.1***(0.083)
Poverty gap index (PGI) (%)	- 14.4***(0.058)	-	-	-
Square poverty gap index (SPGI) (%)	- 6.2**(0.030)	-	-	-
Balancing property satisfied	yes	yes	yes	yes
Common support imposed	yes	yes	yes	yes
Sample size	587	587	587	587

Note: 1. Parentheses indicate bootstrap standard error with 100 replications. Ln=Log, 2. ***p < 0.01, **p < 0.05. NS = Not significant

For pool model, causal effect of wet season BRRI modern rice technology adoption on per capita household annual real income (Tk/year) appeared positive and statistically significant. The increase in real income by the MV adopting farms was 48.8% higher than non-adopters (Table 21). Furthermore, wet season per capita real rice income (Tk/year) was positive and statistically significant and effect of adopting MV rice was 82.2% higher than non-adopters. The results further imply that, difference in rice yield in wet season was statistically significant and the effect of adopting BRRI MVs was 25.4% higher than non-adopters over the years. Moreover, poverty gap index and squared poverty index appeared positive and statistically significant. The decrease in poverty gap index and squared poverty index by the MV adopting farms was 14.40% and 6.20%, respectively higher than non-adopters over the period. However, per capita household real income, wet season per capita real rice income, and yield obtained by the MV adopters under DID-kernel 1st quantile to 3rd quantile farmers increase significantly compared to that of non-adopters (Table 21). It implies that, new rice technology adoption have impact not only on food availability, but also on farmers' welfare over time. DID treatment effect model estimates indicate that wet season BRRI MV rice technology adoption has a positive and robust impact on household welfare in terms of per capita household annual real income, wet season per capita real rice income, as well as wet season rice yield in Bangladesh. In addition, there has been a trend towards decreasing poverty over the periods of 2011-12 to 2015 in Bangladesh.

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ECONOMICS OF JHUM CULTIVATION IN BANGLADESH

Hilly area is very important in Bangladesh covering 13,295 sq.km (10% of the country) areas of the country. The hilly districts are food deficit. There are around 77% hill and 3% undulating bumpy. Only 20% plain land (valley) is available for crop production. About 26% area is under irrigation facility. The principal source of income in the hilly area is farming and *Jhum* cultivation. Rice production technology and input use in the hilly area is totally different. The present study was under taken with the following specific objectives to:

- Know the present status of *Jhum* rice in the hilly districts; and
- Estimate the profitability from *Jhum* cultivation.

The study was conducted in two district namely Rangamati and Khagrachari where ARD and RFS Divisions of BRRI setup demonstration trial. A total of 4 FGD were conducted in 2019 where total participant farmers were 60 (15 from each location). Simple tabular form of analysis was done to analyse the data.

Rice areas in hilly districts. In the hilly districts, around 16% areas was under *jhum* cultivation. Rangamati and Banderban districts covered vast areas for *jhum*. In valley, more than 45% area was covered by T. Aman rice followed by Boro (32%) and Aus (7%). In the three hilly districts, Banderban alone covered 55% total *jhum* rice areas followed by Rangamati (31%) and Khagrachari (14%) (Table 22). The highest number (20) of *jhum* rice found in Banderban followed by Rangamati and Khagrachari (12). Gunda was the most dominant variety in the hilly districts due to higher yield.

Production cost and return from *Jhum* cultivation

Input cost for *Jhum* cultivation. More than 25 crops including rice are grown at a time in hills. Out of these crops 8-13 are common in all locations. Rice alone covered around 75% areas though return from rice is lowest. As a part of culture and heritage people produce rice and some farmers have no rice land in the valley for rice production. It is difficult to estimate input used for different crops separately because all types of inputs (except seed/seedlings and labour for seeding/plantation) were applied at a time. Farmers apply only urea fertilizer to produce all types of crops. From input use and cost, Banana incurred higher cost (Tk 27,170/ha) next to rice (Tk 14,573/ha). Only 247 kg/ha urea fertilizer was applied for all crops. Farmers used pesticides to control pest in hills. To control seasonal weeds that emerged after slash and burn due to rain, some farmers used herbicide. To control insects, farmers also applied insecticides when needed. In total Tk 1,00,879 incurred for one hectare of land (Table 23).

Table 22. *Jhum* cultivation (Aus season) in Chattogram Hill Tracts.

Item	District			Total
	Banderban	Khagrachari	Rangamati	
Cultivated area (ha):	8890(55%)	2252(14%)	5040(31%)	16182
No. of variety	20	12	12	
Dominant variety(1)	Gallong	Gallong	Gallong	
Area coverage(ha)	1800(20%)	1185(53%)	460(9%)	
Yield(t/ha)	1.69	2.15	2.24	
Dominant variety(2)	Pedi	Binni	Charai	
Area coverage(ha)	1435(16%)	585(26%)	434(9%)	
Yield(t/ha)	1.85	1.90	2.15	
Average yield(t/ha)	1.96	2.13	2.13	
Highest yielding variety	Gunda (1.89)	Rangi (2.12)	Nerica (1.52)	

Return from *Jhum* cultivation

Return from Jhum cultivation is not considered from economic point of views always. Rice alone covered around 75% of land but return from this crop is very low, only Tk 32110/ha. Maximum return come from Banana, Tk 123500/ha and it is available round the year. Chilly was the third return provider for farmers. In total ,Tk 276887/ha was earned from *Jhum* cultivation.

Total return was Tk 2,76,887/ha and total cost was Tk 1,00,879/ha. Considering full cost, excluding land rental value, profit was Tk 176008/ha (Table 23).

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Table 23. Cost of production in *Jhum* cultivation.

Crop	Amount of seed/seedlings (kg)	Price of seed/seedlings	Labour (no.)	Amount of inputs	Total costs
Human labour for clean and burn (work-day)			37		14,800
Rice	25	988	29.64	Urea 247 kg	14,573
Chilly	5	2470	25		9,880
Marfa fruits	0.612	247	5	-	1,482
Sesame	1.85	370	10		33,35
Country bean		494	5		1,482
Banana	741 no.	25	49		27,170
Lota alu	0.247	123	2.5		1,111.5
Yard long	0.612	123	2.5		864.5
Pumpkin	0.247	123	10		3,087.5
Turmeric	296.4	1482	25		9,880
Spinach	25	494	2.5		1,235
Brinjal	5	123	10		1,482
Bottle gourd		123	5		1,605
Pesticides					8,892
Total cost					100,879
Total return					276,887
Total benefit					176,008

Agricultural Statistics Division

SUMMARY

Among T. Aman varieties, BRRI dhan49 were found stable with stability index 2.02 while BR3, BR5, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan56, BRRI dhan70 and BRRI dhan77 appeared to be below average stable. BR 4, BR10, BR 11, BR 22, 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 dhan78, BRRI dhan79, BRRI dhan80, BRRI dhan87, BRRI hybrid dhan4 and BRRI hybrid dhan6 were found having average stability among T. Aman varieties. No unstable variety was found in T. Aman season.

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. In long duration and accordingly three mega-environments were identified. One mega-environment had three locations, Gazipur (E4), Rajshahi (E5) and Rangpur (E6). In medium duration; the biplot grouped the test locations into three mega-environments. The first mega-environment had four locations, Barishal (E1), Cumilla (E3), Gazipur (E4) and Sonagazi (E8). The biplot was divided into three mega-environments in short duration. The first mega-environment had four locations, Barishal (E1), Cumilla (E3), Rajshahi (E5) and Satkhira (E7).

To increase national production of rice we adopt the potential high yielding variety at the respective season and region with the best crop management practice (BRRI recommended) than total clean rice production increase 24.22% than present production. In case of the highest yielding variety production increased 11.03% but for wrong selection of variety (low yielding variety) production decrease more than 50%.

Weather forecast based rice crop management systems were to enable farmers/ researchers/ decision makers to make effective decisions on rice crop supervision for different weather conditions, well ahead of time. It is not only reducing the risk but also enables to maximize the benefit from favourable weather conditions. And also has potential for increasing the rice yield, avoiding insect and disease outbreaks, proficient use of pesticides, herbicides and fertilizer application and efficient agricultural water management, thus, reducing the overall production cost as well. An uptake of the system can contribute in overall food security of the country and achieving sustainable development goals by increasing the agricultural productivity and incomes of small-scale food producers.

Among the BBRI dhan80-86 and BRRI hybrid dhan6 most of the varieties are suitable in north-west side of Bangladesh except BRRI dhan85, which is suitable in north-eastern and central-eastern side of Bangladesh. Productivity will be increased, if we cultivate rice varieties according to their suitable area.

More or less in all seasons eastern side of Bangladesh is characterised by high rainfall and low temperature area and western side as low rainfall and high temperature area. There were more rainfall in 2017 than 2016 and thus 2016 was warmer than 2017.

In a nut shell, the western side of the country is suitable for cultivation of BRRI dhan72 and north-west side is suitable for cultivation of BRRI dhan71. North-east and some central part of northern areas are suitable for BRRI dhan50.

STABILITY ANALYSIS OF BRRI VARIETIES

The main objectives of the study were to determine the stability index of BRRI released varieties, maintain season, year and location-wise database and identify the bio-physical and socio-economic factors causing instability. Experiments are being conducted in T. Aman season with BRRI released rice varieties since 2002-18 at 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 numbers of varieties were 42. The design was RCB with three replications and the effective plot size (harvest area) was 2.6-×-2.6 m^2 leaving the two border row from each side. Recommended crop management practices were 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.

Table 1. Stability parameters of grain yield for T. Aman.

Variety	Stability parameter 2001-2018			Stability index	Stability rank	Nature of stability
	Si	Di	Pi	Gi	Ri	
			Non-aromatic rice			
BR 3	18.15	-8.84	76	0.75	34	BAS
BR 4	13.13	1.02	69	1.28	22	AS
BR 10	13.61	9.10	66	1.54	8	AS
BR 11	14.16	6.96	71	1.48	13	AS
BR 22	14.51	6.60	68	1.42	16	AS
BR 23	14.89	3.13	73	1.30	21	AS
BR 25	15.07	0.57	68	1.18	29	AS
BRRI dhan30	11.80	5.91	69	1.57	6	AS
BRRI dhan31	14.75	1.57	70	1.22	24	AS
BRRI dhan32	16.47	8.89	78	1.51	9	AS
BRRI dhan33	20.25	-10.95	67	0.55	36	BAS
BRRI dhan39	19.06	-2.95	68	0.91	31	BAS
BRRI dhan40	13.10	6.46	70	1.48	12	AS
BRRI dhan41	16.41	5.20	72	1.30	20	AS
BRRI dhan44	14.24	8.95	49	1.51	10	AS
BRRI dhan46	16.25	3.02	42	1.18	30	AS
BRRI dhan49	9.99	13.04	38	2.02	1	Stable
BRRI dhan51	13.20	6.31	36	1.55	7	AS
BRRI dhan52	10.45	9.80	34	1.85	2	AS
BRRI dhan53	15.42	2.80	25	1.22	26	AS
BRRI dhan54	16.76	10.52	25	1.45	14	AS
BRRI dhan56	16.73	-6.26	26	0.83	33	BAS
BRRI dhan57	23.22	-21.64	28	0.13	40	BAS
BRRI dhan62	27.69	-22.42	23	0.11	41	BAS
BRRI dhan66	13.44	5.25	16	1.44	15	AS
BRRI dhan70	21.91	-10.65	14	0.59	35	BAS
BRRI dhan71	10.07	7.80	13	1.78	3	AS
BRRI dhan72	13.69	10.31	10	1.50	11	AS
BRRI dhan73	17.91	6.12	15	1.36	19	AS
BRRI dhan75	14.83	2.22	12	1.22	25	AS
BRRI dhan76	9.97	-3.62	13	1.36	18	AS
BRRI dhan77	13.72	-6.85	10	0.86	32	BAS
BRRI dhan78	NA	6.09	8	1.23	23	AS
BRRI dhan79	NA	9.80	8	1.37	17	AS
BRRI dhan80	NA	5.22	8	1.20	28	AS
BRRI dhan87	NA	17.89	8	1.67	5	AS
BRRI Hybrid dhan4	15.40	0.80	20	1.21	27	AS
BRRI Hybrid dhan6	11.76	9.52	9	1.76	4	AS
			Aromatic rice			
BR5	18.73	-22.60	74	0.24	39(3)	BAS
BRRI dhan34	19.69	-26.73	73	0.03	42(4)	BAS
BRRI dhan37	17.85	-22.82	76	0.25	38(2)	BAS
BRRI dhan38	15.93	-20.22	67	0.35	37(1)	BAS

Note: AS=Average stable, BAS=Below average stable

Among T. Aman varieties, BRRI dhan49 were found stable with stability index 2.02 while BR3, BR5, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan56, BRRI dhan70 and BRRI dhan77 appeared as 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 dhan78, BRRI dhan79, BRRI dhan80, BRRI dhan87, BRRI hybrid dhan4 and BRRI hybrid dhan6 were found as average stability among T. Aman varieties. No unstable variety was found in T. Aman season (Table 1).

GENOTYPE × ENVIRONMENT INTERACTION OF BRRI VARIETIES

The development of rice varieties is affected by the environment, genotype and their interaction. Yield performance of different varieties varies across testing environments and its grain yield performance is a function of genotype (G), environment (E) and genotype × environment interaction (GEI). The experiment was conducted in multienvironment trials for T. Aman 2018. Forty-two BRRI released T. Aman rice varieties were evaluated in nine environmental conditions of Bangladesh, such as Barishal (E1), Bhanga (E2), Cumilla (E3), Gazipur (E4), Rajshahi (E5), Rangpur (E6), Satkhira (E7), Sonagazi (E8) and Kushtia (E9). The experimental sites covered all ecosystem of Bangladesh. The experiments were carried out in randomized complete block design (RCBD) with three replications and evaluated for rice grain yield. Each experimental plot comprised of 3m × 2m. Standard agronomic practices were followed and plant protection measures were taken according to Adhunik dhaner chash, BRRI (2016). AMMI model was used to quantify the effect of different factors (genotype, location) of the experiment. The model further provides graphical representation of the numerical results (GGE biplot analysis) with a straight-forward interpretation of the underlying causes of G × E. The major objective of the present study was to identify BRRI released rice genotypes that have both high mean yield and stable yield performance across different environments for different ecosystems of Bangladesh.

ANOVA of combined analysis

The combined analysis revealed that the yield of rice genotypes was significantly influenced by environment and contributed 52.32, 51.05 and 47.29% of the total variation for long, medium and short duration respectively. Additionally, the relative contribution of genotype sum of squares was found 17.34, 10.37 and 24.84% for long, medium and short duration respectively. Genotype by environment (G × E) contributed the most 27.03% to the total variation for medium duration followed by 20.85% and 20.71% for short and long duration. Greater portion of total variation was explained by environmental main effect indicating that the environments were diverse and a major part of variation in grain yield reflected from environmental changes. The highly significant genotype × environment interaction effects for grain yield confirmed that genotypes responded differently to the variation in environmental conditions. The yield variations could be attributed to the different environmental (climatic) conditions and to different edaphic conditions at different locations. In this case application of stability analysis for identifying widely and/or specifically adaptation of rice genotype (s) is essential.

Table 2. ANOVA of individual category (long, medium and short).

SV	Long duration			Medium duration			Short duration		
	DF	MS	SS (%)	DF	MS	SS (%)	DF	MS	SS (%)
ENV	8	43.38	52.32	8	25.48	51.05	8	38.20	47.29
REP(ENV)	18	0.34	0.92	18	0.3	1.36	18	0.30	0.82
GEN	16	7.19	17.34	10	4.14	10.37	13	12.35	24.84
ENV:GEN	128	1.07	20.71	80	1.35	27.03	104	1.30	20.85
Residuals	288	0.2	8.7	180	0.23	10.19	234	0.17	6.20
CV (%)		10.89			10.53			9.25	
$LSD_{0.05}$		0.24			0.26			0.22	
Mean		4.11			4.51			4.47	

Note: ENV=environment, GEN= genotype, DF = degrees of freedom; MS = mean sum square; SS (%) = explain % sum of squares; ** = significant at the 1% level.

Evaluation of test environments

The GGE biplot explained 71.68%, 71.71%, and 77.46% of the total variation of the environments for long, medium and short duration respectively. In long duration (Fig. 1a), there were two clusters of environments, one contains Barishal (E1), Bhanga (E2), Cumilla (E3), Sonagazi (E8) and Kushtia (E9); the other cluster contains Gazipur (E4), Rajshahi (E5) and Satkhira (E7). Among them Barishal (E1), Kushtia (E9) and Cumilla (E3) were closely associated (Fig. 1a). Rangpur (E6) had the longest vector and hence was highly discriminating. The locations Barishal (E1), Satkhira (E7) and Kushtia (E9) were highly representative environments (Fig. 1a). Overall, the location Satkhira (E7) can be considered ideal for evaluating medium duration genotypes.

GGE biplot showed two distinct clusters in medium duration: one contains Barishal (E1) and Sonagazi (E8) and other contains Bhanga (E2), Rajshahi (E5), Kushtia (E9) and Rangpur (E6) (Fig. 1b). The closest association was observed between the environments Barishal (E1) and Sonagazi (E8); Bhanga (E2) and Rangpur (E6). The location Cumilla (E3) showed negative or no correlation with Bhanga (E2), Rajshahi (E5) and Rangpur (E6). The ideal environment was found Sonagazi (E8) for medium duration (Fig. 1a). Satkhira (E7) and Cumilla (E3) had the longest vector and hence was a highly discriminating location (Fig. 1a). The locations Barishal (E1), Sonagazi (E8) and Kushtia (E9) were highly representative of other locations. Considering the above two qualities together, Barishal (E1) and Kushtia (E9) were the ideal locations for testing genotypes for medium duration varieties with its appreciable discriminating ability and representativeness and position nearest to the circle point of Average Environment Axis (AEA).

In short duration GGE biplot showed three distinct clusters (Fig. 1c). Barishal (E1), Bhanga (E2), and Rajshahi (E5) considered one cluster and the second cluster contains Cumilla (E3), Satkhira (E7) and Sonagazi (E8) and the rest cluster contain one location Gazipur (E4). Rangpur (E6) showed the longest vector, making it more discriminating than other environments. Considering the criteria of ideal environment, Bhanga (E2) and Sonagazi (E8) showed a smaller angle with the AEA and hence was a highly representative environment (Fig. 1c) for 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. Fig. 2a-c shows average-environment coordination (AEC) views of the GGE biplot for grain yield of long, medium, and short duration. Table 3 shows the yield performances and summary of ideal genotypes and genotypes with stable and high mean yields in different categories (long, medium and short duration). BR10 (G4) recorded the highest average grain yield in long duration (Fig. 2a). BR11 (G5), BRRI dhan30 (G8), BRRI dhan44 (G14), BRRI dhan41 (G13) and BRRI dhan76 (G16) were the most stable genotypes with above-average yields. Thus, the BR10 (G4) and BR11 (G5) were the most ideal genotype with the highest mean yield and stability among the tested genotypes. The genotype BRRI dhan49 (G21) was the most stable genotype with above-average yield in medium duration (Fig. 2b). BRRI dhan54 (G24), BRRI dhan52 (G23), BRRI dhan79 (G27) recorded the above-average yields. Other stable genotypes with above-average yields were BRRI dhan52 (G23), BRRI dhan54 (G24) and BRRI dhan79 (G27). BRRI dhan87 (G40) recorded the highest average grain yield, most stable and ideal genotype in short duration (Fig. 2c). Also, BRRI dhan72 (G37), BRRI hybrid dhan6 (G42) and BRRI dhan71 (G36) were the most stable genotypes and above average yielder.

Identification of which-won-where and mega-environment

One of the most attractive features of a GGE biplot is its ability to show the which-won-where pattern of a genotype by environment dataset. This plot consists of a polygon with perpendicular lines, called equality lines, drawn onto its sides. These lines divide the polygon into various sectors. Genotypes located on the vertices of the polygon are the best performers in one or more environments falling within a particular sector.

The biplot showed three sectors containing all the test environments in long duration and accordingly three mega-environments were identified (Fig. 3a): One mega-environment had three locations Gazipur (E4), Rajshahi (E5) and Rangpur (E6); the second consisting of five locations- Barishal (E1), Bhanga (E2), Cumilla (E3), Sonagazi (E8) and Kushtia (E9. Hence, the winning genotype in those environment were BR11 (G5) and BR10 (G4) for first; BRRI dhan41 (G13) for another mega environment (Fig. 3a). BRRI dhan37 (G10), BR5 (G3), BRRI dhan34 (G9) and BRRI dhan38 (G11) 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), Cumilla (E3), Gazipur (E4) and Sonagazi (E8). The second had two locations those were Satkhira (E7) and Kushtia (9). The third contained the rest three locations Bhanga (E2), Rajshahi (E5) and Rangpur (E6). BRRI dhan52 (G23) was the winning genotype in the first mega-environment while BRRI dhan49 (G21) was the winner in the second and BRRI dhan32 (G20) was the winner in the last mega-environment. BRRI dhan70 (G25) and BRRI dhan31 (G19) 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 two locations- Barishal (E1) and Satkhira (E7) with BRRI hybrid dhan6 (G42) being the winning genotypes. The second mega-environment had five locations- Bhanga (E2), Cumilla (E3), Gazipur (E4), Rajshahi (E5) and Sonagazi (E8) and BRRI dhan87 (G40) was the winner in this mega-environment. The third mega-environment consisted of one location-Rangpur (E6) and BRRI dhan73 (G38) was the winning genotypes.

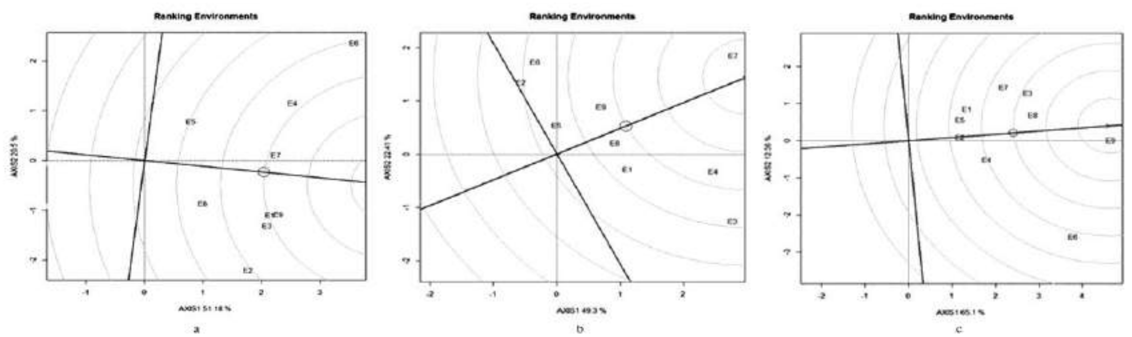


Fig. 1. Association among the test environments based on the average environmental coordinate (AEC), considering stability and adaptability of rice genotypes evaluated across different environments of Bangladesh for grain yield categorized by (a) Long duration, (b) Medium duration, and (c) Long duration in T. Aman 2018 growing seasons.

Table 3. Grain yield performance of BRRI released T. Aman rice varieties during T. Aman 2018.

Gen code	Genotype	Yield (t ha^{-1})	Gen code	Genotype	Yield (t ha^{-1})
		Long duration variety			
G4	BR10	4.87	G17	BRRI dhan77	4.14
G5	BR11	4.80	G1	BR3	4.11
G14	BRRI dhan44	4.58	G15	BRRI dhan46	3.99
G8	BRRI dhan30	4.56	G7	BR23	3.92
G13	BRRI dhan41	4.56	G11	BRRI dhan38	3.54
G16	BRRI dhan76	4.3	G3	BR5	3.35
G6	BR22	4.27	G9	BRRI dhan34	3.35
G2	BR4	4.24	G10	BRRI dhan37	3.13
G12	BRRI dhan40	4.18			
		Medium duration variety			
G24	BRRI dhan54	4.93	G22	BRRI dhan51	4.46
G21	BRRI dhan49	4.92	G18	BR25	4.41
G27	BRRI dhan79	4.85	G20	BRRI dhan32	4.37
G23	BRRI dhan52	4.80	G19	BRRI dhan31	4.00
G26	BRRI dhan78	4.68	G25	BRRI dhan70	3.69
G28	BRRI dhan80	4.56			
		Short duration variety			
G40	BRRI dhan87	5.31	G35	BRRI dhan66	4.64
G37	BRRI dhan72	5.14	G39	BRRI dhan75	4.51
G36	BRRI dhan71	5.01	G29	BRRI dhan33	4.31
G42	BRRI Hybrid dhan6	4.92	G32	BRRI dhan56	4.23
G38	BRRI dhan73	4.87	G41	BRRI Hybrid dhan4	4.03
G31	BRRI dhan53	4.73	G33	BRRI dhan57	3.21
G30	BRRI dhan39	4.69	G34	BRRI dhan62	3.01

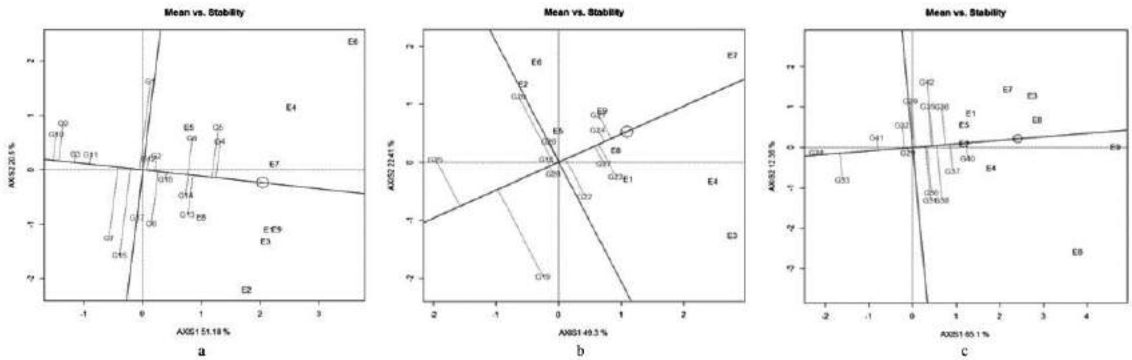


Fig. 2. GGE biplot of mean and stability of rice genotypes for yield and specific genotype × environment interactions of different category (a) Long duration, (b) Medium duration, and (c) Long duration in T. Aman 2018 growing seasons.

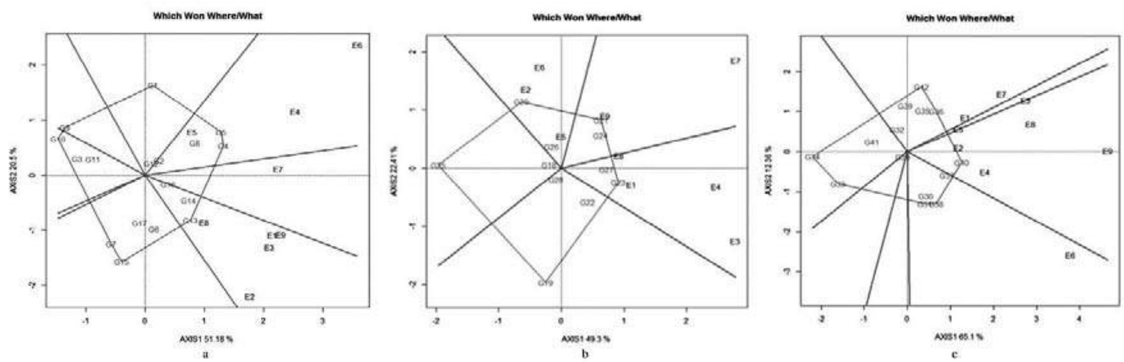


Fig. 3. GGE biplot identification of winning genotypes and their related mega-environments of different category (a) Long duration, (b) Medium duration, and (c) Short duration in T. Aman 2018 growing seasons.

REGION SPECIFIC BRRI VARIETY ADOPTION: A SIMPLE WAY OF INCREASING NATIONAL YIELD

Regional variations in agricultural development show that there is scope to boost up the pace of agricultural development and thereby that of economic development in the country with area specific agricultural development programmes and policies (Singh, 1990). There is functional relationship between agricultural productivity of the regions. This relationship should also be taken into consideration so that appropriate development measure can be taken (Anselin, 2003). Different regions or districts of Bangladesh have specialized in growing different crop (Faroque, *et al* 2011). It is widely known that yield of any crop is fully dependent on Genotype (G), Environment (E) and their interaction. Yield (Y) can be expressed as equation Y = G + E, if there is no interaction between G and E. So, the main objectives of the study are to find out the region specific potential, the highest, average and the lowest yielding varieties and to project the national production of rice in Bangladesh according to that selection.

District wise total area and production of the three different seasons are collected from yearbook of Agricultural Statistics 2016 which is published in May 2017 and divided at different specific regions (Table 4) according to the availability of the trial data. Replicated trial in RCB design with BRRI released 40, 38 and 9 varieties set up in 10, 9 and 7 regions (BRRI HQ and other BRRI RS, at different regions) for Boro, T. Aman and Aus seasons respectively. BRRI recommended management practices were followed to conduct the trials. After collecting, data were compiled, tabulated and analyzed according to the objectives of the study. The analysis was performed by MS excel, and the third generation programming language R.

Table 4. Season and region wise district distribution.

Season→ Region↓	Boro	Aman	Aus
Region 1 (Rangpur)	Kurigram, Lalmonirhat, Rangpur, Gaibandha, Panchagor, Thakurgaon, Nilphamari, Dinajpur	Kurigram, Lalmonirhat, Rangpur, Gaibandha, Panchagor, Thakurgaon, Nilphamari, Dinajpur	Kurigram, Lalmonirhat, Rangpur, Gaibandha, Panchagor, Thakurgaon, Nilphamari, Dinajpur
Region 2 (Rajshahi)	Rajshahi, Chapai, Natore, Noagaon, Sirajganj, Pabna, Joypurhat, Bogura	Rajshahi, Chapai, Natore, Noagaon, Sirajganj, Pabna, Joypurhat, Bogura	Rajshahi, Chapai, Natore, Noagaon, Sirajganj, Pabna, Joypurhat, Bogura
Region 3 (Barishal)	Barishal, Bhola, Jhalakathi, Patuakhali, Perojpur, Barguna	Barishal, Bhola, Jhalakathi, Patuakhali, Perojpur, Barguna	Barishal, Bhola, Jhalakathi, Patuakhali, Perojpur, Barguna,
Region 4 (Bhanga)	Rajbari, Magura, Faridpur, Gopalganj, Narail, Madaripur, Shariatpur	Rajbari, Magura, Faridpur, Gopalgonj, Narail, Madaripur, Shariatpur	Rajbari, Magura, Faridpur, Gopalganj, Narail, Madaripur, Shariatpur
Region 5 (Kushtia)	Kushtia, Meherpur, Chuadanga, Jhenaidah	(Kushtia), Meherpur, Chuadanga, Jhenaidah	Kushtia, Meherpur, Chuadanga, Jhenaidah
Region 6 (Satkhira)	Satkhira, Jashore, Khulna, Bagerhat	Satkhira, Jashore, Khulna, Bagerhat	Satkhira, Jashore, Khulna, Bagerhat
Region 7 (Sonagazi)	Feni, Noakhali, Laxmipur, Chat. 5 dist.	Feni, Noakhali, Laxmipur, Chat. 5 dist.	
Region 8 (Cumilla)	Cumilla, B Baria, Chandpur	(Cumilla), B Baria, Chandpur, Habiganj, Sylhet, Sunamgonj, Maulavibazar	Cumilla, B Baria, Chandpur, Feni, Noakhali, Laxmipur, Chat. 5 dist, Habiganj, Sylhet, Sunamganj, Maulavibazar
Region 9 (Habiganj)	Habiganj, Sylhet, Sunamganj, Maulavibazar		
Region 10 (Gazipur)	Gazipur, Dhaka, Manikganj, Munsiganj, Narayanganj, Narsingdi, Jamalpur, Sherpur, Kishoreganj, Mymenshingh, Netrakona, Tangail	Gazipur, Dhaka, Manikganj, Munsiganj, Narayanganj, Narsingdi, Jamalpur, Sherpur, Kishoreganj, Mymenshingh, Netrakona, Tangail	Gazipur, Dhaka, Manikgonj, Munsiganj, Narayanganj, Narsingdi, Jamalpur, Sherpur, Kishoreganj, Mymenshingh, Netrakona, Tangail

According to the divided region, BBS published area and production data of Aus, Aman and Boro seasons of different regions ware taken (Table 5).

Table 5. Area and production of Aus, Aman and Boro of different regions in Bangladesh.

Season→ Region↓	Boro		Aman		Aus	
	Area (ha)	Production (ton)	Area (ha)	Production (ton)	Area (ha)	Production (ton)
Region 1 (Rangpur)	765974	3118569	1036302	2783516	32353	79819
Region 2 (Rajshahi)	809725	3301627	829324	2233841	179399	448587
Region 3 (Barishal)	130189	485567	711607	1414940	226876	418346
Region 4 (Bhanga)	245777	1071566	269543	595852		
Region 5 (Kushtia)	173822	715969	231360	666884	77344	211715
Region 6 (Satkhira)	327814	1379025	381127	1005446	33266	84304
Region 7 (Sonagazi)	247589	934233	570099	1441365		
Region 8 (Cumilla)	368373	1408759	625588	1385590	341929	776773
Region 9 (Habiganj)	247406	834304				
Region 10 (Gazipur)	1159210	4764129	928302	2128620	50515	114069

Aus season. In Aus season nine different BRRI released Aus varieties were used in the trial at seven different locations. But the trial in Barishal totally damaged for that reason Aus 2016 data present for Barishal. Table 3 presents location wise potential variety with yield, highest yielded variety with yield, average yield of all the varieties and lowest yielded variety with yield. The highest potential yielding variety were found BRRI dhan48 (5.70 t ha^{-1}) at BRRI HQ and the lowest BRRI dhan65 (3.44 t ha^{-1}) in BRRI RS, Rajshahi. BRRI dhan48 shows the highest yielding variety in all the locations. In case of the lowest yielding variety BRRI dhan27 showed the minimum yield (1.30 t ha^{-1}) in BRRI RS, Rangpur.

From the ANOVA results of combined analysis it is clear that the locations (Different regions of Bangladesh) have significant yield difference though the same varieties and management practice were used. Also the varieties showed the significant difference according to yield performance. The DMRT result shows that the location BRRI HQ, Gazipur have significant yield difference compare to the other locations with average yield of 4.31 t ha^{-1} and some other location showed significant yield difference to each other.

Aman season. In Aman season 38 different BRRI released varieties were used in the trial at nine different locations of Bangladesh. We found the highest potential yielding variety BRRI dhan46 (6.99 t/ha) at BRRI RS, Sonagazi and lowest BRRI dhan54 (5.33 t/ha) in BRRI RS, Rajshahi. In case of the lowest yielding variety BRRI dhan57 showed the minimum yield (0.65 t/ha) in BRRI RS, Cumilla.

From the ANOVA results of combined analysis it is clear that the locations have significant yield difference though the same variety and management practice were used. Also the varieties show the significant difference according to yield performance. The DMRT result shows that the location BRRI RS, Sonagazi have significant yield difference compare to the other locations with average yield 5.39 t ha^{-1} and some other location shows significant yield difference to each other.

Boro season. In Boro season 40 different BRRI released varieties were used in the trial at ten different locations in Bangladesh. We found the highest potential yielding variety BRRI hybrid dhan5 (10.14 t ha^{-1}) at BRRI RS, Cumilla and lowest BR9 (6.21 t ha^{-1}) in BRRI RS, Barishal. All BRRI hybrid dhan in Boro season shows the best performance in most of the location. In case of the lowest yielded variety BR17 shows the minimum yield (2.41 t ha^{-1}) in BRRI RS, Barishal.

From the ANOVA results of combined analysis it is clear that the locations have significant yield difference though the same variety and management practice are used. Also the varieties showed significant difference according to the yield performance. The DMRT result shows that the location of BRRI R/S, Satkhira have significant yield difference compared to the other locations with average yield 6.55 t ha^{-1} and some other location shows significant yield difference to each other.

Total of Aus, Aman and Boro. According to the yield of the experimental data at different regions of Bangladesh the total production at different seasons are estimated. From this paddy production we convert it into clean rice production using the average milling outturn 71% (Annual Report of GQN Division, BRRI). For visual convenience, Figure 4 shows the comparison of experimental production and BBS collected production.

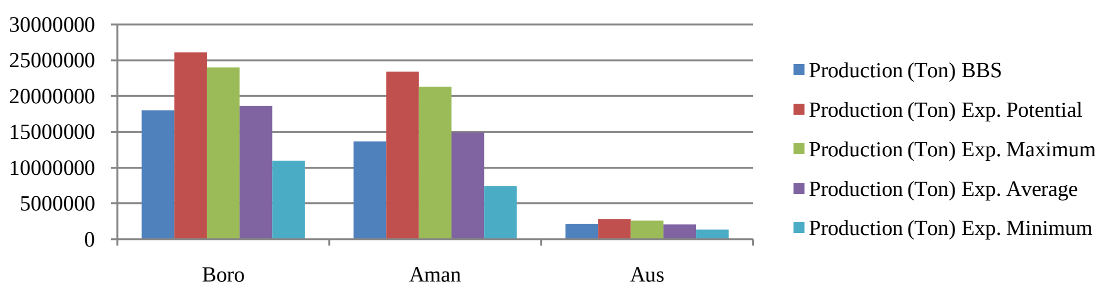


Fig. 4. Comparison of productions at different seasons in Bangladesh.

Table 6. Considering yield gap total clean rice production at different seasons in Bangladesh.

Season	Production (ton) BBS	Production (ton) exp. potential	Production (ton) exp. maximum	Production (ton) exp. average	Production (ton) exp. minimum
Aus	2133613	2257410	2070001	1648725	1082923
Aman	13656054	18789394	17106040	11978249	5967863
Boro	18013748	20944689	19258633	14944918	8803139
Total	33803415	41991494	38434674	28571893	15853926

Kabir *et al* (2015) showed that the yield gap between farmers field and the experimental field is 20.7%. To consider this yield gap the total production of clean rice convert by that yield gap percentage (Table 6). That means, if we adopt the potential high yielding variety at the respective season and region than the total clean rice production will be reached at 4,19,91,494 ton. In case of highest yielding variety it will reach at 3,84,34,674 ton. For average variety selection the estimated production will be 2,85,71,893 ton. But for wrong selection of variety (lowest yielding variety) production goes down to 1,58,53,926 ton (less than half of present production).

To increase national production of rice we adopt the potential yielded variety at the respected season and region with best crop management practice (BRRI recommended) than total clean rice production will increase 24.22% then present production. In case of the highest yielding variety it will increases 11.03% but for wrong selection of variety (lowest yielding variety) production will decrease more than 50%.

MAINTENANCE OF RICE DATABASE

Secondary data of rice and other important crops are collected periodically from Bangladesh Bureau of Statistics (BBS), Agricultural Marketing Directorate, Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB), Bangladesh Agricultural Development Corporation (BADC) and other sources periodically and recorded accordingly. Databases are being updated regularly and uploaded at BRRI website.

MINIMIZING AGRO MICRO CLIMATOLOGICAL RISK FACTORS FOR MAXIMIZING SUSTAINABLE RICE PRODUCTION IN BANGLADESH

Increased climatic variability is a huge constraint on farmer's ability to make tactical and strategic agricultural management decisions, which can substantially hinder rice production. Farmers in Bangladesh continue to face considerable climate risk and extreme events can reverse development gains made over many years. To ensure food security, the rice farmers need to reduce the risks from extreme weather events and address residual risks from climate variability. A single flood could set back all the agricultural development progress that is the result of improved crop productivity. For example, the 2017 flash flood in the north-western region of the country adversely affected the livelihood of 8 million people and overall food security of the country (FAO, 2017). Whereas, we have the ambition to improve the integration of agricultural development and climate responsiveness through climate-smart agriculture, a multi-pronged approach is required to address the full-scale climate variability and tackle the challenges arising from increasingly frequent weather and climate extremes. There is also high demand among the farming communities for such solutions. Considering this context, the objective of this study is to perform weather forecasts at five-day basis and validate forecast based rice crop management system through rice advisory generation in Aus season for sustainable rice production in Bangladesh. The five-day basis weather forecast and rice advisory were generated in Aus season (March to July 2019) for BRRI HQ and eight regional stations of BRRI. A team comprising of multidisciplinary researchers (agronomist, plant pathologist, entomologist, soil scientist, plant physiologist, irrigation specialist, agricultural statistician, and agricultural economist) were participated to generate location-specific weather forecast for six parameters, viz rainfall, relative humidity, wind speed, soil moisture, minimum and maximum temperature and prepared advisories at different growth stages of Aus rice based on weather forecasts. Weather forecasts and advisories were issued on a five-day basis. Weather research and forecasting (WRF) model for forecasting, which is a next-generation mesoscale numerical weather prediction system designed to serve both atmospheric research and operational forecasting needs will be used for the weekly weather forecast. WRF allows researchers to generate atmospheric simulations based on real data (observations, analyses) or idealized conditions. Tables 7 and 8 show the sample of a single location weather forecast and advisory.

Table 7. Weather forecast: Gazipur.

Forecast date	Total rain-fall (mm)	Min. tem. (°C)	Max. tem. (°C)	Min. RH (%)	Max. RH (%)	Min. wind speed (m/s)	Max. wind speed (m/s)
2019-05-21	4.79	28.71	36.79	44.53	78.84	1.06	3.14
2019-05-22	2.77	27.29	37.74	43.81	91.91	1.22	5.65
2019-05-23	15.90	28.04	38.61	42.20	86.31	2.19	7.04
2019-05-24	8.90	27.63	35.87	52.82	86.42	3.32	8.09
2019-05-25	5.69	28.20	36.94	54.19	85.62	2.87	6.44

Table 8. Weather forecast based rice advisories, Gazipur-21/05/2019.

Probable problems and measures of Aus crop season based on 5 days weather forecast at BRRI HQ and different RS.

Growth stage: Early tillering
Production management / Probable problems and tasks
Fertilizer management The second installment of fertilizer i.e. 1/3 of the urea at 12-15 days after transplanting should be applied in case of 4-5 tiller found in each hill.
Weed management Post-emergenc herbicides or hand weeding should be done to control weeds.
Irrigation There is no need for irrigation due to rain.
Insect management At this time, the mainland can be attacked by leaf folder, rice hispa, stem borer. In such cases, setting up of light traps (without rice hispa) on the side of the affected land, catching insects with hand nets, letting the stalk on the ground, destroying eggmases and larvae of stem borer. In the harmful phase of stem-borer attack, approved pesticides such as ***Diazinon*** or ***Carbofuran*** or ***Vir tako*** and leaf folder pest attacks ***Darsban*** should be used in doses at a moderate level.
Disease management Bacterial disease may be observed in the field. In that case, the affected cushion should be broken. Also, in the case of bacterial leaf blight (BLB) disease due to storm rains, an additional 1 kg potash fertilizer should be applied to the affected area. However, urea fertilizer cannot be applied immediately after the storm rains.

So, we can conclude that uptake of the weather forecast based rice crop management systems can contribute to the overall food security of the country and achieving sustainable development goals by increasing the agricultural productivity and incomes of small-scale food producers.

SUITABILITY (EDAPHIC) MAPPING OF BRRI DHAN80-86 AND BRRI HYBRID DHAN6

Our land is not homogenous all over Bangladesh. Various physical and chemical properties of soil varies spatially, on the other hand various rice varieties are suitable for some specific physical and chemical properties. As we need to increase production with limited land, so it will be very helpful if we have variety wise suitability map based on soil properties. BRRI dhan80 to BRRI dhan86 and BRRI hybrid dhan6 are very prospective varieties. So, these varieties suitability maps are very important. The objectives of the study were to construct edaphic suitability maps for newly released BRRI varieties and also find out variety wise suitable 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 moderat 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 GIS 10 Spatial Analyst Module. Step 2, 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.

Proactivity will increase if we cultivate rice varieties according to their suitable area.

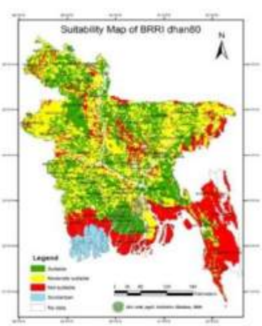


Fig. 5

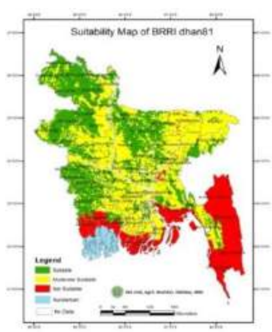


Fig. 6

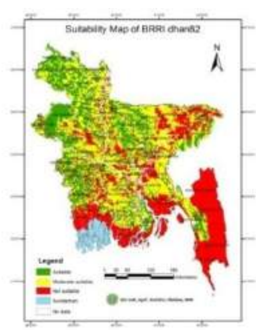


Fig. 7

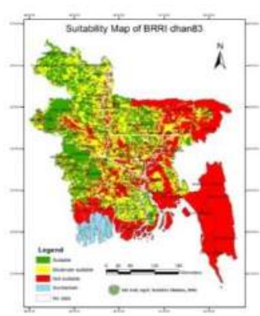


Fig. 8

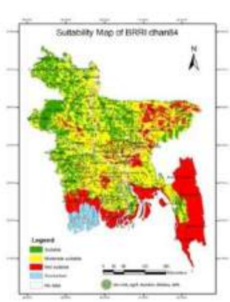


Fig. 9

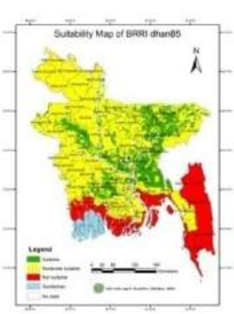


Fig. 10

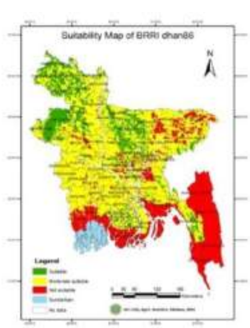


Fig. 11

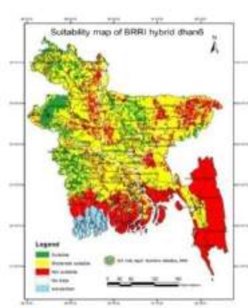


Fig. 12

BRRI dhan80 is a variety of T. Aman season. It is suitable in north-western, north central and south central sides of Bangladesh. Figure 5 shows the suitability map of BRRI dhan80. BRRI dhan81 is a variety of Boro season. Western side and north central side of Bangladesh are suitable for BRRI dhan81. Figure 6 showes the suitability map of BRRI dhan81. BRRI dhan82 is a variety of T. Aus season. North-western sides of Bangladesh are suitable for BRRI dhan82. Figure 7 shows the suitability map of BRRI dhan82. BRRI dhan83 is a variety of B. Aus season, western side of Bangladesh mainly Rajshahi, Naogaon, Kushtia, Magura are suitable for BRRI dhan83. Figure 8 shows the suitability map of BRRI dhan83. BRRI dhan84 is a rice varieties of Boro season rice. Western side of Bangladesh is suitable for BRRI dhan84 and Figure 9 shows the suitability map of BRRI dhan84. BRRI dhan85 is a variety of T. Aus season rice and north eastern and central eastern sides of Bangladesh are suitable for BRRI dhan85. Figure 10 showes the suitability map of BRRI dhan85. BRRI dhan86 is a variety of Boro season rice and north-western side of Bangladesh is suitable for BRRI dhan86. Figure 11 shows the suitability map of BRRI dhan86. BRRI hybrid dhan6 is variety of T. Aman season rice and western side of Bangladesh is suitable for BRRI hybrid dhan6. Figure 12 shows the suitability map of BRRI hybrid dhan6.

CLIMATIC 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 agriculture production. Thus, climatic factors mapping would be a great tool for climatic factors analysis and assist to increase crop production. Hence objectives of the study, to determine expected maximum and minimum temperature and rainfall in different region in Bangladesh are to determine areas of critical maximum and minimum temperature and rainfall map of Bangladesh and year wise comparison of various climatic factors maps and determine their change directions.

Data on daily maximum and minimum temperature and rainfall of 35 weather stations of BMD for the years 2016 and 2017 were used for the study. Year and station wise maximum value of maximum temperature and minimum value of minimum temperature and total rainfall were determined. Then by using Geo-statistical tools of Arc GIS10 software maps were prepared. In the maps scenario of climatic factors were described. In the maps scenario of climatic factors were described.

Maximum temperature was high in western side of Bangladesh but 2016 was warmer than 2017. Figures 13 and 14 show the maximum temperature maps of Bangladesh for 2016 and 2017. Both 2016 and 2017 minimum temperature was low in central western side of Bangladesh and minimum temperature was high in south eastern side of Bangladesh. Figures 15 and 16 show the minimum temperature maps of Bangladesh for 2016 and 2017. Total rainfall was the highest in eastern side of Bangladesh. In the year 2017 had more rainfall than 2016. Figures 17 and 18 show the total rainfall maps of Bangladesh for 2016 and 2017.

More or less in all seasons, eastern side of Bangladesh is markedly high rainfall and low temperature area and western side is marked as low rainfall and high temperature area. 2017 had more rainfall than 2016 thus 2016 was warmer than 2017.

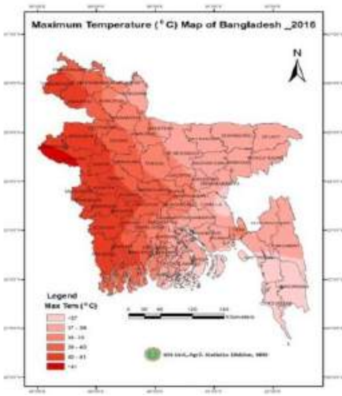


Fig. 13

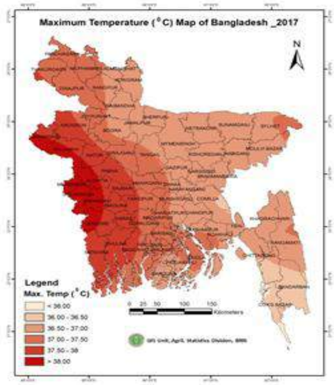


Fig. 14

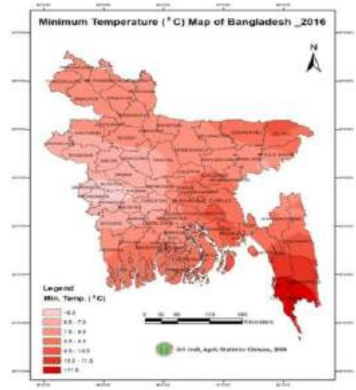


Fig. 15

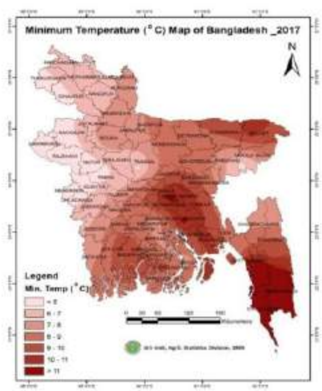


Fig. 16

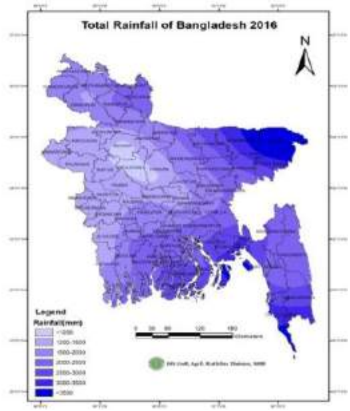


Fig. 17

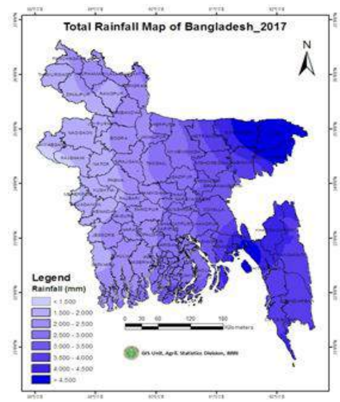


Fig. 18

RICE ZONING OF BRRI RICE VARIETIES

A major purpose of zoning is to put land to the use for which it is best suited. Some land is best left to be cultivated because of its unique soil characteristics. As every rice varieties have some unique characteristics, thus it has different suitable area for cultivation. So, variety wise rice zoning map is needed. BRRI dhan50, BRRI dhan71 and BRRI dhan72 are very prospective varieties. Objectives of the study are to find out suitable area of newly released BRRI rice varieties and to construct upazila wise zonal map of newly released BRRI rice varieties.

These varieties zoning maps are were done by using ArcGIS10 software and the whole process is mainly two steps. Step 1: Suitability mapping, step 2: Zonal mapping. For step 1: soil physical properties have been considered to determine suitable area (suitable, moderate/less suitable, not suitable) for growing particular rice varieties. Soil physical properties have been weighted by the relative influence for suitability assessment. These weights have been the values of per cent influence in the weighted overlay table of the Model Builder. Then final suitability map has been generated by using ArcGIS10 software. For step 2, upazila map has been superimposed on suitability map and suitable area (suitable, moderate/less suitable, not suitable) of each upazila has been calculated by map algebra tool, finally zonal map has been produced based on dominant suitability categories covered by area of each upazila.

Mainly north-east and some central part of northern areas are suitable for BRRI dhan50. Here total 464 upazilas were considered. Among them 80 upazilas were found under suitable zone, 254 were found under moderate suitable zone and 130 were found under not suitable zone. Figure 19 shows the zoning map of BRRI dhan50. North western areas of the country are suitable for BRRI dhan71 and also some areas in north central part of Bangladesh suitable for BRRI dhan71. Other part of Bangladesh are moderate suitable except southern and south-eastern sides are not suitable for BRRI dhan71. In this context 464 upazilas were considered, among them 82 upazilas were found under suitable zone, 355 upazilas were found under moderate suitable zone and 27 upazilas were found under not suitable zone. Figure 20 shows zoning map of BRRI dhan71. Western side of the country is suitable for BRRI dhan72 and some areas in north central part of Bangladesh are suitable for BRRI dhan72. In this context 464 upazilas were considered, among them 128 upazilas were found under suitable zone, 213 upazilas were found under moderate suitable zone and 118 were under not suitable zone. Figure 21 shows zoning map of BRRI dhan72.

In a nut shell, it can be said that the western side is suitable for cultivation of BRRI dhan72 and north-west side is suitable for cultivation of BRRI dhan71. North-east and some central part of northern areas are suitable for BRRI dhan50.

ICT ACTIVITIES

Rice Doctor Apps for BRRI

BRRI has developed 'Rice doctor', an application which is used for disseamination of information regarding BRRI released rice varieties, modern rice cultivation practices, insect and pest, disease and agricultural machinery and other dynamic diagnostic tools. It is an interactive tool for farmers, extension agents, scientists/researches, teachers, students and other users who want to learn and control insect pest and disease as well as other problems of rice cultivation and how to manage them.

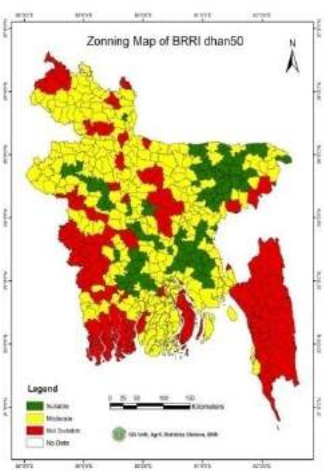


Fig. 19

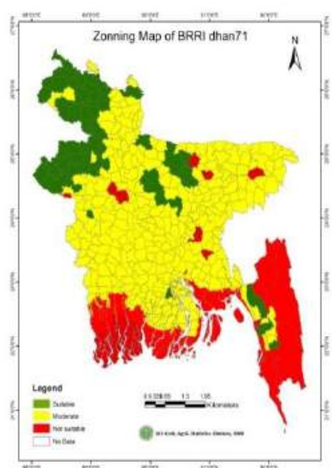


Fig. 20

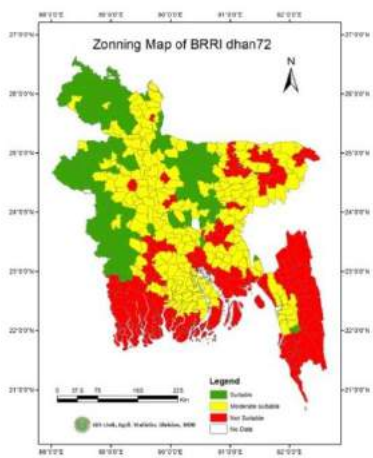


Fig. 21

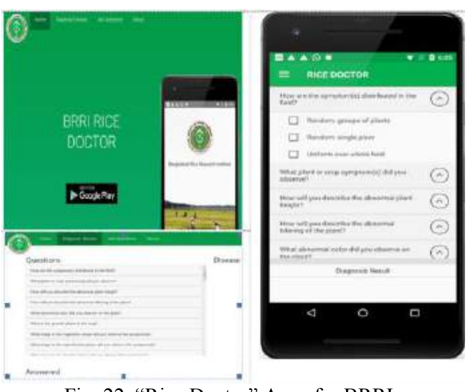


Fig. 22. "Rice Doctor" Apps for BRRI.

Online application system of BRRI

The online application system for recruitment is an ideal portal for the government. BRRI wants to manage their recruitment related activities through online. So BRRI introduced online system to decrease hassles of applicants for job application. It also reduces time of job applications processing for employer. Online application system has developed by Teletalk Bangladesh Ltd. with the help of ICT Cell, Agricultural Statistics Division and Administration of BRRI. The agreement between BRRI and Teletalk Bangladesh Limited completed on 8 March 2017 for Web and SMS based application. BRRI already started online application system from 23 May to 12 June 2019. Applicants completed their application through this system and also got admit card, written test date notification, result and all kinds of information through this online system and SMS based application.

e-File (Nothi) Management System of BRRI

The implementation of e-File (Nothi) system to ensuring 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. It is used by all the divisions, sections and regional stations of BRRI. It is active on 24/7/2017. e-File (Nothi) system is introduced at BRRI with help of Access to Information (A2i), Prime Minister's Office (PMO) since 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 hosted at Google Play Store. It is available at android-based smart phone. So anybody can free download it from Google Play Store. Besides, this mobile app can be shared from other smart phone by SHAREit software. RKB is being regularly updating with all varietal information. RKB has achieved in World Summit Award-2018 on government and citizen engagement category at Bangladesh computer council, ICT Division.

e-Tender System of BRRI

The e-Tender system software e-GP system is developed under Central Procurement Technical Unit (CPTU), IMED. BRRI introduced e-GP on 1 July 2016. BRRI has been incorporated as a first organization among the NARS institute and also a first organization under Ministry of Agriculture (MoA). BRRI has already submitted about 170 tenders into e-GP system and the submission process is being continued.

BRRI web portal management

BRRI web portal is developed, managed and updated by ICT Cell of Agricultural Statistics Division and information is being uploaded with permission of concerned authority. BRRI web portal are in Bangla and English languages. It is connected to the largest web portal (*www.portal.gov.bd*) in the country of the world and BRRI is incorporated with it as a first organization among the NARS institute.

Facebook Group (BRRI Networks) of BRRI

Facebook Groups contain page where you create within the Facebook social networking site that are based around a real-life interest or group or to declare an affiliation or association with people and things. The Facebook group BRRI *Networks* can be accessed through (*https://www.facebook.com/groups/1409267722690061/*). It is also linked with the Public Service Innovation (PSI) group maintained by Access to information (A2i) program and Krishi Bhabna group maintained by Ministry of Agriculture (MoA). Thus, the *BRRI Networks* is continuing with regular updating by the users of this group. At present it has 332 users. It is increasing gradually.

Management of BRRI local area network and internet connectivity

ICT network and internet connectivity of BRRI is managed and maintained by ICT Cell, Agricultural Statistics Division with the help of the Network developer company. We have increased our digital data network (DDN) bandwidth connectivity from 51 Mbps To 60 Mbps. It established new and high configured router where internet speed capacity increased to 1000 Mbps; the internet speed capacity was 25 Mbps previous device. We also established local area network (LAN) connectivity at five regional stations i.e. Rangpur, Barishal, Sonagazi, Cumilla and Habiganj.

BRKB website management

Bangladesh Rice Knowledge Bank (BRKB) is a hub 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 is being updated regularly with latest information of Aman, Aus and Boro rice varieties with the help of Training Division and concerned divisions.

Personal data sheet database

We have created PDS database for all scientists, officers, clerks as per requirement of the Ministry of Agriculture (MoA). It has been increased up to 339 users into BRRI PDS database. PDS database is updated regularly with latest information. It is a routine work.

Web mail and group mail

BRRI web mail server sends, receives and stores e-mail for all users. Almost every internet service provider (ISP) includes at least one mailbox on their mail server as part of their basic service. When a client connects to a server, both the computers must be communicated by the same protocol. The most widely protocol is POP3 (Post Office Protocol version 3). It is almost always used in conjunction with SMTP (Simple Mail Transfer Protocol). POP3 is used to retrieve mail from the server (incoming) while SMTP is used to send mail through the server (outgoing). We have created individual e-mail account into BRRI domain for all scientists and all class one officers as per requirement of MoA. BRRI Web mail and Group mail have been hosted into BCC (Bangladesh Computer Council) server.

Video conference system

Video conferencing system is a two-way communication with live video and audio system so it is needed brands of videophones, webcams, headphones (it can be done with bluetooth headphone also) and video conferencing hardware systems.

We have established video conferencing system (VCS) at BRRI to communicate with MoA and others government organization. Also, established Distance Communication Center (DCC) at BRRI with the help of Bangladesh Research and Education Network (BDREN) funded by University Grant Commission (UGC), which is similar to VCS. Besides, we have created Skype account for all divisional head and regional stations head. The communications between BRRI headquarter and other's regional station has been conducted by Video Conference System in every monthly co-ordination meeting.

SUPPORT SERVICES

Innovation team activities

Innovation can be defined simply as a 'new idea, device or method'. However, innovation is often also viewed as the application of better solutions that meet new requirements, unarticulated needs, or existing market needs. In the organizational context, innovation may be linked to positive changes in efficiency, productivity, quality, competitiveness, and market share. In these circumstances, BRRI formed an Innovation team and reformed this team on 11 October 2017 under the Innovation Team Gazette 2013. BRRI has implemented all innovation under Innovation Action Plan Guideline 2015 and several annual innovation work plan of BRRI.

This division organized Five day-long, Two day-long, day-long 'Public Service Innovation' workshops and Two day-long 'e-learning workshop' by Access to Information (A2i), Ministry of ICT (MoICT) and Cabinet Division. During the reporting year, Participated showcasing program at Bangladesh agricultural research council (BARC) arranged by A2i and Ministry of Agriculture (MoA) and displaying own innovation activities. We have been organizing monthly innovation team meeting regularly and review performance in monthly coordination meeting properly by innovation team of BRRI.

ICT and related fair

ICT Cell of Agricultural Statistics Division has been participated several ICT and related fair such as Digital World Fair, Development Fair, Tatha Mela and World Food Fair etc.

Other Services

The scientists of this division are also engaged in helping scientists of other disciplines in planning experiments, statistical data analysis and interpretation of results. Sixty-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.

Overall, ICT cell of Agricultural Statistics Division has taken initiative in accordance with government perspectives but BRRI Networks group is first introduced among all National Agricultural Research System (NARS) and also first among all research institutes. The ICT cell of Agricultural Statistics Division provides e-Filing management system and and e-Tender related support services to other divisions, and sections. We provide hardware, network and internet related support services to other divisions.

Farm Management Division

SUMMARY

An experiment was conducted at the West Byde of BRRI HQ farm, Gazipur during T. Aman 2018 and Boro 2018-19 seasons to find out the optimum spacing and seedling number per hill of different short duration rice varieties. In T. Aman season, BRRI dhan71, BRRI dhan75 and BINA dhan17 produced statistically identical yield (5.80 to 5.96 t ha^{-1}). The spacing (20 cm × 15 cm) gave the highest grain yield (6.05 t ha^{-1}). Yield (5.93 and 5.87 t ha^{-1}) obtained from plants grown as one and three seedlings per hill were statistically similar. In Boro season, BRRI dhan84 produced the highest grain yield (6.87 t ha^{-1}) followed by BRRI dhan86 and the lowest in BRRI dhan28 (6.16 tha^{-1}). Among the spacings 25 cm × 15 cm gave the highest grain yield (6.73 t ha^{-1}). Plants grown as one seedling per hill produced higher grain yield (6.58 t ha^{-1}) which was statistically identical with the yield of three seedlings per hill (6.47 t ha^{-1}).

Another experiment was initiated on a permanent layout at BRRI HQ farm, Gazipur since T. Aman 2016. In T. Aman 2017 to Boro 2018-19 the experiment was conducted in two approaches. In Approach-1 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 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). Grain yield, tiller number, panicle number, plant height and straw yield were significantly affected by the different organic matters in both the approaches during T. Aman and Boro season. Poultry litter related treatments and BRRI recommended dose performed better in all the parameter 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 488-540. The wage rate day^{-1} during the peak periods of the year Tk 500 to 550 in May, Tk 500 to 550 in July-August and Tk 500 to 560 in December to January were existed. The wage rate varied between Tk 400-425, 350-450, 450-500, 400-450, 450-500, 350-450 and 450-500 at Habiganj, Rangpur, Rajshahi, Barishal, Sonagazi, Cumilla, Satkhira and Khulna respectively.

This division produced about 19,250 kg rice of which 14,189 kg seed and 5,061 kg mixed rice. This division has grown 12,419 kg breeder seed in collaboration with the GRS division.

BRRI has 742 labours of which 551 regular, 191 irregular. In HQ BRRI, the number of total labour was 464 of which 316 regular and 148 irregular. The institute has 286.33 ha of land of which 172.64 ha was cultivable. Total labour utilization in different divisions was 1,83,761 man days of which 52.30 %, 42.31% and 5.39% were utilized for research, support service and holidays respectively. It was observed that total labour wages was Tk 9,38,52,850/- of which Tk 4,68,98,300/- and Tk 4,20,01,550/- and Tk 49,53,000/- were paid to the labours for research work, support service works, leaves and holidays respectively. A total of 81.56 ha of land were utilized by different divisions in different season of which 7.94 ha in Aus, 35.17 ha in Aman and 38.44 ha in Boro season. This division manages the BRRI flower garden to maintain the aesthetic view of the campus. It has grown visible flower garden during summer and winter season.

RESEARCH ACTIVITIES

Effect of spacing and seedling number per hill on the yield and yield components of different short duration rice varieties in T. Aman and Boro seasons

This experiment was conducted at the West Byde of BRRI farm, Gazipur during T. Aman 2018 and Boro 2018-19 seasons to find out the optimum spacing and seedling number per hill 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), four spacings (S1= 15 cm × 15 cm, S2= 20 cm × 15 cm, S3= 25 cm × 15 cm and S4= 20 cm × 20 cm) and two seedling number (1 seedling per hill and three seedlings per hill). In Boro season the treatments were three rice varieties (V1= BRRI dhan84, V2= BRRI dhan86 and V3=BRRI dhan28), three spacings (S1= 20 cm × 15 cm, S2= 25 cm × 15 cm and S3= 20 cm × 20 cm) and two seedling number (1 seedling per hill and three seedlings per hill). In each season, the treatments were arranged in a split-split plot design as variety in the main plots, spacing in sub plots and seedling number per hill in the sub-sub plot. Each treatment was replicated three times. Fertilizers were applied as per BRRI recommended dose. Twenty-five-and-30-day old seedling as per treatment were transplanted in T. Aman and Boro seasons respectively. All other intercultural operations were done as and when necessary. Yield and yield components data were taken at maturity. The collected data were analyzed using Crop Stat 7.2 Software programme.

Experiment of T. Aman 2018

The interaction between variety, spacing and seedling number per hill 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

Except straw yield, none of the parameters was significantly affected by variety (Table 1). The BINA dhan17 produced the highest grain yield (5.96 tha^{-1}) followed by BRRI dhan75 (5.94 tha^{-1}) and lowest BRRI dhan71 (5.80 tha^{-1}). The highest straw yield was observed in BRRI dhan71 and lowest in BINA dhan17.

Effect of spacing

The 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 of spacing (Table 1). The (20 cm × 20 cm) gave the highest number filled grain per panicle, which was gradually decreased with decreasing spacing i.e. increasing planting density and found the lowest in (15 cm × 15 cm) spacing. The 1000-grain weight (TGW) was not significantly affected by spacing. The highest grain yield (6.05 t ha^{-1}) was observed in closer (20 cm × 15 cm) spacing which was statistically identical with the yield (6.02 t ha^{-1}) of (15 cm × 15 cm) and (5.98 t ha^{-1}) of (25 cm × 15 cm) spacing. The grain yield gradually decreased with increased spacing. It was the lowest (5.56 t ha^{-1}) in widest (20 cm × 20 cm) spacing.

Effect of seedling number per hill

None of the parameters were significantly affected by seedling number per hill (Table 1). Plants grown as one seedling per hill produced higher grain yield (5.93 t ha^{-1}) followed by three seedlings per hill (5.87 t ha^{-1}).

It may be concluded that in T. Aman season, BRRI dhan71, BRRI dhan75 and BINA dhan17 produced statistically identical yield (5.80 to 5.96 t ha^{-1}). The (20 cm × 15 cm) spacing gave the highest (6.05 t ha^{-1}) grain yield in T. Aman season for short duration (113 to 115 days) rice varieties. Yield (5.93 and 5.87 t ha^{-1}) obtained from one and three seedlings per hill were statistically similar.

Experiment of Boro 2018-19

The interaction between variety, spacing and seedling number per hill was insignificant in all the parameters of yield and yield components (Table 2). Therefore, only the main effect has been described and discussed below.

Effect of variety

BRRI dhan28 produced the highest number of tiller m^{-2} followed by BRRI dhan84 and the lowest in BRRI dhan86 but no significant difference between BRRI dhan84 and BRRI dhan86 (Table 2). The same trend also observed in panicle m^{-2}. The highest number of filled grain panicle^{-1} was found in BRRI dhan84 followed by BRRI dhan86 and the lowest in BRRI dhan28 but different variety had no significant effect on percentage of unfilled grain. The highest TGW was found in BRRI dhan84 followed by BRRI dhan86 and the lowest in BRRI dhan28. BRRI dhan84 produced the highest grain yield (6.87 tha^{-1}) followed by BRRI dhan86 but no significant difference between BRRI dhan84 and BRRI dhan86. The lowest grain yield (6.16 tha^{-1}) was recorded in BRRI dhan28, which was statistically similar to the yield of BRRI dhan86.

Effect of spacing

The highest number of tiller and panicle was found in closest spacing of 20 cm × 15 cm, which was statistically identical to 25 cm × 15 cm spacing and the lowest in 20 cm × 20 cm spaacing (Table 2). The tiller and panicle number decreased with the

Table 1. Effect of variety, spacing and seedling number on yield and yield components of short duration rice cultivars in T. Aman 2018.

	Tiller no. m^{-2}	Panicle no. m^{-2}	Filled grain no. $panicle^{-1}$	Unfilled grain (%)	TGW (gm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
			Effect of variety				
BRRI dhan71	268	262	112	22.14	23.04	5.80	7.19
BRRI dhan75	274	268	113	19.23	21.57	5.94	6.77
BINA dhan17	275	269	114	20.27	22.56	5.96	6.78
Lsd at 5%	ns	ns	ns	ns	ns	ns	0.27
			Effect of spacing				
15cmx15cm (44 hills m^{-2})	283	277	110	22.56	22.36	6.02	7.15
20cmx15cm (33hills m^{-2})	282	275	112	20.41	22.29	6.05	6.93
25cmx15cm (27 hills m^{-2})	267	262	114	20.32	22.53	5.98	6.87
20cmx20cm (25 hills m^{-2})	257	253	115	19.14	22.40	5.56	6.65
Lsd at 5%	13.03	12.78	2.92	ns	ns	0.28	0.31
			Effect of seedling number per hill				
1 Seedling	274	268	114	21.46	22.36	5.93	6.86
3 Seedlings	270	264	111	20.27	22.43	5.87	6.93
Lsd at 5%	ns	ns	2.06	ns	ns	ns	ns

increased spacing. The number of filled grain $panicle^{-1}$ was the highest in (25 cm × 15 cm) spacing but no significant difference with (20 cm × 20 cm) spacing. The lowest number of filled grain $panicle^{-1}$ was observed in closest spacing (20 cm × 15 cm). The highest TGW was observed in 25 cm × 15 cm spacing, which was insignificant to 20 cm × 20 cm spacing. In Boro season, the plants grown in 25 cm × 15 cm spacing produced the highest grain yield (6.73 t ha^{-1}), which was statistically identical with the yield of 20 cm × 20 cm spacing. Grain yield obtained from closest spacing (20 cm × 15 cm) decreased significanly.

Effect of seedling number per hill. None of the parameters were significantly affected by seedling number per hill (Table 2). Plants grown as one seedling per hill produced higher grain yield (6.58 t ha^{-1}), which was statistically identical with the yield of three seedlings per hill (6.47 t ha^{-1}).

It may be concluded that in Boro season, BRRI dhan84 produced the highest grain yield (6.87 t ha^{-1}) followed by BRRI dhan86 and the lowest in BRRI dhan28 (6.16 t ha^{-1}). Among the spacing the 25 cm × 15 cm gave the highest grain yield (6.73 t ha^{-1}). Comparing seedling number per hill, plants grown as one seedling per hill produced higher grain yield (6.58 t ha^{-1}), which was statistically identical with the yield of three seedlings per hill (6.47 tha^{-1}).

PI: Dr K P Halder **CI:** Setara Begum and Md Mamunur Rashid

Effect of organic matter on soil properties and yield of rice

This experiment was initiated on a permanent layout at BRRI HQ farm, Gazipur since T. Aman 2016. In T. Aman 2017 to Boro 2018-19 the experiment was conducted in two approaches. Five treatments in randomized complete block design (RCBD) 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, treatment combinations were- i) BRRI recommended fertilizer dose, ii) Kitchen waste (3 t ha^{-1}) + ½ BRRI recommended dose, iii) Cowdung bio-slurry (3 t ha^{-1}) + ½ BRRI recommended dose, iv) Poultry litter (3 t ha^{-1}) + ½ BRRI recommended dose and v) control (no nutrient supply). 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. Collected data were 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 the approaches during T. Aman and Boro seasons. Poultry litter related treatments and BRRI recommended dose performed better. On the other hand control plot (no nutrient supply) gave the lowest result. The details have been discussed below.

Table 2. Effect of variety, spacing and seedling number on yield and yield components of short duration rice cultivars in Boro 2018-19.

	Tiller no. m^{-2}	Panicle no. m^{-2}	Filled grain no. $panicle^{-1}$	Unfilled grain (%)	TGW (gm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Effect of variety							
BRRI dhan84	250	244	141	22.82	22.47	6.87	7.64
BRRI dhan86	245	239	137	23.28	22.17	6.55	6.62
BRRI dhan28	272	252	133	22.11	21.51	6.16	7.23
Lsd at 5%	16.71	10.40	5.61	ns	0.62	0.44	0.58
Effect of spacing							
20cmx15cm (33hills m^{-2})	264	250	134	25.01	21.17	6.29	6.92
25cmx15cm (27 hills m^{-2})	256	243	140	20.71	22.23	6.73	7.18
20cmx20cm (25 hills m^{-2})	247	241	138	22.50	22.18	6.57	7.38
Lsd at 5%	16.71	10.40	5.61	ns	0.62	0.44	0.58
Effect of seedling number per hill							
1 Seedling	257	246	138	23.01	22.03	6.58	7.21
3 Seedlings	254	244	137	22.47	22.06	6.47	7.11
Lsd at 5%	ns	ns	ns	1.02	ns	ns	ns

Yield and yield components for approach-1

Plant height. The tallest rice plant (102.11 cm) was found in BRRI recommended fertilizer management, which was statistically similar with 100.05 cm in poultry litter used plot, followed by Kitchen waste (92.89 cm) and bio-slurry (90.83 cm) used plot. The shortest rice plant (89.61 cm) was found in control plot. In Boro season, similar trend was observed like T. Aman. Here also the tallest plant (100.6 cm) was found in the plot where BRRI recommended fertilizer was used and the shortest plant was found in control plot (78.38 cm) (Table 3).

Tiller number. BRRI recommended dose and poultry litter used plot produced statistically similar tiller number. BRRI recommended fertilizer produced the highest number of tiller m^{-2} (246) followed by kitchen waste (186) and bio-slurry (185) used plot whereas control plot produced the lowest number of tiller m^{-2} (175) among all the treatments. Similar results had been observed in Boro season. Poultry litter produced the highest number of tiller m^{-2} (286) whereas control plot gave the lowest number of tiller m^{-2} (185) (Table 3).

Panicle number. The highest number of panicle m^{-2} was (237) found in BRRI recommended dose, which is statistically similar with poultry litter used plot, followed by kitchen waste (176) and bio-slurry (171) used plot. The lowest number of panicle m^{-2} (161) among all the treatments was observed in control plot. On the other hand during Boro season, among all the treatments, poultry litter used plot gave the highest panicle m^{-2} (255) and control plot gave the lowest panicle m^{-2} (161) (Table 3).

Grain number and grain weight. During T. Aman season BRRI recommended dose, poultry litter, kitchen waste and bio-slurry used plot produced almost similar number of grain per panicle which was statistically significant from control plot whereas control plot gave the lowest number of grain/panicle. There was no significant difference among the treatments in case of grain weight. Similar trend was found in both the cases of grain number and grain weight during boro season like T. Aman (Table 3).

Grain yield. During T. Aman 2018 and Boro 2018-19 seasons, grain yield was significantly affected by different nutrient management practices. In T. Aman, BRRI recommended fertilizer management produced the highest grain yield (5.09 t ha^{-1}), which was statistically similar with poultry litter used plot (4.87 t ha^{-1}) followed by kitchen waste (4.33 t ha^{-1}) and bio-slurry (4.07 t ha^{-1}). The lowest yield was observed in control plot (3.05 t ha^{-1}). In Boro, BRRI recommended fertilizer produced highest grain yield (6.02 t ha^{-1}) which was statistically similar with poultry litter used plot (5.78 t ha^{-1}) followed by kitchen waste (3.88 t ha^{-1}) and bio-slurry (3.64 t ha^{-1}) used plot. And the lowest grain yield (2.4 t ha^{-1}) was also observed in control plot (Table 3).

Straw yield. In T. Aman, BRRI recommended dose produced the highest straw yield 5.16 t ha^{-1} which was statistically similar with poultry litter used plot 4.90 t ha^{-1} followed by 4.06 and 3.83 t ha^{-1} in kitchen waste and bio-slurry used plot respectively. The lowest straw yield 3.47 t ha^{-1} was observed in control plot. In Boro 2018-19 seasons, similar trend was found like T. Aman. The highest straw yield was found in BRRI recommended dose (6.24 t ha^{-1}) and lowest was from control pot (2.76 t ha^{-1}) among the all treatments (Table 3).

Table 3. Yield and agronomic parameter of different nutrient management practices during T. Aman 2018 and Boro 2018-19.

Treatment	Plant height (cm)	Tiller m^{-2} (no.)	Panicle m^{-2} (no.)	Grain panicle^{-1} (no.)	TGW wt. (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Aman 2018							
Control	89.61	175	161	132	19.43	3.05	3.47
BRRI dose	102.11	246	237	151	20.11	5.09	5.16
Kitchen waste (6 t ha^{-1})	92.89	186	176	147	19.39	4.33	4.06
Bio-slurry (cow-dung) (6 t ha^{-1})	90.83	185	171	145	19.71	4.07	3.83
Poultry litter (6 t ha^{-1})	100.05	230	225	143	19.47	4.87	4.90
LSD at 5% level	2.93	16.45	14.06	8.02	0.89	0.34	0.41
CV %	1.89	5.77	6.35	6.55	2.56	4.24	5.32
Boro 2018-19							
Control	78.38	185	161	95	21.82	2.40	2.76
BRRI dose	100.6	266	251	122	22.50	6.02	6.24
Kitchen waste (6 t ha^{-1})	82.61	218	192	117	22.26	3.88	3.44
Bio-slurry (cow-dung) (6 t ha^{-1})	83.39	229	195	115	21.88	3.64	3.38
Poultry litter (6 t ha^{-1})	98.89	286	255	123	22.30	5.78	5.88
LSD at 5% level	2.93	22.42	23.06	8.28	0.85	0.41	0.44
CV %	1.89	5.77	6.35	7.95	3.51	5.24	5.52

Yield and yield components for approach-2

Plant height. In T. Aman, the tallest rice plant was found in the BRRI recommended fertilizer management (100.25 cm) which is statistically similar to poultry litter used plot (99.81 cm), followed by kitchen waste (93.67 cm) and bio-slurry (92.94 cm) used plot respectively. The smallest rice plant (85.77 cm) was found in the control plot. In Boro season, poultry litter (97.35 cm) and BRRI fertilizer management plot (96.83 cm) gave statistically similar tallest plant followed by others and the shortest plant (74.27 cm) was found in control plot (Table 4).

Tiller number. In T. Aman, BRRI recommended dose (250 tiller m^{-2}) and poultry litter (236 tiller m^{-2}) produced the highest and statistically similar number of tiller whereas control plot gave the lowest number of tiller (184 tiller m^{-2}) among all the treatments. Similar trend was observed in Boro season, poultry litter (276 tiller m^{-2}) and BRRI dose (270 tiller m^{-2}) gave the highest and statistically similar number of tiller whereas control plot (206 tiller m^{-2}) gave the lowest (Table 4).

Panicle number. BRRI recommended fertilizer dose (237 panicle m^{-2}) and poultry litter (226 panicle m^{-2}) used plot produced statistically similar and highest panicle followed by kitchen waste (208 panicle m^{-2}) and bio-slurry (201 panicle m^{-2}) used plot in T. Aman. The lowest number of panicle m^{-2} (177) among all the treatments was observed in control plot. On the other hand, in Boro season similar result like T. Aman was observed. Among all the treatments poultry litter (260 panicle m^{-2}) and BRRI recommended dose (256 panicle m^{-2}) used plot gave the highest panicle and control plot (184 panicle m^{-2}) gave the lowest (Table 4).

Grain number and grain weight. BRRI recommended fertilizer produced the highest number of grain per panicle (119) whereas control plot gave the lowest number of grain panicle^{-1} (99) in T. Aman. And there were no significant difference among the treatments in case of grain weight. In Boro, similar trend of grain per panicle was observed. Here BRRI fertilizer management produced the highest grain per panicle (141) and control plot produced the lowest number of grain panicle^{-1} (94). No significant difference was found in grain weight among the treatments (Table 4).

Grain yield. In T. Aman 2018 and Boro 18-19 seasons, grain yield was significantly affected by different nutrient management practices. BRRI recommended fertilizer management produced the highest grain yield (4.90 t ha^{-1}), which was statistically similar to poultry litter used plot (4.86 t ha^{-1}) followed by kitchen waste (4.20 t ha^{-1}) and bio-slurry (4.13 t ha^{-1}). The lowest yield was observed in control plot (3.11 t ha^{-1}). In Boro, poultry litter used plot (6.10 t ha^{-1}) and BRRI recommended fertilizer management (5.95 t ha^{-1}) again produced higher and statistically similar grain yield followed by bio-slurry (5.33 t ha^{-1}) and kitchen waste (5.20 t ha^{-1}) used plot. The lowest grain yield (2.53 t ha^{-1}) was also observed in control plot (Table 4).

Table 4. Yield and agronomic parameter of different nutrient management practices during T. Aman 2018 and Boro 2018-19.

Treatments	Plant height (cm)	Tiller m^{-2} (no.)	Panicle m^{-2} (no.)	Grain $panicle^{-1}$ (no.)	TGW wt. (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
			Aman 2018				
Control	85.77	184	177	99	20.92	3.11	3.53
BRRI dose	100.25	250	237	119	21.32	4.90	5.12
Kitchen waste (3 t ha^{-1}) + ½ BRRI dose	93.67	217	208	108	21.25	4.20	4.43
Bio-slurry (3 t ha^{-1}) + ½ BRRI dose	92.94	216	201	115	21.12	4.13	4.33
Poultry litter (3 t ha^{-1}) + ½ BRRI dose	99.81	236	226	114	21.24	4.86	4.98
LSD at 5% level	1.68	18.55	17.71	6.48	0.78	0.35	0.43
CV %	1.25	4.18	4.28	5.22	3.62	4.32	4.62
			Boro 2018-19				
Control	74.27	206	184	94	21.89	2.53	2.68
BRRI dose	96.83	270	256	141	22.39	5.95	5.83
Kitchen waste (3 t ha^{-1}) + ½ BRRI dose	90.50	253	223	113	22.11	5.20	5.11
Bio-slurry (3 t ha^{-1}) + ½ BRRI dose	91.61	245	218	107	22.60	5.33	5.27
Poultry litter (3 t ha^{-1}) + ½ BRRI dose	97.35	276	260	135	22.17	6.10	6.20
LSD at 5% level	1.41	14.11	17.77	7.43	0.76	0.41	0.51
CV %	2.35	7.21	6.48	6.42	2.89	5.05	8.76

Straw yield. BRRI recommended dose (5.12 t ha^{-1}) and poultry litter (4.98 t ha^{-1}) produced the highest and statistically similar straw yield followed by kitchen waste (4.43 t ha^{-1}) and bio-slurry (4.33 t ha^{-1}) used plot respectively in T. Aman. The lowest straw yield 3.53 t ha^{-1} was observed in control plot. In Boro, poultry litter management plot produced the highest straw yield of 6.20 t ha^{-1} which was statistically similar to BRRI recommended dose (5.83 t ha^{-1}) followed by bio-slurry and kitchen waste used plot. Control plot gave the lowest (2.68 t ha^{-1}) straw yield among the treatments (Table 4).

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 seasons. Every parameter, poultry litter related treatments and BRRI recommended dose performed the best. This study indicates poultry litter 6 t ha^{-1} or poultry litter 3 t ha^{-1} + 50% BRRI dose fertilizer is sufficient for rice cultivation and it also indicates combined nutrient management is needed for higher rice yield. Further research may be required to find out the suitable amount of organic matter or combined fertilizer management.

PI: Md Mamunur Rashid **CI:** Md Nayeem Ahmed and K P Halder

Monitoring labour wage rate at different locations of Bangladesh

Survey and monitoring of laborers' 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 488-540. The wage rate day^{-1} during the peak periods of the year Tk 500 to 550 in May, Tk 500 to 550 in July-August and Tk 500 to 560 in December-January were existed. The wage rate varied between Tk 400-425, 350-450, 450-500, 400-450, 450-500, 350-450 and 450-500 at Habiganj, Rangpur, Rajshahi, Barishal, Sonagazi, Cumilla, Satkhira and Khulna respectively.

PI: K P Halder **CI:** M M Rashid, M S Islam, M R Manir and S Begum

Rice seed production

In different seasons, this division produced 19,250 Kg rice of which 14,189 Kg seed and 5,061 Kg mixed rice. All the rice has been stored in the BRRI general store. As a part of the breeder seed programme of GRS division, this division produced 12,419 Kg breeder seed. These seeds were deposited to GRS division.

PI: Md Mamunur Rashid

CI: Setara Begum and K P Halder

Management of land and labour. Including regional stations, BRRI has 742 labours of which 551 regular and 191 irregular (Table 5). In BRRI HQ, total labor number is 464 of which 316 regular and 148 irregular labours. BRRI has 286.33 ha of land of which 172.64 ha is cultivable. Total labour utilization in different divisions was 1,83,761 man days of which 52.30%, 42.31 % and 5.39% were utilized for research, support service and holidays respectively. It was observed that total labour wages was Tk 9,38,52,850/- of which Tk 4,68,98,300/- and Tk 4,20,01,550/- and Tk 49,53,000/- were paid to the labours for research work, support service works, leaves and holidays respectively. A total of 81.56 ha of land were utilized by different divisions in different seasons of which 7.94 ha in Aus, 35.17 ha in Aman and 38.44 ha in Boro season. This division manages the BRRI flower garden to maintain the aesthetic view of the campus. It has grown visible flower garden in summer and winter seasons.

PI: K P Halder **CI:** M M Rashid, M S Islam, M R Manir and S Begum

Table 5. Land and labor strength of BRRI, 2018-2019.

Name of station	Total land (ha)	Cultivable land		Labor (no.)		
		Area (ha)	% of total land	Muster roll		Total
				Regular	Irregular	
HQ at Gazipur	76.83	44.45	57.86	316	148	464
Cumilla	24.68	16.03	64.95	31	14	45
Habiganj	35.03	25.90	73.94	33	05	38
Sonagazi	45.77	35.90	78.44	38	04	42
Barishal	41.10	10.74	26.13	29	03	32
Rajshahi	13.24	8.92	67.37	28	04	32
Bhanga	11.46	9.55	83.33	16	05	21
Rangpur	6.07	4.05	66.72	30	05	35
Satkhira	20.00	8.10	40.50	19	02	21
Kushtia	4.05	3.0	74.07	11	01	12
Sirajganj	4.05	3.0	74.07	-	-	-
Gopalganj	4.05	3.0	74.07	-	-	-
Total	286.33	172.64	60.29	551	191	742

Farm Machinery and Postharvest Technology Division

SUMMARY

A study was conducted to modify, fabricate and test the performance of the BRRI developed prototype (version-1) of head feed mini combine harvester with locally available materials in Janata Engineering Workshop, Chuadanga under Public Private Partnership (PPP). BRRI provided engineering design, drawing, technical and financial support to improve and fabricate the machine. The second prototype of combine harvester was redesigned and fabricated according to 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 1.25~1.50bigha/h and 3.84~3.96 l/h respectively. The improved combine harvester becomes appropriate in both dry and muddy fields with a plough pan up to 15-20 cm. The average harvest loss was 2.46% and off them the cutter bar, scattering and threshing losses were found to be 0.648, 0.373 and 1.327%respectively.

Mixed fertilizer deep placement mechanism was incorporated in the existing walking (ARP-4UM)type rice transplanter under the NATP sub-project. In the transplanter, spiral type mechanism was incorporated as metering device to receive and dispense desired amount of mixed fertilizer. Engine power 1800 rpm was reduced and transmitted to the applicator main shaft at 22 rpm with the arrangement of a belt-pulley, worm gearing, shaft-bearing, chain-sprocket and bevel gear with engage-disengage facility. A control lever was also used to calibrate fertilizer dose based on variety and seasons. Walking type rice transplanter, that we developed was evaluated in the laboratory, soil bin, research field and farmer’s field. In the laboratory and soil bin test, it was observed that fertilizer control lever can control fertilizer dispensing rate and dispensed uniformly in the furrow and covered effectively. It was also observed that agitatorrotated smoothly to prevent the bonding of fertilizer mixture.

A research was conducted to design, develop and validate a multi-row power weeder to control weeds in line transplanted wet rice field. Recoil starting mode petrol engine (1.35 kW) was used as power source. Engine power 6500 rpm was reduced and transmitted to the rotors of the weederat 185 rpmwith the arrangement of a coupling, spline shaft-bearing, worm gearing and rotary shaft with engage-disengage facility. Spike angle and arrangement were designed critically considering the effective depth of weeding and total area of coverage in between two lines. A total of six spike plates comprising three spikes in each plate were attached in each side rotor whereas six spike plates comprising one spike in each plate were attached in each middle rotor. The developed power weeder were tested in both research laboratory and farmers’ field at sadar and Sreepurareas ofGazipur; Bhaluka, Mymensingh; Netrakonasadar, Habiganjsadar, BRRI RSCumilla and Rangpursadar under different soil conditions. The treatments were: one weeding by power weeder (BPW) followed by (fb) one hand weeding (HW), one weeding by BRRI manual weeder (BW) fb one HW, Weedy check, Weed free and Mulching fbby two HW (Farmers’ practice). Average of seven locations and three replications, actual and theoretical field capacity of the multi-row power weeder was found 0.229 and 0.290 $hahr^{-1}$ whereas average field efficiency was found 78.74%. In all cases, significantly lower weeding efficiency was observed for BRRI manual weeder (69.28%) whereas weeding efficiency of BRRI multi-row power weeder was 78.93%. However, weed control efficiency of the developed weeder was 73.18%.

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 BRRIdhan80. 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. Old steel 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. In addition, separately collected husk and bran can be used for making briquette and extracting edible oil respectively.

Farm Machinery and Postharvest Technology (FMPHT) Division, BRRI and HarvestPlus jointly conducted research on ‘Processing of rice for zincefficacy study’. The aims of this study were to

determine the percentage of milling effect on weight loss, head rice recovery, zinc (Zn) and iron (Fe) loss of rice. Two rice varieties such as BRRIdhan28 (not Zn enriched) and BRRIdhan42 (bio-fortification) were used in this study. Grain Zn and Fe content were estimated in the brown rice (dehusked unpolished grain) and different degrees of polished rice (7.5, 10, 12, 13.75 and 15%). The Zn content was calculated by using X-ray fluorescence (XRF) machine at HarvestPlus laboratory in Bogura. It was observed that the Zn content of both the varieties decreased with the increase of the degree of milling (passing number 1 to 5). Zinc content of two varieties was varied up to 12%degrees of milling (DoM) and after 13.75%DoM there have no difference in Zn content, both bio-fortification and not Zn enriched varieties. A similar trend was found in Fe content in the parboiled grain of these two varieties. During the milling process, the broken percentage increases with increasing of DoM, due to low surface hardness which leads to low quality and recovery of milled rice. It was also observed that there had negative relationship between DoM and head rice yield.DoM affects not only the quality but also the appearance of rice kernels. This study showed that the DoM and whiteness are positively correlated. It was clearly shown that more food loss occurred due to more degree of milling that hampers the food security of a nation. It can be concluded from these results that over DoM affect the losses of Zn and Fe content as well as lower head rice recovery.

Solar light trap manufactured, distributed andadaptive field trial was done in farmer's field under special research budget allocation of the Ministry of Agriculture for 2018-19. Aiming to validate and adaptive field trial of BRRI solar light trap to the end users, manufacturer and resource poor farmers that reduces the application of insecticides. Seven sides namely, Kaliakoir of Gazipur (Rice), Jhikargacha of Jashore (Vegetable and rice), Bogurasadar (Vegetable and rice), Manohardi of Narsingdi (Vegetable and rice), Nakla of Sherpur (Rice and vegetable) andDumuria and Koyra of Khulna (Rice and fish) were selected for research cum adaptive trial programme. A total 120 solar light trap were distributed and installed at the farmer's 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 catch in each solar light trap. The hghest number of insect pests was trapped in May than that of April. 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 14 awareness cum demonstration and training programme were conducted along with more than 500 potential farmers, manufacturers, NGO personnel. Use of solar light traps both in rice and vegetable crops found effective tool for controlling insect pests. By means of this solar light trap reduces chemical insecticide application and save environment.

An initiative was taken to produce briquette mixing rice husk along with dry rice straw at different ration to increase calorific value of rice straw and alternate use as well. Five treatments (T_1: 10% straw + 90% husk; T_2: 20% straw + 80% husk; T_3: 30% straw + 70% husk; T_4: 40% straw + 60% husk and T_5: 50% straw + 50% husk) were used for this experiment. The percentage productions of briquette were decreased with the increased percentage of straw. The average density of husk and straw are 128 kg/m^3 and 89 kg/m^3. The density of produced briquette decreased with the increase of rice straw.

AGRICULTURAL MACHINERY DEVELOPMENT AND TESTING

Head feed mini combine harvester

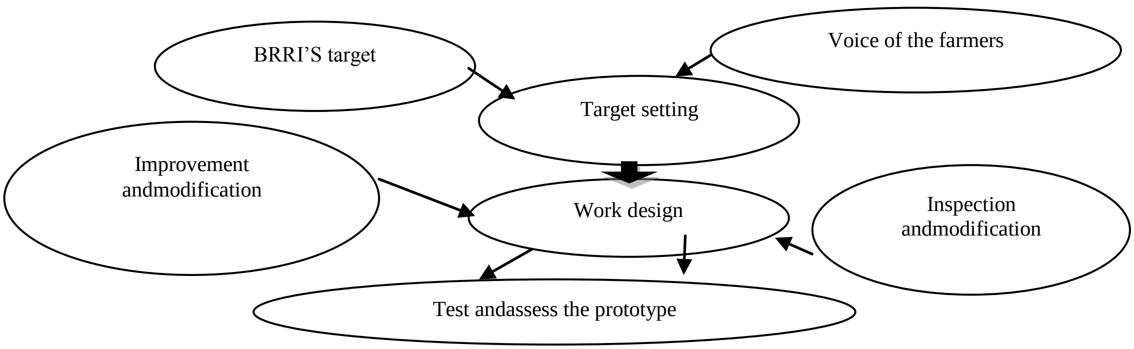
Harvesting can be done manually using sickles and knives, or mechanically with the use of threshers or combine harvesters. Regardless of the method, a number of guidelines should be followed that will ensure harvest losses keep to a minimum and grain quality is preserved during harvest operations. The head feed combine is different from whole feed combine where only the panicle is feed into the machine, as a result straw remains intact but capacity is lower than the whole feed. In Bangladesh, straw is used to feed the cattle, as fuel for cooking and packing materials for different industries. So it is necessary to develop a head feed combine harvester.

Design and fabrication

FMPHT Division provided design, technical and financial support to Janata Engineering, Chuadanga (Fig. 2-6) to fabricate the improved version of heed feed mini combine harvester using locally available materials under Public Private Partnership (PPP) approach. The literature review was done to know the working principle and fabrication procedure of different types of combine harvester, which helped to design and 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.

Prototype development

According to field test results the combine was modified and fabricated again to improve the prototype using locally available materials in the BRRI research workshop. After finalizing the prototype, multiplication was done in a local manufacturer's workshop as per design, guidance and project financial help provided by BRRI through NATP– sub-project. After that, locally developed combine harvester was tested, evaluated and demonstrated in farmers' fields and collect farmers feedback. The process was continued until the perfection of the machine was achieved. Figure 1 shows the improved combine harvester images and field operation.

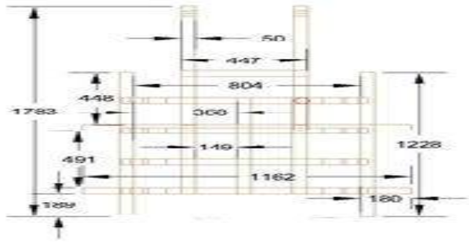


Flow diagram of modifying process of the second prototype

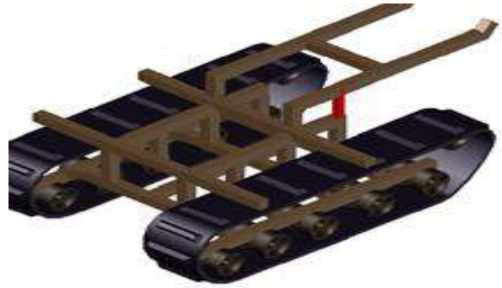
Development procedure

The work aims to develop a mini combine harvester using locally available materials in the view of public private partnership (PPP) approach between the FMPHTDivision, BRRI, Gazipur and Janata Engineering, Chuadanga. Total two versions of prototype were developed and performance was tested in a farmer's field. According toIRRI, combine harvester is called mini when cutting width is in between 120 cm. The first version was developed by using GoB fund of BRRI, but modified and improved version (second) was done by using of CRG, NATP-2 project fund. The field test of improved version was conducted during the Aus and Aman/2018 and Boro 2019 seasons.

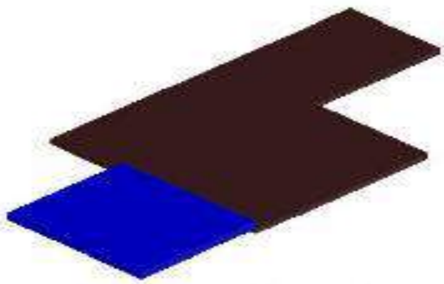
Fig. 1. Final prototype and field operation of the developed head feed combine harvester.



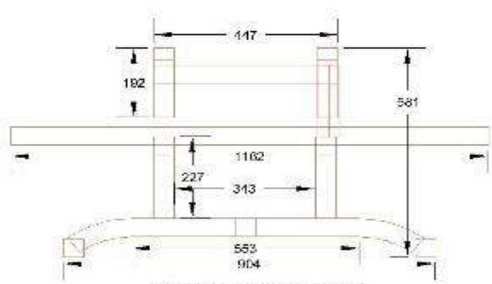
Top view dimension



Crawler with frame

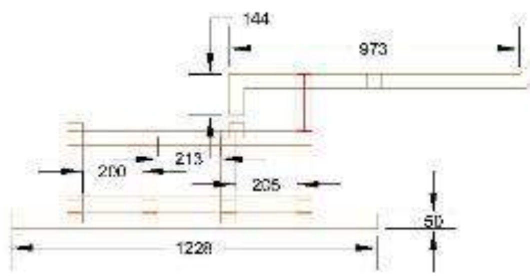


Isometric view-Flat form



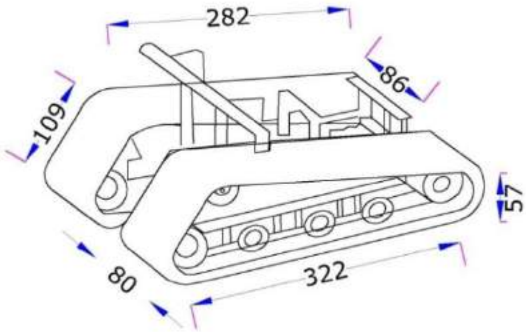
Side view dimension

Isometric view

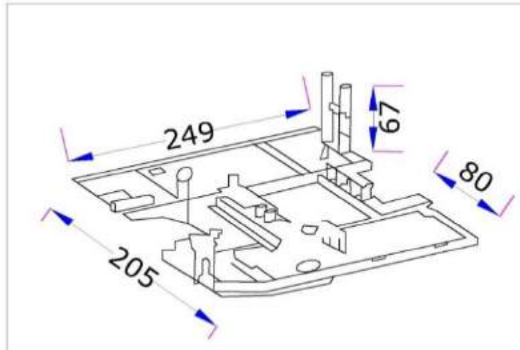


Front view dimension

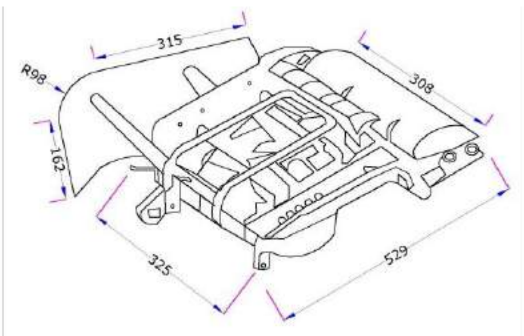
Fig. 2. Base of combine harvester.
Note: All dimensions are in mm



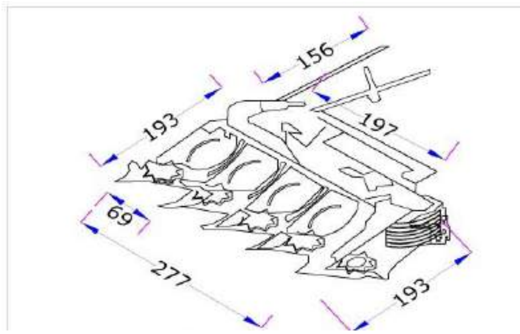
Travelling mechanization



Platform /base of the machine

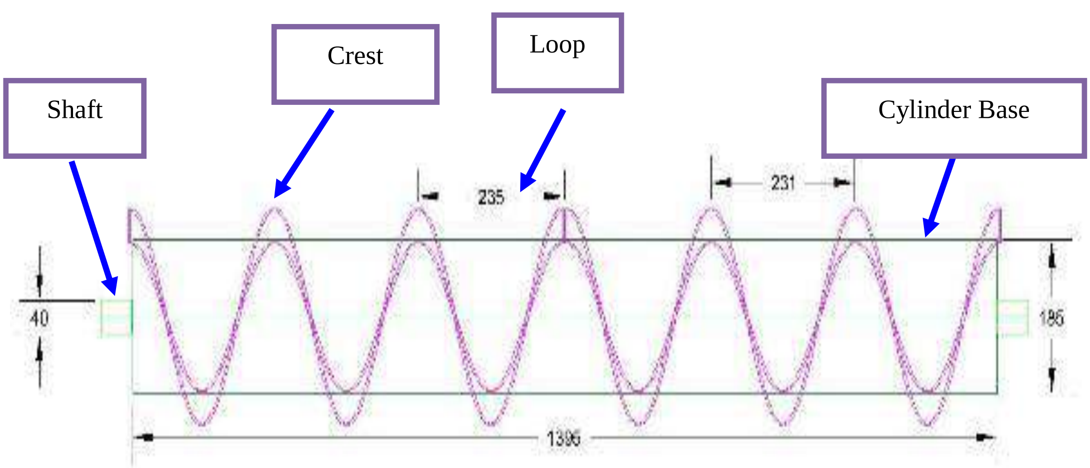


Threshing part



Cutting part

Fig. 3. The main functional units of combine harvester.
Note: All dimensions are in cm



Grain conveyor

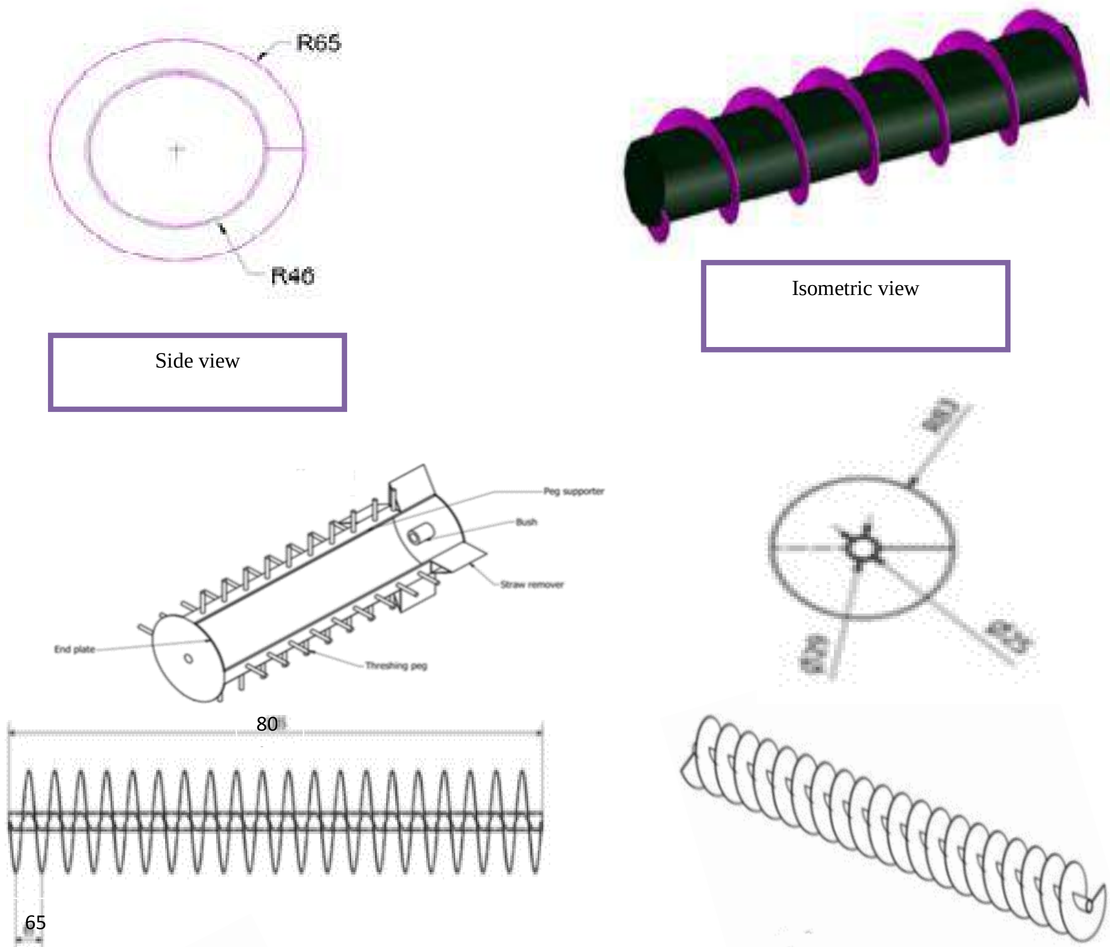
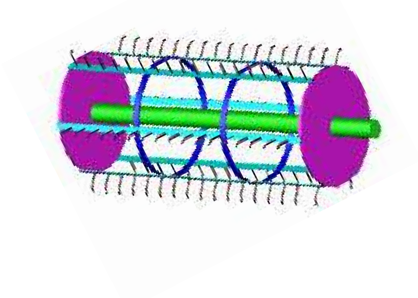
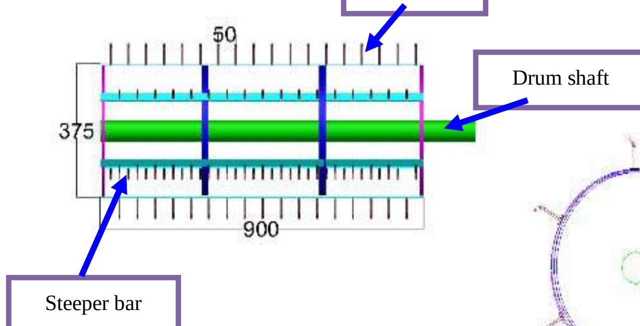


Fig. 4. Grain conveyor assembly.
Note: All dimensions are in cm





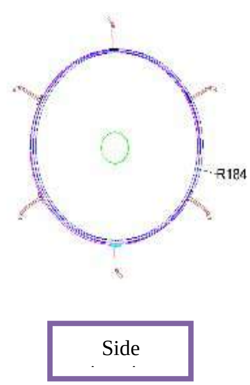
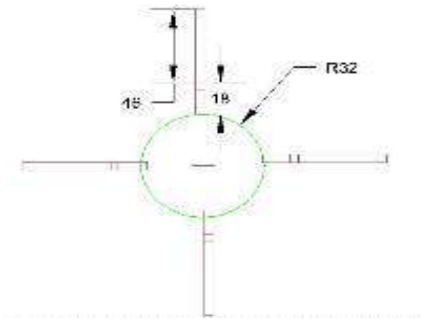
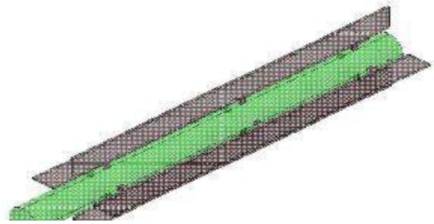


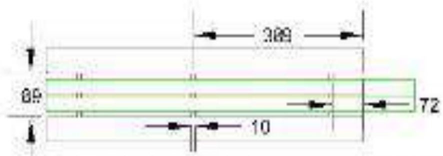
Fig. 5. Threshing part assembly.
Note: All dimensions are in cm



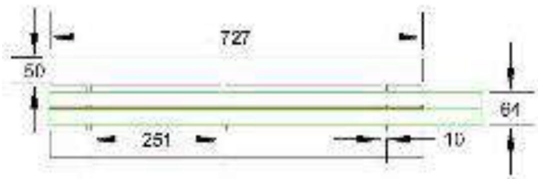
Blower Assemble-Side View



Blower Assemble-Isometric View



Blower Assemble-Top View



Blower Assemble-Front View

Fig. 6. Winnowing assembly.
Note: All dimensions are in cm

Field performance of improved version

The performance test of second version head feed mini combine harvester was conducted in different field (Dry and wet) conditions in Chuadanga. The identified problems and results were analyzed and necessary actions were taken for further improvement. The improved combine harvester was tested on load and no-load conditions. Fine tuning and modification has been done of the second version combine harvester based on laboratory and field tests. Modification was carried out based on the performance of the laboratory and field tests until it became user friendly.

Afterwards several field tests were conducted to evaluate the performance of second version combine harvester during Aman 2018 and Boro 2019 seasons 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. The following factors were considered in field test:

- Harvesting area and harvesting time
- Walking speed
- Fuel consumption
- Field capacity

The average walking speed was 1.40 km/h and 1.30 km/h in Aman 2018 and Boro 2019 season respectively. The working speed in Aman season was higher than that of Boro season due to muddy field. Although working speed was low in Boro season but fuel consumption was little bit more due to muddy field. The average fuel consumption was found 3.84 l/h in Aman season where as 3.96 l/h was in Boro season. The average field capacity was 1.25- 1.50 bigha/h.

Problem identified

A limited scale interview was conducted during the validation test of developed combine harvester and opinions were collected from the participants, operators, farmers and machinery users regarding the overall performance of the machine. In general, they expressed their satisfaction about the machine's performance making special reference to the following problems and comments:

- Grain breakage was found in main outlet;
- The shuttering of grain was observed in the laid down crop during harvesting; and
- Some straw was broken due to thresher loop.

Harvesting loss assessment

Cutter bar loss

Grain loss due to rough handling and out of research of cutter bar is called cutter bar loss. The combine harvester was allowed to move forward for 50 m to attain a steady constant speed and it was suddenly stopped. The header unit was lifted up and the machine was moved back for about 2 m. The quadrate with an area of 1 m^2 was placed in front of the parked machine and the grains and panicles were manually picked up. The panicles were then manually threshed and the cutter bar losses were determined by weighing the fallen grains and collected panicle grains.

Scattering loss

Grain spread over the ground from cleaning/threshing unit and any other part of the machine is called scattering loss. In the field, a number of random quadrants are chosen of one square meters surface area each. After the harvesting procedure, all grains that are lying on the ground within the quadrants are collected. After that collected grain weighed carefully.

Threshing loss

Grain loss over the straw rack in the form of un-threshed heads is called cylinder loss or header loss. And grain loss outside the rear of the combine in the form of threshed grain is called separation loss. The cylinder loss and separation loss combinedly known as threshing loss of the combine harvester. The threshed rice straw was collected from combine harvester on a longtripol. The rice straw was separated and threshed grain was collected on tripol. The collected rice straw again threshed manually and the grain collected.

In general, harvest loss could be attributed to harvest and threshing method, harvest time, type of variety and its physical properties, crop condition in terms of maturity, lodging and soil condition. Since the cut crop is laid out on residuals from 24 to 48 hours depending on climate condition and then they are collected after moisture reduction and threshed later, therefore crop moisture reduction would lead to not only a rise in grain shattering during gathering and packing but also paddy would be exposed to environmental impacts that bring about qualitative crop loss in consequence. Table 1 shows the different losses of modified combine harvester. The average harvest loss was 2.46%. Off them the cutter bar, scattering and threshing loss were found to be 0.648, 0.373 and 1.327% respectively which is quite acceptable in terms of harvest loss.

Table 1. Harvest loss assessment for combine harvester (10 m^2 area data).

Component	Test I	Test II	Test III
A. Obtained yield (OY)			
Obtained wet weight, kg	5.40	6.00	6.00
Moisture content, %	23.8	23.8	23.6
OY, Adjusted weight, kg	4.78	5.32	5.33
Average		5.14	
B. Cutting loss			
Cutter bar loss weight, g	38.25	21.50	39.50
Cutter loss, %	0.800	0.404	0.741
Average		0.648	
Scattering loss			
Scattering loss			
Threshed grain weight, g	22.50	15.00	19.50
Scattering loss, %	0.471	0.282	0.366
Average		0.373	
C. Threshing loss			
1) Cylinder loss			
Cylinder loss weight, g	40.50	16.00	27.75
Cylinder loss, %	0.847	0.301	0.521
2) Separation loss			
Separation loss weight, g	40.00	40.50	38.00
Separation loss, %	0.837	0.761	0.713
Total threshing loss, %	1.684	1.062	1.234
Average		1.327	
Total harvesting loss, %	2.955	2.083	2.341
Average threshing loss, %		2.460	

Design and development of fertilizer deep placement mechanism for existing rice transplanter

A study was conducted to develop a mixed fertilizer deep placement mechanism incorporating in the walking (ARP-4UM) and riding type (S3-680) rice transplanter. In both type rice transplanters, spiral type mechanism was incorporated as metering device to receive and dispense desired amount of mixed fertilizer. In case of walking type rice transplanter, engine power 1800 rpm was reduced and transmitted to the applicator main shaft at 22 rpm with the arrangement of a belt-pulley, worm gearing, shaft-bearing, chain-sprocket and bevel gear with engage-disengage facility. Necessary modification of the rice transplanter was done to receive engine power for fertilizer deep placement (FDP) technology (Fig. 7). Engine power of the selected transplanter transmitted to the hydraulic pump, driving wheels and rotary picker and water pump of the transplanter with the belt-pulley arrangement. At the first stages of power reduction from 1,800 rpm to 810 rpm. Bevel gear also used in the gear box to change the direction of power at 90 degree intersecting shaft at the same velocity ratio. In the 2nd stage, power reduced from 810 to 23 rpm. Power transmitted from output shaft of the gear box to the applicator main shaft with the ratio of 10:9 by chain-sprocket arrangement. Chain-sprocket was used to convey the power from output shaft of the bevel gear to the main shaft of the applicator at the velocity ratio of 10:9 (Fig. 8). Straight face worm gear was used to reduce engine rpm at the velocity ratio of 35:1. Size of the gear box is 140 × 85 × 120 mm.

3Number of sprocket teeth in the gear shaft and applicator main shaft are 20 and 18 respectively. Length of pitch, radius of roller, distance between two inside plates are 13, 7 and 6 mm. Bevel gear was also used in the gear box to convert the rotation at 90 degree to the intersecting shaft (Fig.9).Spiral conveyor of the metering device conveyed fertilizer mixture from inner chamber to the outlet pipe connected with the chamber (Fig. 10). Fertilizer dispensing rate increased with the increase of opening in between fertilizer hopper and fertilizer metering chamber, which can be controlled by a lever. Rate of fertilizer dispensing can be controlled by adjusting the lever based on season and variety.

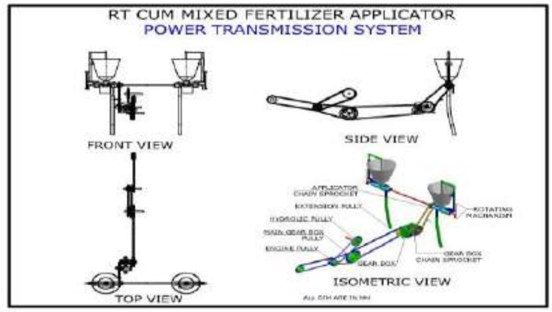


Fig. 7. Power transmission from engine to the mixed fertilizer applicator.

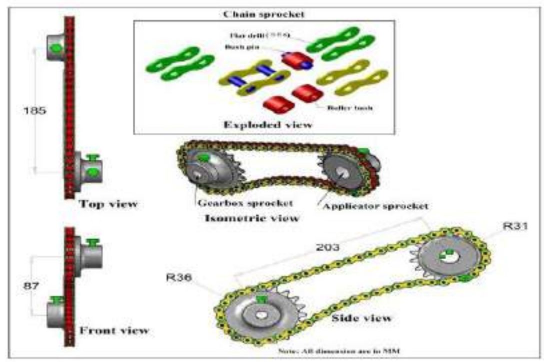


Fig. 8. Power transmission from gear box to the main shaft of the applicator.

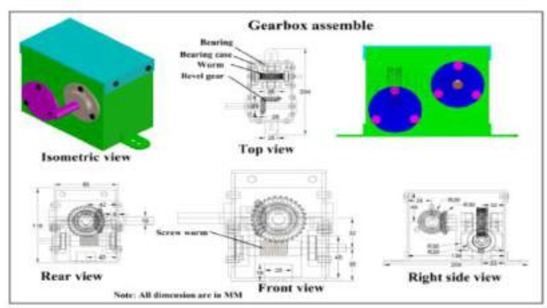


Fig. 9. Gear box incorporating with warm and bevel gearing.

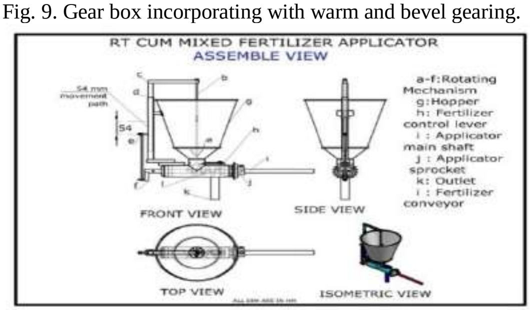


Fig. 10. Mixed fertilizer applicator.

Field evaluation of the rice transplanter cum mixed fertilizer applicator

The experiment was laid out in a randomized complete block (RCB) design with three replications. About half meter of buffer spacing was maintained among the sub-plots. The treatments were:

T_1= Mechanical transplanting along with mixed fertilizer deep placement

T_2= Mechanical transplanting and hand broadcasting of fertilizer and

T_3= Manual transplanting and hand broadcasting of fertilizer.

BRRI dhan29 and BRRI dhan58 were used as test crop to conduct the study in Kushtia and Habiganj respectively. Seedlings were raised on plastic tray (280×580×25 mm) both in BRRI HQ, Gazipur and farmers' field for mechanical and manual transplanting at the same date. Thirty-and 45-day-old seedlings were used in mechanical and hand transplanting respectively. The developed rice transplanter cum mixed fertilizer applicator (RTFA) was used to transplant the rice seedling in $T_1$and T_2 whereas T_3 was transplanting manually using seedling raised in farmers' seed bed (Table 2 and Fig. 11).

Mixed fertilizer deep placement

Recommended dose of fertilizers were applied manually in T_2 and T_3 according to farmers' practices.Urea fertilizer (70% of RD) along with triple super phosphate (TSP), muriate of potash (MoP) and gypsum fertilizer were applied at transplanting time using the developed machine in T_1 plot at non-oxidized zone 6-8 cm (Table 3). This formula was developed for easy calibration of the applicator.

$$\text{FDR} = \frac{\pi D \times 2L \times RoF}{10^5}$$

Where,

FDR = Fertilizer dispensing (from each channel) rate per rotation of the driving wheel (g/rotation)

D = 60 cm, wheel diameter of the rice transplanter

L = Line to line spacing of the transplanted rice, cm

RoF = Desired rate of fertilizer application, kg ha^{-1}

Table 2. Basic information of the experiments regarding seedling raising and transplanting.

Parameter	Gazipur	Kushtia	Habiganj
Variety	BRRI dhan58	BRRI dhan29	BRRI dhan58
Date of soaking	14/12/2018	03/12/2018	07/01/2019
Date of sowing and tray preparation	16/12/2018	06/12/2018	10/01/2019
Date of mechanical transplanting	10/01/2019	15/01/2019	15/02/2019
Date of hand transplanting	02/02/2018	15/01/2019	15/02/2019
Experimental Plot size in decimal	32	105	73
Date of harvesting			
Crop duration (day)			

Fig. 11. Field operation of the RTFA.

Field capacity of the RTFA

Field capacity of the developed rice transplanter cum mixed fertilizer applicator was measured with and without fertilizer deep placement mechanism in the two studied locations (Table 4). Theoretical field capacity varied with forward speed of machine operation whereas actual field capacity varied with forward speed, turning time loss, seedling and fertilizer re-filling time etc. In two cases, theoretical and actual field capacity of the rice transplanter was found higher to some extent without fertilizer deep placement mechanism during transplanting due to extra fertilizer re-filling time and slowing of operation. Field efficiency varied from 55 to 65% irrespective of soil and location. Average of two locations and three replications, actual field capacity of the rice transplanter was found 0.11 and 0.12 ha hr^{-1} with and without fertilizer deep placement mechanism respectively.

Actual amount of fertilizer application

Before field operation of the machine, it was calibrated to apply desired amount of fertilizer based on recommended dose of mixture fertilizer. During field operation, actual dispending amount of fertilizer was calculated to determine percentage of deviation (Table 5). Actual amount of dispensed fertilizer was 583 and 589 kg/ha in Kushtia and Habiganj respectively. In both cases, 10 and 16 kg/ha more fertilizer dispensed in the field at Kushtia and Habiganj, respectively. It might be due to variation of operational speed, more penetration of the driving wheel in the field during operation etc. Maximum deviation was observed in Habiganj. High vibration of the machine, turning losses of fertilizer, uniform and fine prilled urea size might be the causes of more dispensing rate of fertilizer compared to calibration.

Table 3. Calibration of mixed fertilizer (g/rotation).

Urea fertilizer (70% RD) (kg ha^{-1})	TSP fertilizer (kg ha^{-1})	MoP fertilizer (kg ha^{-1})	Gypsum fertilizer (kg ha^{-1})	Total amount urea, TSP, MoP and Gypsum (kg ha^{-1})	FDR (g/rotation)
196	100	165	112	573	64.77

Note: RD-Recommended dose.

Table 4.Field performance of the RTFA.

Condition of RTFA Operation		Forward speed of operation (km hr^{-1})	Actual field capacity (ha hr^{-1})	Theoretical field capacity (ha hr^{-1})	Field efficiency (%)
Kushtia					
With FDP		1.59	0.10	0.19	0.55
Without FDP		1.62	0.11	0.19	0.58
Habiganj					
With FDP		1.63	0.12	0.20	0.60
Without FDP		1.69	0.13	0.20	0.65
Average	With FDP	1.61	0.11	0.19	0.57
	Without FDP	1.66	0.12	0.20	0.61

Note: Average value of three replications, width covered per pass of the applicator is 1.2 m. FDP-Fertilizer deep placement

Table 5. Percent of deviation from calibrated amount of fertilizer as affected by soil condition and location.

Location	Area (m^2)	Mixed fertilizer dispensed (kg)	Actual dispensing rate		Theoretical dispensing		Deviation (±%)
			(kg/ha)	(g/rotation)	(kg/ha)	(g/rotation)	
Gopalganj	1200	23.2	573	64.8	583	65.9	+1.1
Kushtia	1404	26.1	do	64.8	589	66.58	+1.78

Note: Average value of three replications, width of covered per pass of the machine is 1.2 m.

Mechanical rice transplanter is a promising technology considering the present labour crisis in Bangladesh. Mixed fertilizer deep placement technology successfully incorporated with the walking type rice transplanter having proper design and found suitable in operations under laboratory, research field and farmers' field condition. Crop performance will be analyzed after harvesting to observe the effect of mixed fertilizer deep placement along with mechanical transplanting compared to traditional practices.

Development, validation and adoption of power weeder for wet land rice cultivation

Anexperiment was conducted to design, develop and validate a multi-rows power weeder suitable to control weeds in line transplanted wet rice field. Recoil starting mode petrol engine (1.35 Kw) was used as power source. Engine power (6500 rpm) transmitted to rotors at 185 rpm of the weederwith the arrangement of a coupling spline shaft-bearing, worm gear and rotary shaft with engage-disengage facility. The developed power weeder were tested in both research laboratory and farmers' field.The treatments were: One weeding by power weeder (BPW) followed by (fb) one hand weeding (HW), one weeding by BRRI manual weeder (BW) fb one HW, weedy check, weed free and mulching fb two HW (Farmers' practice).

Multi-rows power weeder

Multi-rows power weeder was designed and fabricated in the fmpht divisional research workshop. Table 6 presents the major specification of the weeder. Figure 12 representsthe photographic view of the weeder.

Table 6. description of the power weeder.

Item		Specification
Country of origin and model		Bangladesh and mrpw-1
Type		Forward motion walking type
	Overall length × width × height (mm)	1417×762×807
	Overall weight (kg)	20
Dimensions	Maximum output kw rpm^{-1}	1.35/7000
	Engine type	Petrol engine
	Starting method	Recoil
	Crawling	Hand controlling system
Traveling section	Rotor type	Spike work as lug in the wheel
	Gearshift: forward	Power engaged with the increase of engine rpm
	Weeding mechanism	Rotary: spike used in the rotor for weeding
	Number of rows	3
Weeding section	Row to row distance (mm)	200 to 300 (adjustable)
	Field capacity (ha/hr)	0.16-0.20
	Working life (yrs)	3-4

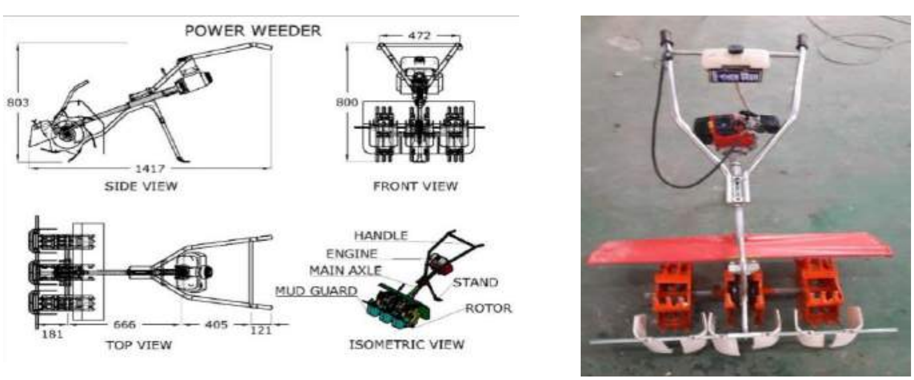


Fig. 12. Brri multi-row power weeder.

Power transmission system from engine to the rotor Worm gear is used to reduce the high rpm of the engine to a desired rated of the rotor rpm (Fig. 13). Spline shaft is directly connected with worm screw, which is connected with worm wheel. Finally power transmitted to the weeder rotor from worm wheel to the shaft of the rotor.

Field evaluation of the developed BRRI multi-rows power weeder

Location of the study

This study was conducted to evaluate the performance of the BRRI developed multi-row power weeder in the farmer's field at Gazipursadar, Sreepur, Gazipur; Bhaluka, Mymensingh, Netrakonasadar, Habiganjsadar,BRRI RS Cumilla and Rangpursadarduring Boro2018-19season.

Soil sample collection and analysis

A metal core (50 mm height and 49.8 mm diameter) was used to collect soil samples from three different places at the depth of 0-150 mm to identify soil textural class, pH, organic matter and soil fertility classes. Samples were analyzed in the Soil Analytical Laboratory, BRAC, Gazipur. The soils of the experimental location represented the silty loam, clay loam and loam soil (Table 7). Textural class was determined by the USDA Soil Texture Triangle (Blake, 1986).

Experimental design and treatments

The experiment was laid out in a RCB design with three replications. About one meter of buffer spacing was maintained among the sub-plots whereas experimental plot size was 56.2, 85.0, 30.3, 35.8, 70.0, 64.0 and 32.0 decimal at Gazipur sadar, Sreepur, Gazipur; Bhaluka, Mymensingh; Netrakona sadar, Habiganj sadar, BRRI RS Cumilla and Rangpur sadar respectively. The treatments were:

T_1 = One weeding by power weeder (BPW) followed by (fb) one hand weeding (HW)

T_2 = One weeding by BRRI manual weeder (BW) fb one HW

T_3 = Weedy check

T_4 = Weed free and

T_5 = Mulching fb two HW (Farmers' practice)

Weeds of the trial plots were managed according to the design and treatments. BPW and BW were operated at 25 dates after transplanting (DAT) in T_1 and T_2. One hand weeding was done at 45 DAT to control the weeds of T_1, T_2 and T_5. T_3(no weeding) was not weeded during the crop growing periods. In contrary T_4 (weed free) was weeded at 25, 35, 45 and 55 DAT to keep the field weed free throughout the growing periods of crop. In case of T_5, farmers manually controlled weeds at 15, 25 and 45 DAT using their local practices. Figure 14 presents field operation of the weeder in different locations.

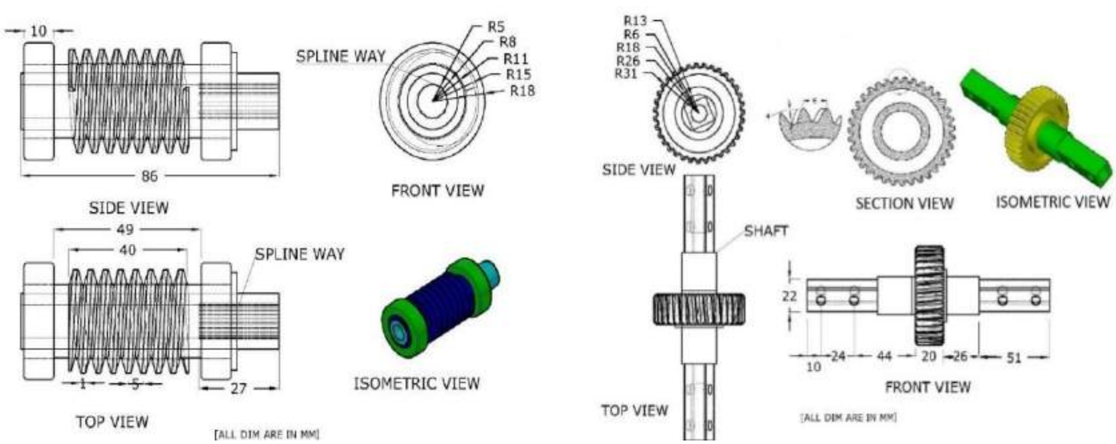


Fig. 13. Worm screw and worm wheel of worm gearing.

Table 7. Soil conditions of the experimental fields.

Location	Particle distribution (%)			Textural Class	P^H	OM (%)
	Sand	Silt	Clay			
Gazipursadar	29.92	50.84	19.24	Silt Loam	5.66	2.48
Sreepur, Gazipur	33.33	40.00	26.67	Clay Loam	5.33	1.61
Bhaluka, Mymensingh	50.00	43.7	6.30	Loam	7.05	1.41
Netrakonasadar	43.63	48.81	7.56	Loam	6.93	1.68
Habiganjsadar	40.47	46.97	12.56	Loam	5.06	1.34
BRRI RS Cumilla	24.75	56.50	18.75	Silt Loam	5.12	2.68
Rangpursadar	44.66	41.76	13.58	Loam	5.36	2.68

Fig. 14. Field operation of the BRRI multi-rows power weeder.

Yield and yield contributing character

Tiller number and plant height were assessed from 12 hills per plot at 15-day intervals. Crops were harvested when 85-90% of the grains become golden. Rice grain yield per plot was recorded from a pre-selected 10 m^2 harvest area and was determined with the adjustment to 14% moisture content. For computing above ground biomass and yield attributes, samples from 1 m^2 quadrates were collected from outside of the pre-selected 10 m^2 area of each plot. Straw yield (above ground biomass), plant height, panicle length, number of tillers $hill^{-1}$ and number of panicles $hill^{-1}$, filled and unfilled spikelet's $panicle^{-1}$ and 1000 grains weight were recorded from these quadrates. Data were analyzed as a single factorial design according to Gomez and Gomez (1984) using Statistix 10 programme (Statistix 10 software, 2013). Means were compared with the least significant difference (LSD) test. Simple correlation analysis was carried out with Excel 2010 to determine the relationship of grain yield to yield attributes.

Weed density before 1st weeding at 25 DAT. Weed density was counted at 25 DAT (Table 8). Weed type and density varied with soil condition, locations and irrigation condition. Two-ways interaction was not found significant whereas single effect of locations and weeding methods were significant on weeds density. Weeds density was significantly higher in Cumilla followed by Habiganj whereas lower weeds density was observed in Shreepur, Netrakona and Rangpur.

Weed biomass before 1st weeding at 25 DAT. Weed biomass was measured at 25 DAT (Table 9). Weed biomass varied with weed type, density and age of the weed. Two-way interaction was found significant on weed biomass as were single effects of location was significant on weed biomass. Weed biomass was significantly higher in Gazipursadar, Habiganj, Cumilla and Rangpur. Significantly higher weed biomass were observed at Cumilla under T_1, T_3 and T_5,at Gazipur under T_2, at Habiganj under T_2 and T_4 and at Rangpur under T_5.

Field capacity of the power weeder and BRRI manual weeder. Field capacity of the developed multi-row power weederand BRRI manual weederwas measured during field operation in seven locations of the country (Table 10 and 11). Theoretical field capacity varied with forward speed of machine operation whereas actual field capacity varied with forward speed, turning time loss, weeder placing in between rows time etc. In all cases, theoretical and actual field capacity of the power weederand manual weederwere found higher to some extent in the loamy soil compared to silty loam and clay loam soil. Both the capacity was found more in Rangpur and less in Gazipur due to soil condition. Field efficiency power weedervaried from 68.2 to 83.5% and manual weeder45 to 85% irrespective of soil and location. Average of seven locations and three replications, actual and theoretical field capacity of the multi-row power weeder was found 0.229 and 0.290 ha hr^{-1} whereas average field efficiency was found 78.74%. However, actual and theoretical field capacity of manual weeder was found 0.038 and 0.05 ha hr^{-1} whereas average field efficiency was found 76.25%. Manual weeding capacity varied with weeds type, density, soil condition and water condition. Average of seven locations, manual weeding capacity was found 62.5 m^2hr^{-1}

Table 8. Weeds density (no. m^{-2}) as affected by different weeding methods and locations.

Treatment	Weed density n/m^2							Mean
	$Gazipur_1$	$Gazipur_2$	Mymensingh	Netrakona	Habiganj	Cumilla	Rangpur	
T_1	178	108	246	94	206	460	94	198.0 ab
T_2	158	78	120	98	260	272	152	162.6 c
T_3	196	72	96	80	226	366	120	165.1 bc
T_4	158	66	102	74	222	402	112	162.3 c
T_5	192	138	222	116	238	374	128	201.1 a
Mean	176.4 c	92.4 e	157.2 cd	92.4 e	230.4 b	374.8 a	121.2 de	-
CV	30.9							
LSD	L=40.03 and T=33.83							
LoS	L=**, T=* and L × T = ns							

Note: T_1 - One weeding by power weeder (BPW) followed by (fb) one hand weeding (HW), T_2 - One weeding by BRRI manual weeder (BW) fb one HW, T_3- Weedy check, T_4 - Weed free and T_5 - Mulching fb two HW (Farmers' practice), NS-Not significant, *-Significant at the 5%, **-Significant at the 1%, LoS-Level of significance, L-Locations, T- Weeding methods.

Table 9. Weed biomass per m^2 as affected by different weeding methods and locations.

Treatment	Weed biomass g/m^2							Mean
	$Gazipur_1$	$Gazipur_2$	Mymensingh	Netrakona	Habiganj	Cumilla	Rangpur	
T_1	63.0	31.5	17.5	22.8	57.8	82.3	66.5	48.8
T_2	78.8	29.8	24.5	26.3	75.3	21.0	61.3	45.3
T_3	47.3	33.3	49.0	29.8	66.5	75.3	59.5	51.5
T_4	52.5	31.5	42.0	31.5	84.0	50.8	63.0	50.8
T_5	47.3	36.8	36.8	21.0	49.0	92.8	73.5	51.0
Mean	57.767 a	32.587 b	33.973 b	26.287 b	66.527 a	64.413 a	64.753 a	
CV	34.55							
LSD	L=12.45 and L × T = 27.85							
LoS	L=**, T=ns and L × T = *							

Note: T_1 - One weeding by power weeder (BPW) followed by (fb) one hand weeding (HW), T_2 - One weeding by BRRI manual weeder (BW) fb one HW, T_3- Weedy check, T_4 - Weed free and T_5 - Mulching fb two HW (Farmers' practice), NS-Not significant, *Significant at the 5% level, **Significant at the 1% level, LoS-level of significance, L-location, T- Weeding methods.

Table 10.Field performance of the BRRI multi-row power weeder.

Place	Area of operation (m^2)	Operationa l time (m)	Forward speed of operation (km hr^{-1})	Actual field capacity (ha hr^{-1})	T. field capacity (ha hr^{-1})	Field efficiency (%)
Gazipursadar	1374	39.44	4.44	0.209	0.266	78.5
Sreepur, Gazipur	1085	32.39	4.91	0.201	0.295	68.2
Bhuluka, Mymensingh	1250	30.86	4.93	0.243	0.296	82.1
Netrakonasadar	1050	26.81	4.87	0.235	0.292	80.4
Habigangsadar	1080	27.34	4.84	0.237	0.290	81.6
BRRI RS Cumilla	1400	37.00	4.92	0.227	0.295	76.9
Rangpursadar	1280	30.60	5.01	0.251	0.301	83.5

Note: Average value of three replications, width covered per pass of the weeder is 0.6 m.

Table 11. Field performance of the BRRI manual weeder and hand weeding capacity.

Place	Area of operation (m^2)	Operational time (m)	Forward speed of operation (km hr^{-1})	Actual field capacity (ha hr^{-1})	Theoretical field capacity (ha hr^{-1})	Field efficiency (%)	Manual weeding capacity (m^2 hr^{-1})
Gazipursadar	460	86.25	0.73	0.032	0.044	72.9	60.00
Sreepur, Gazipur	320	50.53	0.92	0.038	0.055	69.2	70.00
Bhaluka, Mymensingh	400	60.00	0.81	0.04	0.049	82.3	45.00
Netrakonasadar	350	59.66	0.74	0.0352	0.044	79.5	80.00
Habiganjsadar	320	43.64	0.94	0.044	0.056	78.2	52.50
BRRI RS Cumilla	425	79.69	0.82	0.032	0.049	65.4	45.00
Rangpursadar	425	55.43	0.89	0.046	0.053	86.3	85.00

Weeding efficiency. Weeding efficiency (WE) of weeder depended on weed severity, soil moisture, weeding regime, operator conditions and soil conditions. Two-way interaction of weeding methods and locations showed significant effect on weeding efficiency of the weeder as the weeding method was significant (Table 12). Manual weeding practices showed significantly higher weeding efficiency over the mechanical weeding efficiency due to weed uprooted manuallyin between hill to hill, whereas mechanically can't be done. In all cases, significantly lower weeding efficiency was observed for BRRI manual weeder.

Weeds dynamic. Weed dynamics depends on the weeding quality, soil moisture, weeding regime and soil conditions. Two-way interaction of weeding methods and locations was not observed significant effect on weeds dynamics whereas single effect of locations and weeding methods showed significant effect on weeds dynamics (Table 13). Weeds dynamics observed significantly higher for BRRI manual weeder and farmers practices. Weeds dynamics was also observed minimum in both the locations of Gazipur compared to the other locations of the country.

Weed control efficiency. Weed control efficiency depended on the weeds density of the weedy check plots and weeding efficiency. Two-way interaction effect of the different weeding methods and locations was not significant whereas single effect showed significant effects on weed control efficiency (Table 14). Significantly lower weed control efficiency was found for BRRI manual weeder whereas it was observed similar in all locations except Netrakona where higher weed control efficiency was found.

Crop performance

Plant height. Plant height was counted at every 15 days after transplanting. Different weeding methods did not affect significantly on plant height at all locations of the study except Shreepur, Gazipur where weedy check gave significantly lower plant height after 45 days of transplanting (Fig. 15).

Table 12.Weeding efficiency as affected by different weeding methods over the locations.

Treatment	$Gazipur_1$	$Gazipur_2$	Mymensingh	Netrakona	Habiganj	Cumilla	Rangpur	Mean
T_1	74.667	77.41	81.593	80.933	85.467	75.207	77.253	78.93 b
T_2	68.9	75.827	69.75	73.733	67.61	61.13	68.04	69.28 c
T_5	92.867	87.333	76.667	82	89.367	94.713	85	86.85 a
Mean	78.811	80.19	76.003	78.889	80.814	77.017	76.764	
CV				6.41				
LSD				T=3.13 and L × T = 8.28				
LoS				L=ns, T=*ns and L × T = *				

Note: T_1 - One weeding by power weeder (BPW) followed by (fb) one hand weeding (HW), T_2 - One weeding by BRRI manual weeder (BW) fb one HW, T_5 - Mulching fb two HW (Farmers' practice), NS-Not significant, *Significant at the 5% level, **Significant at the 1% level, LoS-level of significance, L-location, T- Weeding methods.

Table 13. Weed dynamics after 1st weeding as affected by different weeding methods over the locations.

Treatment	$Gazipur_1$	$Gazipur_2$	Mymensingh	Netrakona	Habiganj	Cumilla	Rangpur	Mean
1	74.667	77.41	81.593	80.933	85.467	75.207	77.253	16.73 b
2	68.9	75.827	69.75	73.733	67.61	61.13	68.04	20.98 a
5	92.867	87.333	76.667	82	89.367	94.713	85	21.82 a
Mean	14.464 b	13.64 b	21.89 a	21.11 a	22.59 a	22.85 a	22.34 a	
CV				24.83				
LSD				L=4.69 and T=3.07				
LoS				L=*, T=** and L × T = ns				

Table 14. Weed control efficiency after 1st weeding as affected by different weeding methods over the locations

Treatment	$Gazipur_1$	$Gazipur_2$	Mymensingh	Netrakona	Habiganj	Cumilla	Rangpur	Mean
1	77.17	66.1	53.67	77.33	86.73	69.07	82.17	73.18 ab
2	75.533	75.63	60.53	67.93	61.43	71.03	59.53	67.38 b
5	92.867	73.83	48.97	74.2	88.53	94.53	84.27	79.6 a
	81.856 a	71.86 a	54.39 b	73.16 a	78.9 a	78.21 a	75.32 a	
CV				17.87				
LSD				L=12.495 and T= 8.1796				
LoS				L=**, T=* and L × T = ns				

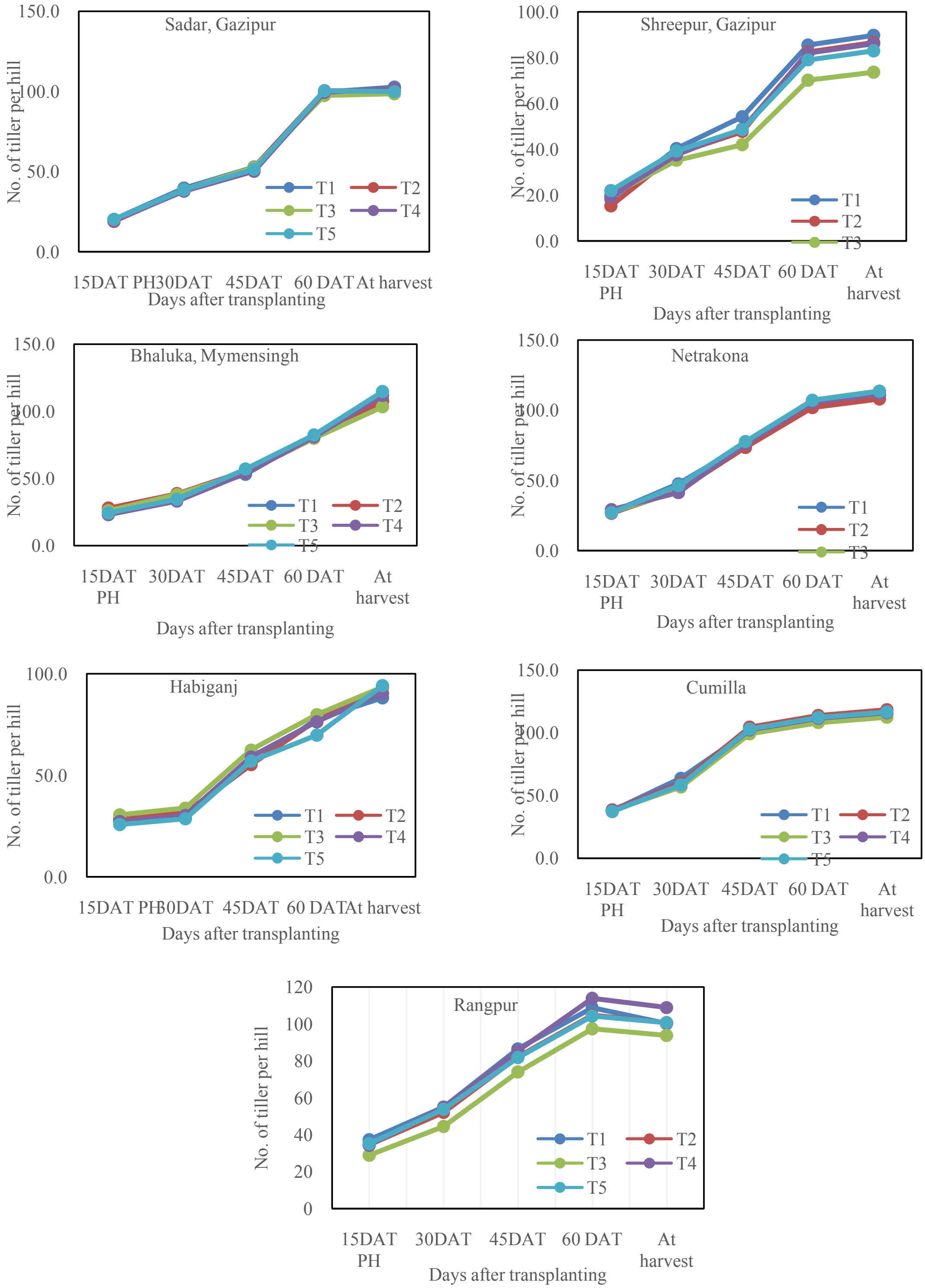


Fig. 15. Plant height with respect to days after transplanting as affected by weeding methods at different study locations.

Number of tiller. Figure 16 presents number of tiller per hill at different dates after transplanting varied with the mode of weed management practices. Number of tiller of the studied variety was counted at every 15 days after transplanting (DAT). Most of the places, number of tiller per hill didn't varied significantly with the different weeding management methods upto 30 DAT except Gazipur sadar whereas significant difference was observed at 45, 60 DAT and at harvest time. In all cases, weedy check plots produced significantly lower number of tiller per hill. Power weeder operated plots produced significantly higher number of tillers per hill along with BRRI manual weeder and weed free plots followed by farmers' practices plots.

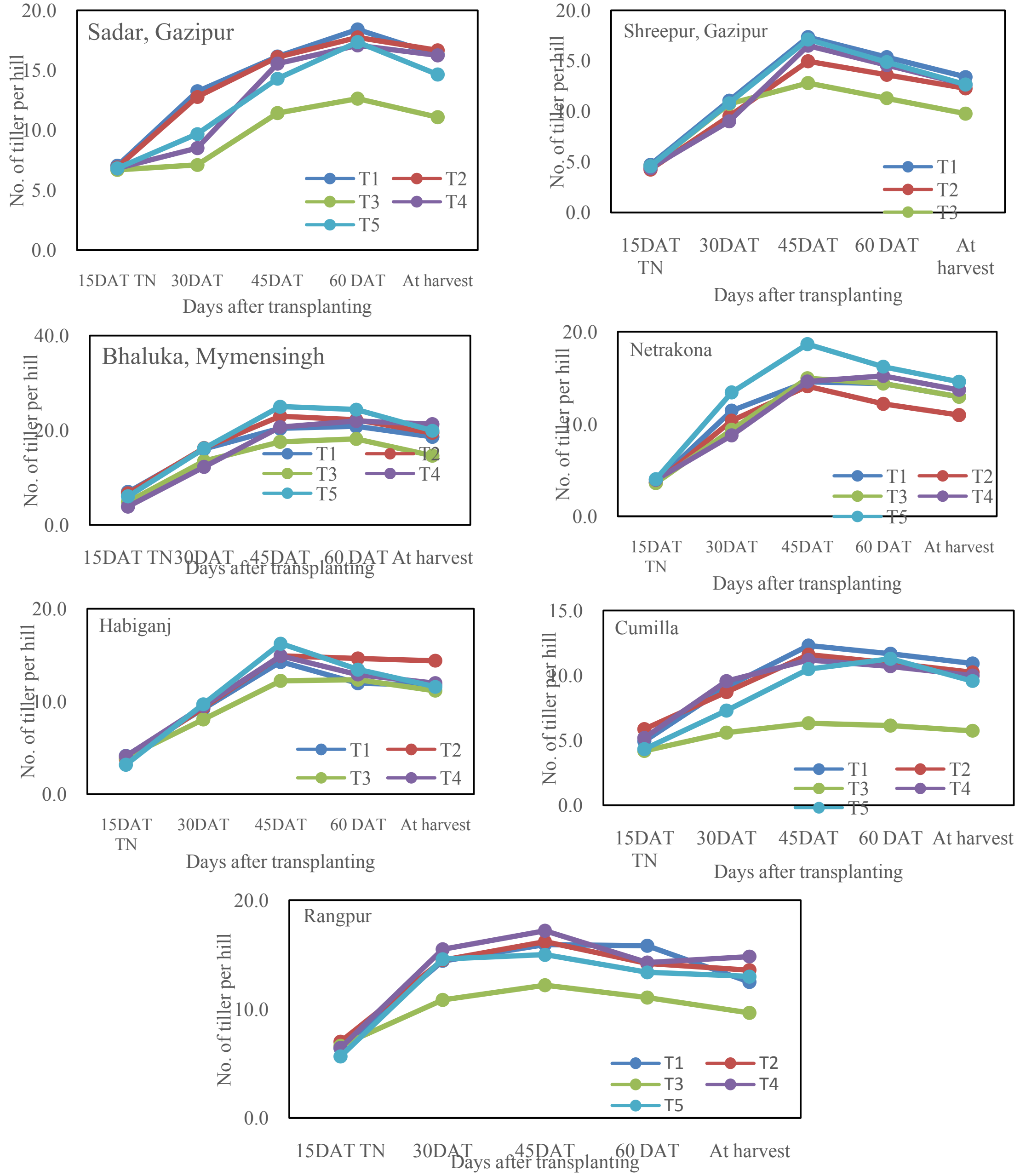


Fig. 16. Plant population with respect to days after transplanting as affected by weeding methods at different study locations.

Grain yield performance

Significantly lower yield was obtained at Sreepur, Netrakona and Habiganj compared to the potential yield of the variety. At Sreepur, crops were damaged by severe hail storm during vegetative periods and late transplanting was the main causes of less yieldat Netrakona and Habiganjdue to late irrigation scheme started. However, crop yield was not varied significantly with the weeding management practices at Sreepur, Gazipur. Weed control methods did not affect significantly on crops yield at Gazipursadar, Rangpur, Cumilla and Bhaluka except weedy check plots which produced lower yield. However, weedy check plots gave significantly lower yields in all cases followed by BRRI manual weeder weeded plots at Netrakona. At Habiganj, BRRI manual weeder weeded plots along with weedy check gave lower yield followed by farmers practices.

BRRI multi-row power weeder was found suitable in operation under different soil conditions of Bangladesh and benefited over traditional weeding practices. Considering filed capacity, weeding efficiency, weed control efficiency and save Tk 5,384/- per hectare over traditional weeding practices, BRRI multi-rows power weeder could be suggested for dissemination after large scale validations.

MILLING AND PROCESSING TECHNOLOGY

Test, evaluation and modification of rubber roll de-husker

Modified rubber roll de-husker was used to improve the performance of rice processing operates with a 4 kW (3-phase 4 wire 1440 rpm) electric motor. Two rubber roll rotated 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 1043.7. Another is adjustable rubber roll having same diameter and length as fixed rubber roll and RPM of the adjustable rubber roll is 783. Blower 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. Bottom end of the de-husker connected with a husk aspirator through a pipe (dia. 200 mm).

Table 19. Yield performance as affected by different weeding methods.

Treatment	Yield at 14% MC (t ha^{-1})						
	Gazipur (BRRI dhan28)	Sreepur (BRRIdhan28)	Rangpur (BRRI dhan58)	Netrakona (BRRI dhan89)	Cumilla (BRRI dhan89	Habiganj (BRRI dhan29)	Bhaluka (BRRI dhan28)
T_1	4.57 a	4.44	4.93 a	5.64 a	5.77 a	4.16 ab	4.93 a
T_2	4.32 a	3.08	4.95 a	5.10 bc	5.63 a	3.48 c	5.90 a
T_3	3.13 b	2.86	4.48 b	4.80 c	3.55 b	3.15 c	2.39 b
T_4	4.60 a	3.47	5.26 a	5.63 a	6.46 a	4.39 a	4.96 a
T_5	4.09 a	3.61	5.07 a	5.32 ab	5.97 a	3.90 b	5.30 a
CV, %	6.58	22.24	5.5	5.0	16.19	8.07	14.63
LoS	**	ns	**	**	**	**	**

Note: T_1 - One weeding by power weeder (BPW) followed by (fb) one hand weeding (HW), T_2 - One weeding by BRRI manual weeder (BW) fb one HW, T_3- Weedy check, T_4 - Weed free and T_5 - Mulching fb two HW (Farmers' practice), NS-Not significant, LoS-level of significant.

Table 20.Power weeder operational cost over traditional method.

Mechanical weeding (BMPW)					Traditional weeding (HW)			
Price (Tk)	T. fixed cost (Tk/hr)	T. variable cost (Tk/hr)	Op. cost (Tk/hr)	Op. cost (Tk/ha)	Manual capacity (decimal/hr)	Capacity (hr/ha)	Cost, Tk/ha	Save over traditional (Tk/ha)
30000	37.12	119.78	156.91	790.93	2	123.5	6175	5384.06

Note: Life: three years, Annual use: 320 hrs and Capacity: 49 decimal/hr.

Aspirator fan (dia.330 mm) operates by 1.5 kW (2840 rpm) motor (Plate 1 and 2). A cyclone separator attached in the de-husker for collecting husk. Rubber roll de-husker does not damage the aleuronic layer of paddy. An airstream is blown over the grains and immature grains drop into the separate hopper for discharge. The paddy and husk discharged separately. BRRI dhan81 (un-parboiled) was used in this experiment. The moisture content was 11.0 % (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 found 665 kg h^{-1} and husking efficiency was about 91.3% (Table 21). Husking efficiency can be increased by closing the adjustable roller which increases the broken percentage of brown rice. The average brown rice percentage was found 78% and the rest was husk and embryo. Average fixed and adjustable rubber roll rpm was found 1043.7 and 783 respectively.

Adjustable rubber roll rotate 24.94 % less rpm than the fixed rubber roll. The difference in peripheral speed subjects the paddy grain falling between the rolls to a shearing action that strips off the husk. The clearance between the rolls is adjustable and it should be less than the thickness of the grain.

Evaluation of milling parameter of BRRI dhan81 processed in friction type polisher

Brown rice of BRRI dhan81 from rubber roll de-husker was polished in friction type polisher (Plate 3 and 4). The average capacity of the polisher was 675 kg/h and the average milling recovery was 63.7%. The average head rice recovery (based on input paddy) was 55.0% and head rice recovery (based on total milled rice) was 86.44% (Table 22). The broken rice percentage was 8.6% (based on input paddy) and 13.60% (based on total milled rice).

Plate1. Modified de-husker

Plate 2.Husker in operation

Table 21.Performance of de-husker for BRRIdhan81.

Capacity (one pass) kg h^{-1}	Husking efficiency (one pass) %	Brown rice, % (based on input paddy)	Adjustable roll speed (rpm)	Fixed roll speed (rpm)	Ratio of fixed and adjustable roller
660	91	79.0	784	1045	24.97
665	92	77.0	783	1042	24.85
670	91	78.0	783	1044	25.00
665	91.3	78.0	783	1043.7	24.94

Table 22. Milling parameter of BRRI dhan81 processed in friction type polisher.

Capacity of polisher Kg h^{-1}	Milling yield %	Head rice, % (Based on input paddy)	Head rice, % (Based on total milled rice)	Broken rice, % (Based on input paddy)	Broken rice, % (Based on total milled rice)
668.0	64	55.2	86.25	8.8	13.75
676.0	63	54.8	86.98	8.2	13.00
680.0	64	55.0	86.11	9.0	14.06
675.0	63.7	55.0	86.44	8.6	13.60

Plate 3. Friction type polisher

Plate 4. Polisher in operation

Husking efficiency was found around 91.3% for BRRI dhan81 de-husked in rubber roll de-husker. Milling recovery of BRRI dhan81 was 63.7% polished in friction type polisher followed by de-husking. The average head rice recovery based on input paddy was 55.0%, which is promising for processing of premium quality rice. Engelberg huller may be replaced with the combination of one rubber roll de-husker and polisher for better quality rice. Beside this, rubber roll de-husker separate husk and friction type polisher separate bran. Separately collected husk and bran is suitable for briquette and edible oil production.

Effect of milling degrees (DoM) on rice quality

FMPHT Division and Harvest Plus jointly conducted research on 'Processing of rice for zinc efficacy study', which programme funded by IFPRI, Washington, DC, USA.BRRI dhan28 and BRRI dhan42 were collected from the Ali seed farm, Jashore to determine the milling effect. The experimental sample was prepared for DoM, whiteness, head rice yield (HRY) determination and zinc (Zn) and iron (Fe) content (Table 23) as per various sample sizes and manufacturer recommended (for analysis).

Number of samples: 6 (Brown rice, 7.5, 10, 12, 13.75 and 15% of DoM)

Replication: three

Estimation of Zn and Fe content (ppm)

Grain zinc and iron content were estimated in the brown rice (De-husked unpolished grain) and polished rice (7.5, 10, 12, 13.75 and 15% of DoM) from the selected variety. The zinc content was calculated using X-ray fluorescence (XRF) machine at HarvestPlus laboratory in Bogura. The instrument was switched on 24 hours before the time when observations were to be recorded. Initially, five grams of grains were subject to XRF as a standard to check the calibration of the equipment. Then the samples of the two genotypes were subjected to XRF and the concentration was recorded in ppm. Three replications were maintained and their average was considered. In polished rice, large variation in iron and zinc was observed among the varieties. Twelve parboiled rice samples, six of each variety, were analyzed with three repetitions using XRF machine. It was observed that the zinc content of both the varieties decreased with the increase of milling degree indicating that the zinc is reduced during milling. Statistically significant difference in zinc content of two varieties was found up to 12%DoM. It is interesting that after 13.75% DoM, no difference in Zn content was found for both bio-fortification and not Zn enriched varieties (Fig.17). Similar trends were found for iron content in the parboiled grain of these two varieties (Fig.18).

Table 23. The sample optimization.

Item	Number of sample	Amount/each
Degree of milling (DoM)	36	200 gm
Whiteness of rice	36	200 gm
Head rice yield	36	1000 gm
Estimation of Zn and Fe content	72	10 gm

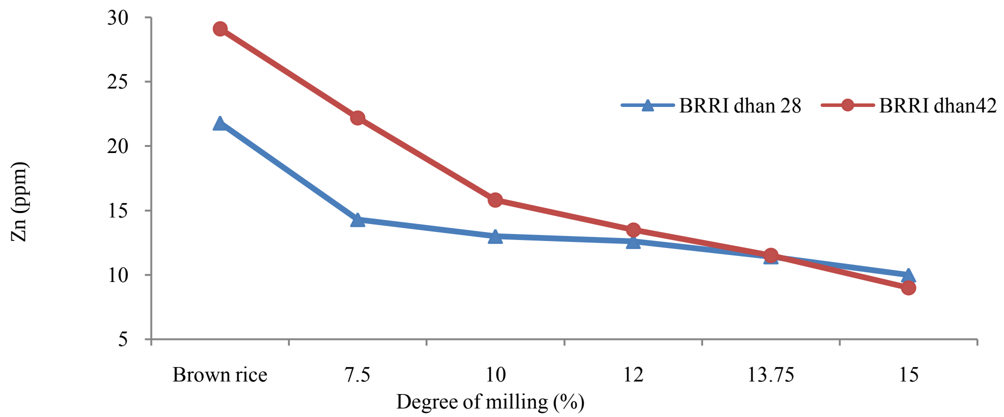


Fig. 17. Trend of zinc reduction in parboiled grain of two varieties at different degree of milling (DoM).

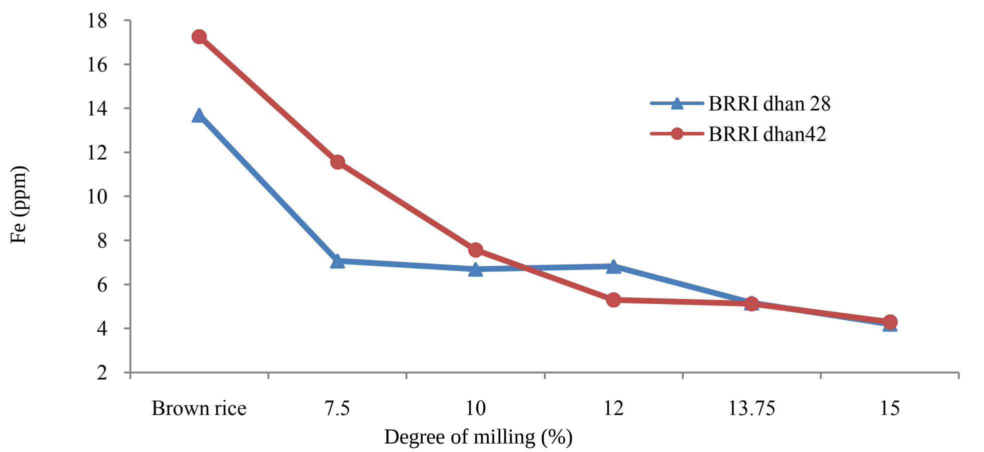


Fig. 18. Trend of iron reduction in parboiled grain of two varieties at different DoM.

Head rice yield

The main aim of milling process is to get maximum head rice yield. The rice kernels which are three quarters or more in length as compared to the length of original kernels obtained after complete milling is termed as head rice. Head rice yield (HRY) can be defined as the ratio of weight of milled rice kernels obtained in percentage of the weight of rough rice or paddy by the following equation.

$$HRY=\left(\frac{Wt.\ of\ milled\ \ head\ rice}{Wt.\ of\ roug\,h\ \ rice\ or\ paddy}\right)*100$$

During milling, increase of DoM the broken percentage increases due to low surface hardness which in turn leads to low quality and low recovery of milled rice. Figure 19indicates that there had negative relationship between DoM and head rice yield.

Whiteness

Variation in the whiteness of rice depends upon the amount of bran present on rice kernels. Moreover, whiteness of milled rice, sometimes dependent on variety. The whiteness was determined by Kett Instant Whiteness Tester (Model: C600). Rice is needed to polish in between 7-10% for human consumption and nutritional aspect. But DoM affects not only the quality but also the appearance of rice kernels. Figure 20 shows that the Do M and whiteness are positively correlated.

Weight loss

In general, de-husk brown rice exhibited more weight compared to polished rice (Fig. 21). This was due to increase of Do M decrease in size of individual grain. The standard degree of milling is 10% and it goes more termed as over polished (FAO). The brown rice and below 7.5% DoM is problematic for digest as a daily consumption. It is clearly shown in figure 21 that more food loss occurred due to more degree of milling, hampers the food security of a nation.

It can be concluded from these results, over DoM affect the losses of Zn and Fe content as well as lower head rice recovery. However, the experiment could be conducted in more details with the help of Harvest Plus.

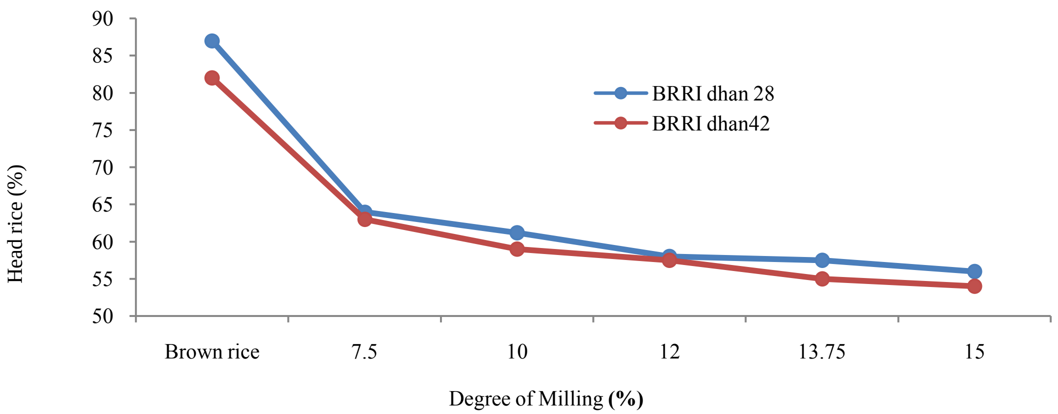


Fig. 19. Relationship between head rice recovery and DoM.

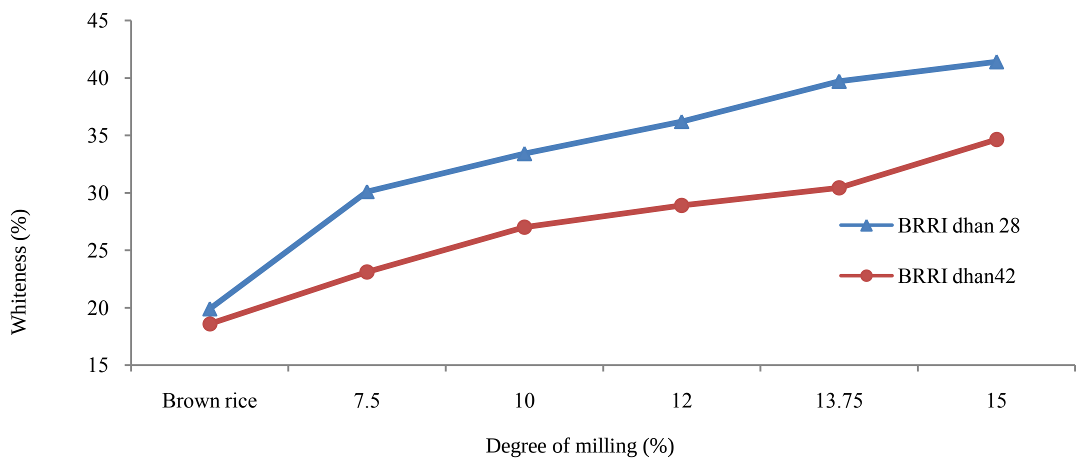


Fig. 20**.** Relationship between whiteness and degree of milling.

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 in the BRRI research workshop using locally available materials. The multiplication was done in a local manufacturing workshop with the help of BRRI provided design, guidance and project financial support, thereby manufacturing capability was enhanced of that workshop. The fabricated solar light trap was tested in the field and observations were done. MS sheet and angle bar, MS pipe, nuts, bolts, solar panel, controller, battery, DC bulb, electric cable were used for fabricate the solar powered light trap.The AutoCAD Design and design view of solar light trap shown in Figs. 22 and 23.

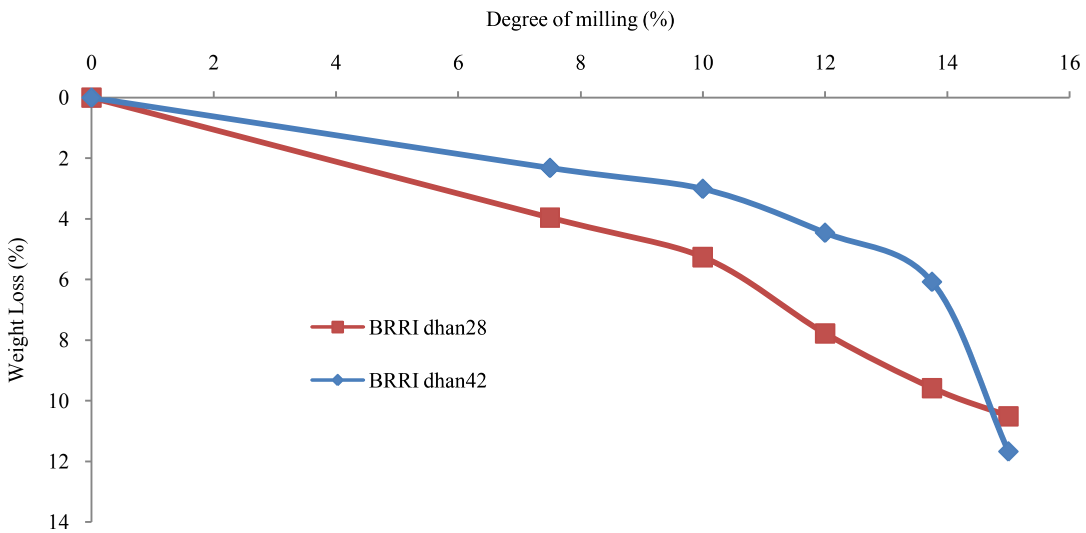


Fig. 21. Relationship between whiteness and degree of milling.

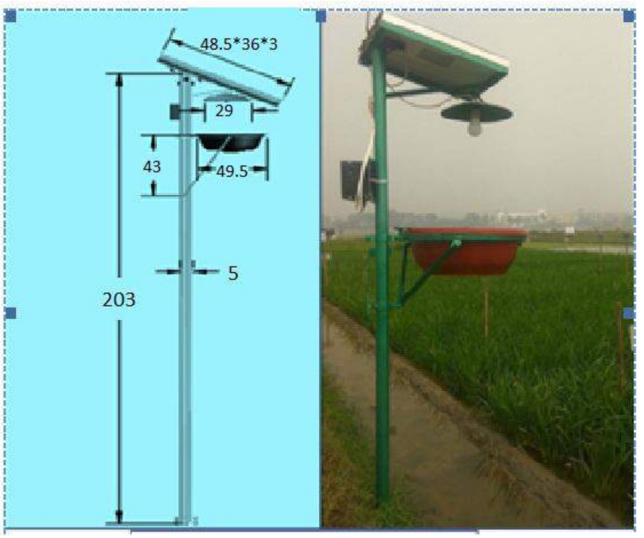


Fig. 22. AutoCAD design of BRRI developed solar light trap

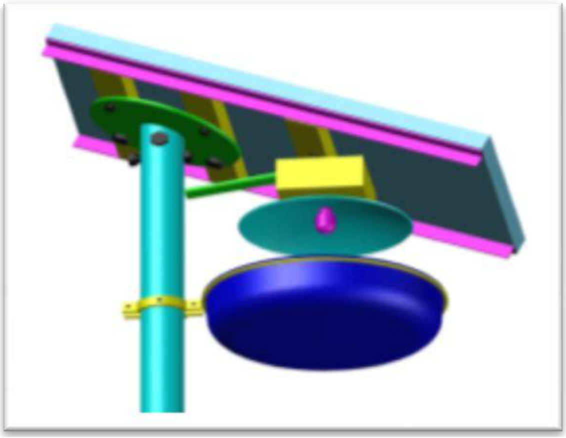


Fig.23. Design view of the prototype of solar light trap.

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 each separate plot. The pilot research and field trials were conducted at five locations in Bangladesh including Narsingdi, Bogura, Jashore and Khulna. Selected five solar light traps from each location were for insect pest catches and each light trap were monitored on a daily basis. 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. No insecticide/ chemicals were used in the trialfield. One rice plot similar area to trap treated plots was remained under farmers' practice. Three solar light traps were used inper hectare area.

The stand of the trap was divided into two parts for ease of packing and movement from one place to another. Two parts (male and female) were joined with facilitating the pipe creating two holes that anchoring with two nuts. Table 24 presents the newly developed solar light trap specification.

As per specification and design, 120 frames of 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 solar light trap was tested in the FMPHT Divisional research area for testing of bulb, duration light hour and load test. Test results showed that battery can back up the bulb for light emission with the duration of 3.5-4 hours. After completion all test and observation the solar light trap was distributed and installed in the project site of Bogura, Jashore, Narsingdi, Gazipur, Sherpur and Khulna in the farmers' 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 were demonstrate at the 14 locations of the project site and more than 500 progressive farmers', mechanic, NGO personnels attended in these demonstration cum training programmes. BRRI scientist had given a brief description on solar light trap operation, repair and maintenance during training programme. Farmer's opinions regarding this trap were also recorded. Almost all the farmers' told that it is a magic machine and a lot of insect pests were trapped in the light trap and every day they cleaned the trapped insect pests and damp under the soil.

Adaptive field trial cum research of solar light trap was conducted in Bogura, Jashore, Narsingdiand 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 at every location. This report shows only two months data of rice insect pests that were caught in light trap (Fig. 24).

Table 24. Specification of BRRI developed solar light trap.

Solar panel	20W (16.8V)
Auto control	Input 20 volt DC and output 12V DC(No dangerof short circuit, electric shock and lightning)
Battery	DC 12 V (6V X 2), AH : 4.5, Lead acid battery with operating time 3.5-4 hrs
Bulb	DC 12V, 3W UV led, pest attractive bulb
Weight	Approximately 12 kg
Dimension	Main body: Net length90 inch, bowl dia. 20 inch and 2 inch dia. steel pipe
Type of product	Eco friendly
Type of energy	Solar energy
No of legs	01
Battery charging hours	8to 10
Set up working area	1 acre per light trap
Set up working hours	3.5- 4.0 hours
Type of moment	Flexible
Type of bulb colour	Bluish

Fig. 24. Insect pests trapped in light trap.

Rice insect pests including yellow stem borer (YSB), green leafhopper (GLH), white leafhopper (WLH), leafroller (LR), caseworm (CW), brown planthopper (BPH), mole cricket, field cricket, grasshoppers, rice bug (RB) and vegetable insect pest such as brinjal shoot and fruit borer (BSFB) in solar light trap in each location. Highest numbers of insect pests were trapped in May than that of April. The highest incidence of YSB was observed at May followed by GLH showed in Fig. 25. More than 900 YSB could be caught in each light trap per month inJashore site. This result indicates that solar light trap would be a promising pest control tool in rice field as well vegetable crops in Bangladesh. Data also recorded on 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 the control (farmers plot). This result indicates that use of solar light traps both in rice and vegetable crops are very much effective to control and monitor insect pests.It can also be used an effective tool for sustainable pest management system when incidence of insect pests remain in peak position. Use of solar light trap reduces chemical insecticide use and it saves the environment. The farmers showed high interest to use this solar light trap in their crop field. More solar light traps demanded for large scale field demonstration and distribution among the farmers.

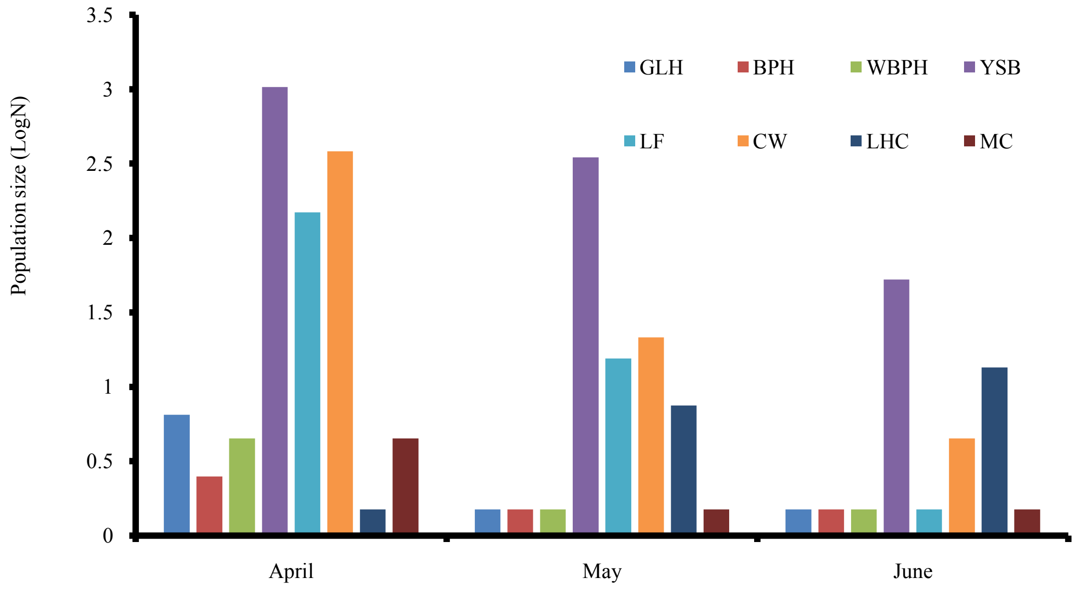


Fig. 25. Rice insect pest trapped in solar light trap at Chowgacha, Jashore during Boro 2018-19. YSB= yellow stem borer, GLH= green leafhopper, WLH= white leafhopper, LF= leafroller, CW= caseworm, and RB= rice bug.

Feasibility of rice straw for biomass briquette production

Normally rice husk and straw is used as briquette material and fuel, cattle feed as well as packing material in different industries in Bangladesh. If rice straw can be used as briquette then fuel efficiency will be increased. That's why an initiative was taken to produce briquette mixing rice husk along with dry rice straw at different ratio. Rice husk was collected from FMPHT Divisional rice mill and rice straw was collected from Farm Management Division and dried it's in FMPHT Division in the range of 6-16% moisture content. Then this straw was chopped by chopper machine into small size (2-3 cm). Briquette machine with 30 kW motor (screw press densification technology), power supply (3 phase, 4 wire), chopper machine, thermometer, balance, scale, cylindrical container, calorific value meter rice husk and straw were used as materials to conduct the study. Screw press densification technology was used to make briquette. The die temperature was maintained in between 250°C to 300°C that enhance agglomeration of the material occurs as a result of the pressure-induced intimate contact between particles and release lignin from the biomass. Basically, material is gravity fed from a storage hopper into a lower chamber, where it encounters a rotating, tapered screw feed mechanism. This forces the granular material into a tapered, heated barrel (or die) in which high compaction pressures are generated. Lignin release is enhanced by heating the extrusion barrel to a temperature of perhaps 400°C, giving a surface temperature in the compacted material of a little over 300°C.

Treatments

T_1: 10% straw + 90% husk
T_2: 20% straw + 80% husk
T_3: 30% straw + 70% husk
T_4: 40% straw + 60% husk
T_5: 50% straw + 50% husk

Physical characteristics of rice husk-straw briquette, straw size and moisture content of husk, straw and briquette were determined. Figure 26 illustrates percentage productions of briquette. The percentage productions of briquette were decreased with the increased percentage of straw.The average density of husk and straw are 128 kg/m^3 and 89 kg/m^3. Figure 27 shows the density of produced briquette decreased with the increased of rice straw.

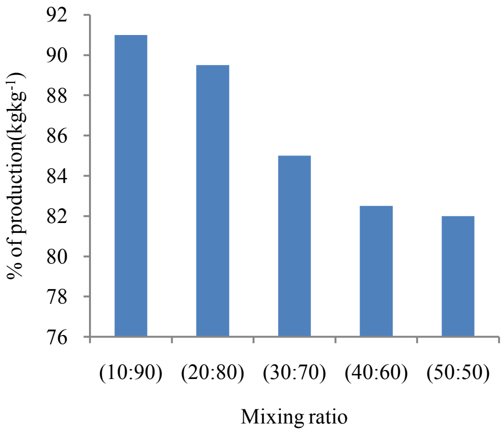


Fig. 26. Percent of production ($kgkg^{-1}$) with various mixing ratio.

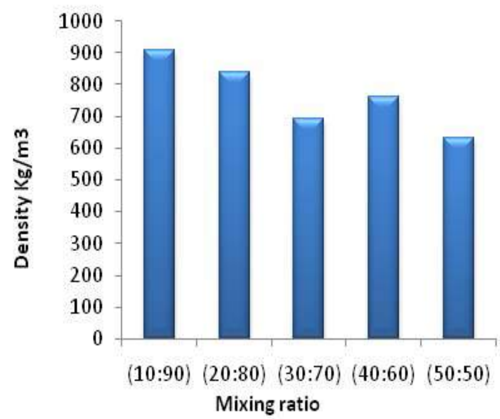


Fig. 27. Density of briquette with various mixing ratio.

Workshop Machinery and Maintenance Division

SUMMARY

In dry land, reaper performed well in harvesting of rice. But in wet land its performance was not smooth. Thus, the reaper travelling wheel was modified increasing the width of the wheel and fabricated at BRRI Research Workshop. The width of reaper travelling wheel was increased to resist the soil resistive force. It has been tested in the semi-wet paddy field at BRRI HQ farm, Gazipur. It performed well at semi-wet land condition due to the increased contact area between the reaper travelling wheels. It will be tested in wet land condition.

The effects of tillage depths on the productivity of paddy were determined in field experiments in Aman 2018 at research farm of BRRI RS, Rajshahi and in Boro 2019 at research farm of BRRI RS, Rajshahi and Rangpur in different tillage depths. There were five tillage depths i.e. 2-3, 3-4, 4-5, 6-7 and 7-8 inches. Tillage depths affected tiller, panicle number and yield of BRRI dhan34 in Aman 2018, BRRI dhan28 at Rajshahi and BRRI dhan63 at Rangpur in Boro 2019 season. Tiller and panicle number of plant also increased with the increase of tillage depth. Plant height, plant dry weight, root length and root dry weight of cultivated paddy were increased with the tillage depth at both Aman and Boro seasons. These were found highest in 6-7 inches tillage depth and nearly same in 7-8 inches tillage depth. The highest grain yield was found 2.55 t ha^{-1} and 5.22 t ha^{-1} in the tillage depth of 6-7 inches and lowest yield was found 2.00 t ha^{-1} and 3.98 t ha^{-1} in the tillage depth of 2-3 inches in Aman 2018 and Boro 2019 respectively at BRRI RS Rajshahi. At Rangpur the highest grain yield was found 7.46 t ha^{-1} in the tillage depth of 7-8 inches and the lowest yield was found 6.33 t ha^{-1} in the tillage depth of 2-3 and in 6-7 tillage depth inches the yield was found 7.40 t ha^{-1}. Number of tiller, panicle, yield of both the 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 for paddy cultivation.

Different kinds of farm machinery had been used in the farmers' field and these are power tiller, shallow tube well, pedal thresher, open drum thresher, close drum thresher, sprayer etc. The questionnaire survey was conducted on machinery used in farmer's field at Dharabazar of Netrakona district and Krishnapur village of Magura district. A number of machinery were used in these villages and these were power tiller, shallow tube well, engine operated pedal thresher and sprayer. Only one close drum thresher was used in Krishnapur village of Magura district. There were no rice transplanter, reaper, combined harvester at the farm level of these areas. So, there is a scope to introduce these machinery in these areas. The problem was that the operator 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 operator.

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. Arafat engineering workshop, Dinajpur was surveyed by follow the questionnaire. The facilities of machinery of the workshops were lathe, shaper, drill, grinding and welding. It produced different kinds of agricultural machinery using locally available materials in their workshops. Open drum thresher, and close drum thresher were the common machinery produced by the local manufacturers.

Solar operated grain cleaner was designed and developed. DC motor (0.5 hp) and an accelerator were incorporated to operate the blower of the cleaner. Then it was tested in cleaning of threshed paddy in Boro 2019. Its capacity was found 560 kg/hr. Pedal thresher was modified to use solar energy in threshing of paddy. Its performance was evaluated in Boro and Aman season 2018. Revolution per minute (RPM) of it was 300. Two operators can thresh paddy simultaneously. Capacity of paddy threshing in modified pedal thresher using solar energy was found 320 kg/hr. Solar energy was used to thresh paddy at BRRI threshing yard in Aman 2018 and Boro 2019 successfully.

There was different kinds of transport/vehicles and farm machinery at BRRI. Repair and maintenance works of these were done by WMM Division. Repair works and change 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

67,68,503 from July 2018 to June 2019. Among these major repair and maintenance cost was Tk 50,04,730 and moderate/minor repair and maintenance cost was Tk 17,63,773. The major repair and maintenance work was done by direct cash purchase, direct contracting through work order and RFQ (Request for quotation). On the other hand, the moderate/minor repair and maintenance work was done only by using the revolving fund.

DEVELOPMENT OF AGRICULTURAL MACHINERY

Modification of reaper travelling wheel for wet land condition. The contact area between the reaper travelling wheels and soil has been increased by increasing the width of the reaper wheels to increase the soil resistive force. Fabrication of the reaper wheels have been completed according to the design using the locally available materials at BRRI Research Workshop. A second version of travelling wheel had been developed by increasing the width of the wheel (21 cm but the old was 9 cm) and fabricated at BRRI Research Workshop. The width of reaper travelling wheel was increased to increase the soil resistive force. It has been tested in the semi-wet paddy field at BRRI HQ farm, Gazipur. It performed well at semi-wet land condition. But the weight of the wheel of the 2nd version was high which was a problem to operate it in the wet land. A 3rd version have been developed having 25 cm width and weight was half of the 2nd version (Fig. 1). It will be tested in next season.

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 significantly affected 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 that needs intensive field research.

Experiments were conducted in Aman 2018 as well as Boro 2019 at BRRI RS, Rajshahi and BRRI RS, Rangpur to determine paddy yield as influenced by different tillage depths. There were five different tillage depths such as: 2-3, 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. 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 eight days after transplanting. Applying irrigation, weeding and other intercultural operations were done 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.

Tiller and panicle number were increased over tillage depth (Tables 1 and 2). Grain yield of BRRI dhan34 in Aman 2018 and BRRI dhan28 in Boro 2019 were varied from different tillage depths in Rajshahi and BRRI dhan63 in Rangpur. Plant height, dry weight, root length and root dry weight of cultivated paddy were increased with tillage depth at Aman and Boro seasons (Tables 3, 4 and 5). These were found highest in 6-7 inches depth of tillage and nearly same in 7-8 inches depth of tillage.

The highest grain yield was found 2.55 t ha^{-1} and 5.22 t ha^{-1} in the tillage depth of 6-7 inches and the lowest yield was found 2.00 t ha^{-1} and 3.98 t/ha in the tillage depth of 2-3 inches in Aman 2018 and Boro 2019 respectively at RS Rajshahi (Table 6). At Rangpur the highest grain yield was found 7.46 t ha^{-1} in the tillage depth 7-8 inches and the lowest yield was found 6.33 t ha^{-1} in the tillage depth of 2-3 but the yield was more or less same at 6-7 inches and 7-8 inches tillage depths (Table 7).

Table 1. Tiller and panicle number of cultivated paddy at Aman 2018 and Boro 2019 in Rajshahi region.

Tillage depth (Inch)	Aman 2018 (BRRI dhan34)		Boro 2019 (BRRI dhan28)	
	Tiller no./12 hill	Panicle no./12 hill	Tiller no./12 hill	Panicle no./12 hill
2-3	103	93	155	150
3-4	113	109	182	175
4-5	121	116	186	176
6-7	124	120	215	205
7-8	120	117	218	206

Table 2. Tiller and panicle number of cultivated paddy at Boro 2019 in Rangpur region.

Tillage depth (Inch)	Boro 2019 (BRRI dhan63)	
	Tiller no. /12 hill	Panicle no. /12 hill
2-3	148	135
3-4	161	150
4-5	164	157
6-7	197	179
7-8	200	189

Table 3. Plant height and plant dry weight at Aman season 2018 and Boro 2019 in Rajshahi region.

Tillage depth (Inch)	Aman 2018		Boro 2019	
	Average plant height (cm)	Average plant dry weight (g)	Average plant height (cm)	Average plant dry weight (g)
2-3	100.50	21.25	88.40	22.74
3-4	108.50	23.30	88.80	23.28
4-5	115.00	27.67	90.60	24.15
6-7	117.50	29.00	94.30	27.82
7-8	114.60	28.00	92.30	26.51

Table 4. Root length and root dry weight of cultivated paddy at Aman season 2018 and Boro season 2019 in Rajshahi region.

Tillage depth (Inch)	Aman 2018		Boro 2019	
	Root length (cm)	Average root dry weight (g)	Root length (cm)	Average root dry Weight (g)
2-3	21.10	10.80	12.38	10.66
3-4	21.80	11.00	12.88	10.77
4-5	22.60	13.30	15.38	13.80
6-7	23.50	14.00	17.38	13.87
7-8	23.00	13.90	18.13	14.00

Table 5. Root length and root dry weight of cultivated paddy at Boro season 2019 (BRRI dhan63) in Rangpur.

Tillage depth (Inch)	Average plant height (cm)	Average plant dry weight (g)	Root length (cm)	Average root dry weight (g)
2-3	83.10	45.23	13.50	18
3-4	83.90	48.25	14.00	20.75
4-5	83.90	55.25	15.25	22.75
6-7	84.10	56.63	16.63	24
7-8	86.00	57.00	17.25	24.25

Table 6. Yield of paddy with different tillage depths in Rajshahi.

Year	Season	Paddy	Tilling depth (Inch)	Paddy yield (t ha^{-1})
2018	Aman	BRRI dhan34	2-3	2.00
			3-4	2.06
			4-5	2.34
			6-7	2.55
			7-8	2.50
2019	Boro	BRRI dhan28	2-3	3.98
			3-4	4.43
			4-5	4.73
			6-7	5.22
			7-8	5.10

Table 7. Yield of paddy with different tillage depths in Rangpur.

Year	Season	Paddy	Tilling depth (Inch)	Paddy yield (t ha^{-1})
2019	Boro	BRRI dhan63	2-3	6.33
			3-4	6.67
			5-6	6.82
			6-7	7.40
			7-8	7.46

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 used in farmer's field at selected areas. Different kinds of farm machinery had been used in these villages and the machinery were power tiller, shallow tube well, sprayer, pedal thresher and open drum thresher. Some farmers were the owner of these machinery and some others used them by custom hire service. Table 8 shows that power tiller, shallow tube well, sprayer, pedal thresher and open drum thresher were 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. Irrigation and threshing are also fully mechanized in these villages. All the farmers of theses village used power tiller, shallow tube well and pedal or open drum thresher. The farmers of these villages used these machinery by purchasing or by custom hire service. 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. Table 9 shows rent/custom-hire service or share of total production and fuel consumption of power tiller, shallow tube well and thresher in these areas.

Table 8. Agricultural machinery used in the farmers' field.

Machinery	Personal	By custom-hire service
Power tiller	26	34
Shallow tube well	44	16
Sprayer	56	4
Pedal thresher	10	0
Open drum thresher	32	10
Close drum thresher	1	7

Table 9. Rent and fuel consumption of different machineriy.

Machine	Variable cost			
Power tiller	Rent of tiller (Tk/bigha)	Fuel requirement/bigha (Liter)	Time requirement/bigha (hr)	Fuel consumption (Liter /hr)
	660.00	5-6	2.00-2.50	2.50-3.00
Shallow tube well	Rent of shallow (Tk/hr)	Rent in Aman season (share of total production)	Rent in Boro season (share of total production)	Fuel consumption (Liter /hr)
	100.00	1/5	1/4	0.50
pedal thresher	Rent of thresher (Tk/day)	--	--	Fuel Consumption (lit/hr)
	100.00	--	--	0.50
Close drum thresher		1/8	1/8	1.00

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, combined 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 machinery were imported with a higher price and those 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.

Arafat engineering workshop, Dinajpur was surveyed. The facilities of machinery of the workshop were lathe machine, shaper machine, drill machine, grinding machine, welding machine (Table 10). It produced different kinds of agricultural machinery using locally available materials. Table 11 shows the result of the produced machinery by the manufacturer. Close drum thresher and open drum thresher were the common machinery produced by the manufacturer, and it also produced reaper and combine harvester by order basis. It had no facility of foundry works but 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 were the common materials used to make these machinery (Table 12). Manufacturer faced some problems to fabrication/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 extension of 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. They need subsidy and proper support from the government, which will help them to produce the machinery by improving their workshop.

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.)
Arafat Engr. Workshop	-	1	-	1	-	1	3		

Table 11. List of machinery produced by manufacturers.

Machine Workshop	Open drum thresher	Close drum thresher	Reaper	Combine harvester	Bed planter	Winnower	Weeder
Arafat Engr. Workshop	√	√	√	√	-	-	-

Table 12. Availability of used materials in workshop.

WorkshopMaterial	Metal sheet	Angle bar	Rod/ Shaft	Wood	Glass	Rubber
Arafat Engr. Workshop	√	√	√	√	√	√

Table 13. Problem of fabrication/manufacturing and marketing of agriculture machine.

Identity	Arafat Engr. Workshop
Lack of capital and credit facility	1
High cost of raw materials	4
High custom duty on finished product	6
Scarcity of skilled labour	2
Load shedding	5
Seasonality of demand	3

Feasibility study of solar energy use in agricultural machinery. The study was conducted primary on solar energy use in agricultural machinery. Photovoltaic system consists of 850 W solar panel was installed at BRRI automobile workshop to operate BRRI winnower and thresher. Solar operated grain cleaner was designed and developed. DC motor (0.5 hp) and an accelerator were incorporated to operate the blower of the cleaner. Then it was tested in cleaning of threshed paddy in Boro 2019 in (Fig. 2). Its capacity was found 560 kg/hr. Pedal thresher was modified to use solar energy in threshing of paddy. Its performance was evaluated in Boro and Aman season 2018 (Fig. 3). Revolution per minute (RPM) of it was 300. Two operators can thresh paddy simultaneously. Capacity of paddy threshing in modified pedal thresher using solar energy was found 320 kg/hr. Solar energy was used to thresh paddy at BRRI threshing yard in Aman 2018 and Boro 2019 successfully.

MAINTENANCE WORK OF WMM DIVISION

Repair and maintenance works of transports/vehicles and different farm machinery. Different kinds of transport/vehicles and farm machinery are used at BRRI. WMM Division of BRRI does repair and maintenance works of different kinds of transport/vehicles and farm machinery. There were 47 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 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 repair
- Minor CNG related trouble shooting and electrical works of vehicles
- Transport/vehicles/machinery cleaning and servicing

(a) **1st version (9 cm)** **(b) 2nd version (21 cm)** **(c) 3rd version (25 cm)**

Fig. 1. Reaper travelling wheel for dry and wet-land land condition.

Fig. 2. Solar power operated winnower.

Fig. 3. Solar power operated thresher.

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 shootings of these vehicles was totally done outside BRRI. A total of 47 vehicles (4-wheeler) in 700 times, 110 motor cycles and other farm machinery in 22 times were repaired and spare parts changed under moderate/minor repair and maintenance work (Table 14).

Major repair and maintenance work. There are seven types of repair and maintenance works:

- Major spare parts change and repair
- 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 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 Vehicle Solution, Ferajitola, Vatara, 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. Table 14 parents the major repair and maintenance cost and times of work of individual vehicles (4-wheeler), motor cycles, tractor/ power tiller/hydro-tiller from July 2018 to June 2019. A total of 47 vehicles (4-wheeler) in 700 times, tractor in 25 times, power tiller in 127 times, hydro tiller in 25 times and others were repaired and spare parts changed in BRRI workshop and outside of BRRI under major repair and maintenance work.

Total cost of major and moderate/minor repair and maintenance was Tk 67,68,503 from July 2018 to June 2019 (Table 14). Major repair and maintenance cost was Tk 50,04,730 and moderate/minor repair and maintenance cost was Tk 17,63,773 (Fig. 4). The moderate/minor repair and maintenance work (26%) was done only by using the revolving fund. On the other hand, the major repair and maintenance work (74%) 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 2018 to June 2019.

Type of vehicle	Vehicle/ Machine No.	Time of major works	Time of moderate/ minor works	Total number of works	Cost of major works	Cost of moderate/ minor works	Total cost (Taka)
Bus	0004	3	13	16	64,000.00	28,900.00	92,900.00
-do-	3831	7	27	34	4,64,720.00	70,202.00	5,34,922.00
Mini-bus	8430	2	16	18	24,500.00	16,270.00	40,770.00
Micro-bus	0034	4	15	19	1,03,000.00	51,590.00	1,54,590.00
-do-	0076	8	16	24	4,38,061.00	28,060.00	4,66,121.00
-do-	3870	8	11	19	2,23,020.00	1,19,330.00	3,42,350.00
-do-	0052	4	11	15	1,31,300.00	45,990.00	1,77,290.00
-do-	0053	0	13	13	00.00	24,180.00	24,180.00
-do-	005	6	28	34	1,34,750.00	64,740.00	1,99,490.00
-do-	0009	3	16	19	1,82,371.00	55,760.00	2,38,131.00
-do-	0010	6	11	17	1,81,865.00	13,130.00	1,94,995.00
Jeep	0170	4	18	22	91,150.00	42,540.00	1,33,690.00
-do-	0036	6	10	16	2,26,550.00	41,725.00	2,68,275.00
-do-	0027	9	15	24	3,65,130.00	45,470.00	4,10,600.00
-do-	0188	3	13	16	47,450.00	23,980.00	71,430.00
-do-	0189	4	19	23	59,600.00	74,860.00	1,34,460.00
-do-	0190	4	08	12	71,535.00	13,500.00	85,035.00
-do-	0194	3	10	13	2,25,700.00	34,750.00	2,60,450.00
-do-	0103	3	09	12	73,015.00	33,170.00	1,06,185.00
-do-	0024	2	06	08	4,89,500.00	10,980.00	5,00,480.00
-do-	0025	0	16	16	00.00	31,420.00	31,420.00
-do-	0026	2	05	07	71,770.00	55,890.00	1,27,660.00
-do-	0082	0	03	03	00.00	6,350.00	6,350.00
Pickup	0091	2	10	12	47,750.00	17,840.00	65,590.00
-do-	0017	3	19	22	47,950.00	40,420.00	88,370.00
-do-	0056	3	12	15	45,450.00	19,230.00	64,680.00
-do-	0057	3	09	12	72,000.00	19,010.00	91,010.00
-do-	0058	3	10	13	74,400.00	11,475.00	85,875.00
-do-	0086	0	00	00	00.00	00.00	00.00
-do-	0089	2	11	13	25,000.00	6,000.00	31,000.00
-do-	0090	0	00	00	00.00	00.00	00.00
-do-	0109	5	11	16	83,782.00	31,220.00	1,15,002
-do-	0002	2	21	23	86500	14509	101009
-do-	0042	4	19	23	57,151.00	46,290.00	1,03,441.00
-do-	0040	0	09	09	00.00	16,400.00	16,400.00
-do-	aj -018	3	14	17	38,465.00	22,800.00	61,265.00

Table 14. Continued

Type of vehicle	Vehicle/ Machine No.	Time of major works	Time of moderate/ minor works	Total number of works	Cost of major works	Cost of moderate/ minor works	Total cost (Taka)
-do-	aj -016	0	06	06	00.00	14,015.00	14,015.00
-do-	aj -015	5	11	16	1,59,165.00	49,550.00	2,08,715.00
-do-	aj -013	0	11	11	00.00	26,650.00	26,650.00
-do-	0011	3	09	12	53,100.00	6,660.00	59,760.00
-do-	0025	3	11	14	46,880.00	19,050.00	65,930.00
-do-	1641	0	15	15	00.00	42,900.00	42,900.00
-do-	004	1	05	6	00.00	00.00	00.00
Truck	0020	0	12	12	00.00	9,670.00	9,670.00
-do-	0101	0	03	03	00.00	5,100.00	5,100.00
-do-	0001	0	17	17	00.00	41,440.00	41,440.00
-do-	0011	2	11	13	24,500.00	25,665.00	50,165.00
Sub total		135	565	700	45,31,080.00	14,18,681.00	59,49,761.00
Motor cycle (110 nos.)		0	22	22	00.00	20,760.00	20,760.00
Tractor (4 nos.)		6	29	35	1,04,300.00	58,895.00	1,63,195.00
Power tiller (21 nos)		0	127	127	00.00	44,340.00	44,340.00
Hydro tiller (13 nos)		2	23	25	24,980.00	10,230.00	35,210.00
Pump+ mower (26 nos.)		0	20	20	00.00	3,570.00	3,570.00
Tyre and tube		0	00	0	00.00	00.00	00.00
Others/Threshers(13nos.)		16	197	213	3,44,370.00	2,07,297.00	5,51,667.00
Sub total		24	418	442	4,73,650.00	3,45,092.00	8,18,742.00
Grand total		159	983	1,142	50,04,730.00	17,63,773.00	67,68,503.00

Repair and maintenance cost

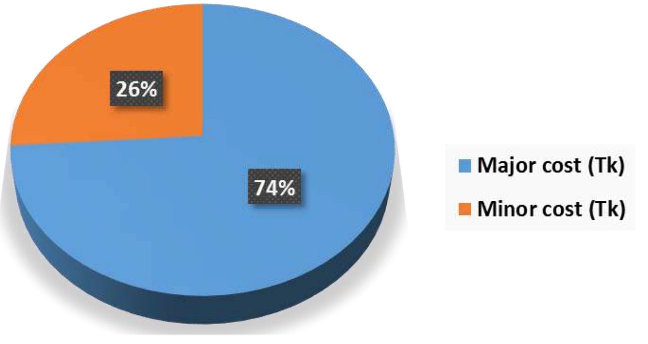


Fig. 4. Repair and maintenance cost of BRRI farm machinery and automobiles.

Adaptive Research Division

SUMMARY

A total of 33 advanced breeding lines were evaluated by conducting 13 advanced line adaptive research trials (ALART) at farmers' field in different agro ecological regions of Bangladesh during the reporting period. Ten advanced lines were found suitable for proposed variety trial (PVT) considering grain yield, yield related characteristics and farmers' opinion. Out of 10 genotypes, two for T. Aus, five for T. Aman and three for Boro were recommended for PVT. However, two recommended genotypes (IRR and BBR-Bio) of Boro 2019 were discarded after threadbare discussion in the VDP meeting Boro 2019-20. So, finally eight recommended genotypes remained in total during 2018-19.

A total of 620 demonstrations were conducted in 165 upazilas of 64 districts during reporting the period using the BRRI varieties (BRRI dhan27, 34, 47, 48, 49, 56, 57, 58, 60, 62, 63, 66, 69, 70, 71, 72, 74, 75, 77, 79, 81, 82, 84, 87 and 89) and other technologies under GoB and different projects (SPIRA, ASRS, TRB, HNRD and TTFP). About 373 tons of seeds were produced and 52 tons were retained as seeds by the farmers for next year cultivation. About 27 thousand farmers gained awareness and knowledge about BRRI varieties and technologies through demonstrations, knowledge sharing, field days, field visit and interactions with farmers and extension personnel. Among them, about 6300 farmers were motivated to adopt BRRI varieties.

A total of 400 head to head adaptive trials (HHAT) were conducted through public private partnership during the reporting period. From the interaction of genotypes and environments, BRRI dhan87 was found the most suitable variety for Aman season followed by BRRI dhan71, BRRI dhan75, BRRI dhan49 and BRRI dhan52. In Boro season, BRRI dhan67 showed potentiality throughout the country although it was released for coastal saline environment. BRRI dhan58 and BRRI dhan81 would be suggested to grow in southwest to northern areas as these varieties were highly infected by neck blast disease in other regions of the country.

Furthermore, ARD conducted seed support programme to farmers and different stakeholders in different locations of Bangladesh under TRB project to enhance rapid dissemination of BRRI varieties in Aman 2018 and Boro 2019. About 10 tons of seed of BRRI varieties were distributed free of cost to 1,435 farmers/Stakeholders. ARD also conducted 49 farmers' training at different locations under GOB and different projects in which 1,520 participants (1,410 farmers and 110 SAAOs of DAE) were trained up. ARD also conducted 60 field days at different locations where around 8,000 participants were present in the field days. Moreover, ARD produced 9 ton seeds of 21 BRRI varieties at BRRI HQ farm, Gazipur which was used to conduct research, demonstrations and seed support programmes. A total of 26 farmers seed centers were established where 78 plastic drum were provided to store quality rice seed at farmer's level.

TECHNOLOGY VALIDATION

Advanced line adaptive research trial (ALART)

T. Aus 2018. Four advanced lines, BR9011-48-4-3, BR9011-64-1-2, BR9011-67-4-1 from Plant Breeding Division and BR (Bio) 9787-BC2-63-2-4 from Biotechnology Division were tested along with the check varieties BR26 and BRRI dhan48 at farmers' field in eight locations during T. Aus 2018. Both BR9011-67-4-1 and BR9011-64-1-2 gave higher grain yield than the check BRRI dhan48 (Table 1). The genotypes showed uniform flowering and maturity having almost similar grain size. Although plant height of the lines is slightly taller than BRRI dhan48, the crop did not lodged. Considering grain yield, growth duration and other attributes, BR9011-67-4-1 and BR9011-64-1-2 were recommended for proposed variety trial (PVT).

Table 1. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART during T. Aus 2018.

Genotype	Location								GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})										
	L1	L2	L3	L4	L5	L6	L7	Mean	Mean	Mean	Mean
BR9011-48-4-3	4.76	4.63	4.65	4.34	4.06	3.94	4.06	4.35	115	22.07	105
BR9011-64-1-2	4.84	4.56	4.27	4.81	4.50	4.18	4.49	4.52	113	22.09	105
BR9011-67-4-1	5.07	4.84	4.36	4.87	4.15	4.77	4.31	4.62	113	22.59	103
BR(Bio)9787-BC2-63-2-4	4.20	4.58	4.29	4.21	4.70	3.25	3.69	4.13	112	19.64	99
BR26 (Ck)	4.12	4.51	3.74	3.48	3.47	3.23	3.01	3.65	113	21.67	106
BRRIdhan48 (Ck)	4.47	5.02	4.14	4.18	4.84	4.61	4.16	4.49	110	22.90	101
LSD				0.41				0.22	0.55	0.37	2.29

L1- Gazipur, L2- Chuadanga, L3- Chattogram, L4- Feni, L5- Jashore, L6- Chapainawabganj, L7- Rangpur.

T. Aman 2018, ALART, rainfed lowland rice (RLR). Three advanced lines BR8841-22-2-4-2, BR8841-38-1-2-1 and IR10F102 along with BRRI dhan39 and BRRI dhan49 as checks were tested at farmers' field in eight locations during T. Aman 2018. The trial site of Barishal (sadar) was damaged due to four times tidal submergence. All the tested entries gave statistically similar grain yield (4.76-4.86 t ha^{-1}) to the check variety BRRI dhan49 (4.75 t ha^{-1}), but statistically higher than the check variety BRRI dhan39 (Table 2). Due to poor yield, slightly longer growth duration, high disease infection compared to the check, none of the tested entries was found suitable for PVT.

T. Aman 2018, ALART, (RLR), Biotechnology. Two advanced lines developed by Biotechnology Division for rainfed lowland rice: BR(Bio)8961-AC22-14 and BR(Bio)8961-AC26-16 were evaluated along with BRRI dhan49 (ck) in eight locations during T. Aman 2018. The trial site of Barishal (sadar) was damaged. On average of seven locations, the tested advanced lines gave little higher yield (4.69 and 4.67 t ha^{-1}) compared to the check (4.58 t ha^{-1}) though the yield was statistically similar (Table 3). Plant height and grain weight of BR (Bio) 8961-AC26-16 was little bit higher than the check and the line BR (Bio) 8961-AC22-14. It is noticeable here that both the tested lines were less infected by false smut disease. Considering all attributes, both the genotypes BR (Bio) 8961-AC22-14 and BR (Bio) 8961-AC26-16 may be recommended for PVT if the irregular flowering is corrected by the concerned division for the respective genotype.

Table 2. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (RLR) during T. Aman 2018.

Genotype	Location								GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})										
	L1	L2	L3	L4	L5	L6	L7	Mean	Mean	Mean	Mean
BR8841-22-2-4-2	4.75	4.58	5.45	3.67	5.23	4.61	5.01	4.76	133	24.64	130
BR8841-38-1-2-1	4.69	4.65	5.72	3.64	5.14	4.70	5.47	4.86	132	24.45	122
IR10F102	4.87	4.82	5.68	3.31	5.30	4.56	4.97	4.79	134	23.56	129
BRRIdhan39 (Ck)	4.58	4.47	4.55	3.85	4.14	3.49	3.77	4.12	123	24.22	114
BRRI dhan49 (Ck)	4.81	4.78	5.54	4.09	5.25	4.12	4.69	4.75	132	19.95	103
LSD				0.55				0.21	0.30	0.32	0.95

L1- Gazipur, L2- Khulna, L3-Habiganj, L4- Chapainawabganj, L5- Rangpur, L6- Feni, L7- Chattogram.

Table 3. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (RLR) Biotechnology during T. Aman 2018.

Genotype	Location								GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})										
	L1	L2	L3	L4	L5	L6	L7	Mean	Mean	Mean	Mean
BR(Bio)8961-AC22-14	4.81	4.67	4.87	4.66	4.61	4.51	4.71	4.69	132	19.6	102
BR(Bio)8961-AC26-16	4.86	4.46	4.81	4.90	4.88	4.25	4.52	4.67	131	22.8	122
BRRIdhan49 (Ck)	4.76	4.85	4.98	3.95	4.84	4.08	4.60	4.58	132	19.8	101
$LSD_{0.05}$				0.43				0.16	0.3	0.4	1.3

L1- Gazipur, L2- Habiganj, L3- Chapainawabganj, L4- Rangpur, L5- Chattogram, L6- Feni, L7- Khulna.

Aman 2018, ALART, (RLR Rangpur). Three advanced lines (BR8189-10-2-3-1-5-RAN7, BR9392-6-2-IB-RAN5 and BR10238-5-1-RAN6) were evaluated against two check varieties (BR11 and BRRI dhan52) in seven locations (Gaibandha, Dinajpur, Kurigram, Thakurgaon and Rangpur) of greater Rangpur region and in BRRI HQ farm, Gazipur during T. Aman 2018. The tested three lines yielded more or less similar compared to the checks (Table 4). Grains of the tested lines were bold type like the check varieties. All the entries produced similar panicle number in a unit area with similar number of grains in a panicle. Considering all the attributes, one of the entries was found suitable for PVT.

T. Aman 2018, ALART (IRR). Two advanced lines, BR8693-8-4-2-1 and BR8693-17-6-2-2, along with BRRI dhan49 and BRRI dhan33 as checks were tested at farmers' field in eight locations during T. Aman 2018. The trial site was of Barishal (sadar). Both the advanced lines produced statistically higher yield than the check varieties (Table 5). Grain type of both the advanced lines was medium bold, whereas grain type of the check variety of BRRI dhan49 was medium fine. The flowering and maturity of the BR8693-8-4-2-1 was regular, but the flowering and maturity of the BR8693-17-6-2-2 was irregular. The main purpose of this ALART (insect resistant rice) is to recommend insect resistant rice genotype which would be more resistant compared to the other existing rice varieties. Considering all the necessary characteristics and farmers' opinion, the advanced line BR8693-8-4-2-1 was found to be suitable for PVT.

T. Aman 2018, ALART (ZER). Two zinc enriched advanced rice genotypes BR8442-12-1-3-1-B5 and BR8442-12-1-3-1-B1along with BRRI dhan72 and BRRI dhan49 as checks were tested at farmers' field in eight locations such as Chattogram (Hathazari), Feni (Dagonbhuiyan), Habiganj (sadar), Khulna (Dumuria), Chapainawabganj (Gomastapur), Rangpur (sadar) and BRRI HQ Gazipur during T. Aman 2018. Based on overall performance, yield, growth duration, grain type; Farmers as well as DAE personnel's preference, BR8442-12-1-3-1-B5 was recommended for PVT.

Table 4. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (RLR) Rangpur during T. Aman 2018.

Genotype	Location: Grain yield (t ha^{-1})								GD day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean
BR8189-10-2-3-1-5-RAN7	4.66	5.87	5.57	4.57	5.80	4.86	5.13	5.10	5.20	150	117
BR9392-6-2-IB-RAN5	4.54	5.84	5.49	4.90	5.27	4.54	4.30	4.98	4.98	145	125
BR10238-5-1-RAN6	4.82	5.92	5.69	5.60	5.48	4.53	4.38	4.81	5.15	144	120
BR11 (Ck)	4.71	5.31	5.18	5.20	4.86	4.24	4.81	4.90	4.90	144	116
BRRI dhan52 (Ck)	4.91	5.17	4.97	5.58	5.75	4.39	4.83	5.00	5.08	141	117
$LSD_{0.05}$				0.9				0.18	0.3		0.9

L1- Gazipur, L2- Sadar, Dinajpur, L3- Parbatipur, Dinajpur, L4- Rangpur, L5- Kurigram, L6- Mithapukur, Rangpur, L7- Thakurgaon, L8- Gaibandha.

Table 5. Grain yield, growth duration, TGW and plant height of rice genotypes under ALART (IRR) during T. Aman 2018.

Genotype	Location: Grain yield (t ha^{-1})								GD (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	Mean	Mean	Mean	Mean
BR8693-8-4-2-1	5.20	4.70	5.13	4.42	5.02	4.90	4.52	4.84	133	23.12	121
BR8693-17-6-2-2	4.63	4.46	5.17	5.04	4.83	5.01	5.11	4.89	135	26.03	125
BRRIdhan49 (Sacks)	5.04	4.75	5.04	4.37	4.82	3.64	3.69	4.48	132	20.90	101
BRRIdhan33 (Racks)	4.45	4.37	4.06	4.12	4.19	3.72	3.51	4.06	120	23.76	104
$LSD_{0.05}$				0.56				0.21	0.29	0.32	0.95

L1- Gazipur, L2- Khulna, L3- Habiganj, L4- Chapainawabganj, L5- Rangpur, L6- Feni, L7- Chattogram.

Table 6. Grain yield, growth duration, TGW and plant height of rice genotypes under ALART (ZER) during T. Aman 2018.

Genotype	Location								GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})										
	L1	L2	L3	L4	L5	L6	L7	Mean	Mean	Mean	Mean
BR8442-12-1-3-1-B5	5.19	4.00	4.45	5.24	5.45	4.82	3.81	4.71	132	22.5	125
BR8442-12-1-3-1-B1	5.21	3.72	4.54	5.03	5.27	4.56	3.05	4.48	129	23.2	118
BRRIdhan72 (Ck)	5.41	4.08	4.31	5.28	5.32	4.70	3.68	4.68	128	28.1	119
BRRIdhan49 (Ck)	4.52	4.28	4.21	5.07	5.11	4.62	4.00	4.54	132	20.1	102
$LSD_{0.05}$				0.40				0.18	1.2	0.35	2.0

L1- Chattogram, L2- Chapainawabganj, L3- Feni, L4- Gazipur, L5- Habiganj, L6- Khulna, L7- Rangpur.

T. Aman 2018, ALART (PQR). Three advanced lines for premium quality rice: BR8493-12-7-4 (Com), BR8493-3-5-1 (Com) and BR8846-38-2-4-3 along with BRRI dhan37, BINA dhan-3 as standard checks; Katerivog and Kalizira as local check were tested at farmers' field in six locations such as Dinajpur (sadar), Thakurgaon (sadar), Chapainawabganj (Gomastapur), Jashore (Monirampur), Naogaon (sadar) and BRRI HQ during T. Aman 2018. Genotypes and environments interaction had significant effect on grain yield, growth duration, plant height and yield components (Table 7). The highest yielder genotype BR8846-38-2-4-3 and the check varieties were almost disease free. Considering overall performances and farmers as well as DAE personnel's feedback, the genotype BR8846-38-2-4-3 could be recommended for PVT.

Boro 2019, ALART (FBR-Bio). Two advanced lines developed by Biotechnology Division for favourable Boro condition (BR (Bio) 9777-26-4-3 and BR (Bio) 9777-118-6-4) along with BRRI dhan58 as check were evaluated in eight locations such as Chattogram (Hathazari), Feni (Sonagazi), Habiganj (Baniachang), Khulna (Dumuria), Barishal (sadar), Rajshahi (Tanore), Dinajpur (sadar) and BRRI HQ during Boro 2019. All the tested entries failed to give significantly higher yield than the check variety (Table 8) and they didn't have any special characters for which they could be considered for further progress. Considering all attributes, none of the genotypes was recommended for PVT.

Table 7. Grain yield, growth duration, TGW and plant height of rice genotypes under ALART (PQR) during T. Aman 2018.

Genotype	Location							GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})									
	L1	L2	L3	L4	L5	L6	Mean	Mean	Mean	Mean
BR8493-12-7-4(Com)	3.30	2.14	3.37	3.91	3.59	3.73	3.34	138	15.0	118
BR8493-3-5-1(Com)	3.26	1.95	3.26	4.00	3.39	3.84	3.28	137	15.2	117
BR8846-38-2-4-3	3.77	2.82	3.91	4.16	3.72	4.10	3.75	134	14.4	113
BRRIdhan37 (Ck)	2.94	2.61	3.02	3.67	3.75	3.46	3.24	141	14.8	123
Binadhan-13 (Ck)	3.14	2.71		3.75	3.61	3.37	3.32	143	14.0	137
Katarivog (L. Ck)	3.22	-	2.74	-	-	3.14	3.04	139	14.6	133
Kalizira (L. Ck)	-	-	2.62	-	-	2.71	2.67	140	12.3	139
$LSD_{0.05}$				0.33			0.12	1.0	0.21	1.0

L1- Dinajpur, L2- Thakurgaon, L3- Chapainawabganj, L4- Jashore, L5- Naogaon t, L6- Gazipur.

Table 8. Grain yield, growth duration, TGW and plant height of rice genotypes under ALART (FBR-Bio) during Boro 2019.

Genotype	Location									GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR(Bio)9777-26-4-3	6.99	6.76	6.13	7.11	6.07	7.63	6.83	7.22	6.84	153	23.2	98
BR(Bio)9777-118-6-4	6.02	7.14	5.89	6.64	5.56	7.86	6.92	7.18	6.65	152	24.3	101
BRRI dhan58 (Ck)	6.47	6.99	5.99	7.29	5.89	7.71	6.71	7.41	6.81	154	22.4	99
LSD $_{(0.05)}$				0.55				0.34		1.0	0.3	1.0

L1- Chattogram, L2- Feni, L3- Habiganj, L4- Khulna, L5- Barishal, L6- Rajshahi, L7- Dinajpur, L8-Gazipur.

Boro 2019, ALART (PQR). Three advanced lines (BR8590-5-2-5-2-1, BR8590-5-2-5-2-2 and BR9207-45-2-2) developed by Plant Breeding Division for premium quality Boro rice were evaluated in eight locations including BRRI HQ during Boro 2019 against the check varieties BRRI dhan50 and BRRI dhan81. The advanced lines have no yield advantage over the checks, high shattering at 80% maturity (10-15%) and longer growth duration (Table 9). Farmers and extension personnel choose BR8590-5-2-5-2-2 and BR8590-5-2-5-2-1 at vegetative and flowering stage due to attractive phenotypic appearance and long panicle size. But at maturity stage they dislike the entries due to shattering problem, delayed maturity of the lower portion of the panicle, blast incidence etc. Considering all attributes, none of the genotypes was recommended for PVT.

Boro 2019, ALART (ZER). Two advanced lines, BR8631-12-3-5-P2 and BR8631-12-3-6-P3 developed by Plant Breeding Division for Zinc enriched Boro rice and were evaluated in eight locations such as Chattogram (Hathazari), Feni (Sonagazi), Habiganj (Baniachang), Khulna (Dumuria), Barishal (sadar), Rajshahi (Tanore), Dinajpur (sadar) and BRRI HQ during Boro 2019 against the check variety of BRRI dhan28 and BRRI dhan74. On average of eight locations, the entry (BR8631-12-3-5-P2) yielded (6.85 t ha-^{1}) significantly higher than all other entries including the checks (Table 10). All the entries showed excellent plant growth with uniform flowering and maturity. Farmers and extension personnel choose BR8631-12-3-5-P2 due to attractive phenotypic appearance, higher yield, long panicle size and good grain size. Considering all attributes, the line BR8631-12-3-5-P2 was recommended for PVT.

Boro 2019, ALART (FBR). Two advanced lines, IR99056-B-B-15 and BR8938-30-2-4-2-1 along with BRRI dhan28 and BRRI dhan58 as checks were tested at farmers' field in eight locations such as BRRI HQ, Chattogram (Hathazari), Dinajpur (sadar), Feni (Sonagazi), Habiganj (Baniachang), Barisal (sadar), Rajshahi (Tanore) and Khulna (Dumuria) during Boro 2019. Grain yield of two tested lines and check variety BRRI dhan58 was almost similar ranged from 6.80 t ha^{-1}to 6.96 t ha^{-1}which were significantly higher than BRRI dhan28 (6.16 t ha^{-1}) and growth duration of BRRI dhan28 was about one week earlier than the other three genotypes (Table 11). In terms of grain type, phenotypic acceptance and farmers' reaction, no significant difference was observed. Considering the above characteristics of the tested genotypes along with check varieties, none of the genotypes was recommended for PVT.

Table 9. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (PQR) during Boro 2019.

Genotype	Location									GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR8590-5-2-5-2-1	5.96	5.82	4.12	5.48	5.84	7.10	5.55	4.77	5.58	157	20.4	106
BR8590-5-2-5-2-2	5.65	5.64	4.53	5.64	5.54	7.26	5.94	5.54	5.72	157	20.4	105
BR9207-45-2-2	6.22	5.64	3.83	4.60	5.81	7.01	5.84	4.50	5.43	158	20.5	108
BRRI dhan50 (ck)	5.94	5.25	4.74	5.82	6.03	6.28	5.55	6.20	5.73	155	20.3	91
BRRI dhan81 (ck)	6.13	4.08	4.43	4.73	5.76	7.91	5.93	5.57	5.57	145	21.7	93
LSD $_{(0.05)}$				0.31					0.25	1	0.4	2

L1- Chattogram, L2- Feni, L3- Habiganj, L4- Khulna, L5- Barishal, L6- Rajshahi, L7- Dinajpur, L8-Gazipur.

Table 10. Grain yield, growth duration, TGW and plant height of rice genotypes under ALART (ZER) during Boro 2019.

Genotype	Location									GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR8631-12-3-5-P2	7.33	7.45	5.73	6.60	5.77	8.24	6.16	7.51	6.85	146	20.6	101
BR8631-12-3-6-P3	6.26	5.96	4.34	6.51	5.40	7.30	5.60	7.07	6.05	147	22.6	102
BRRI dhan28 (ck)	6.38	6.48	4.09	6.50	5.57	7.31	5.39	7.56	6.16	146	22.5	100
BRRI dhan74 (ck)	5.68	6.11	5.84	6.70	6.17	7.35	6.13	7.55	6.44	148	31.0	94
LSD $_{(0.05)}$				0.30					0.22	1	.3	1

L1- Chattogram, L2- Feni, L3- Habiganj, L4- Khulna, L5- Barishal, L6- Rajshahi, L7- Dinajpur, L8-Gazipur.

Table 11. Grain yield, growth duration, TGW and plant height of rice genotypes under ALART (FBR) during Boro 2019.

Genotype	Location Grain yield (t ha^{-1})									GD (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
IR99056-B-B-15	6.85	6.11	6.96	6.27	6.09	7.90	7.07	6.80	7.15	150	22.5	99
BR8938-30-2-4-2-1	6.18	6.25	7.18	6.47	6.71	7.59	7.44	6.96	7.87	153	23.1	107
BRRI dhan28 (Ck)	6.44	5.39	6.35	5.25	5.94	7.26	5.90	6.16	6.71	144	22.4	97
BRRI dhan58 (Ck)	6.32	6.26	5.90	6.45	6.82	8.00	7.30	6.86	7.80	153	23.1	98
LSD ($_{0.05}$)				0.28					0.20	1	.4	1

L1- Gazipur, L2- Chattogram, L3- Dinajpur, L4- Feni, L5- Habiganj, L6- Barishal, L7- Rajshahi, L8- Khulna.

Boro 2019, ALART (BBR-Bio). Three bacterial blight resistant advanced rice genotypes BR (Bio) 8333-BC5-1-20, BR (Bio) 8333-BC5-2-16, BR (Bio) 8333-BC5-2-22 developed by Biotechnology Division were tested along with resistant check (R. ck) IRBB60 and standard check (Std ck) BRRI dhan29 during Boro 2019 at farmers' field in eight locations including BRRI HQ. Irrespective of genotype and location, the genotype BR (Bio) 8333-BC5-1-20 produced significantly higher mean grain yield (7.26 t ha^{-1}) than both the check varieties BRRI dhan29 and IRBB60 (Table 12). Yield performances of all the advanced lines were better compared to the resistant check IRBB60. The advanced line (Bio) 8333-BC5-1-20 was preferred by farmers and DAE personnel for its grain type (medium slender) and less disease incidence. There was no occurrence of BB in any of the experimental sites. As we have no BB resistant variety, BR (Bio) 8333-BC5-1-20 could be considered as a prospective genotype for PVT if somehow the irregularity of flowering is corrected. However, after threadbare discussion in the VDP-meeting, Boro 2019, the house was not convinced enough to consider it for PVT.

Boro 2019, ALART (IRR). Two advanced lines: BR8335-10-6-3-10 and BR8340-5-6-1, along with BRRI dhan58 (Std. ck) and T27A (R. ck) as checks were tested at farmers' field in eight locations such as BRRI HQ, Sirajganj (Tarash), Natore (Singra), Dinajpur (Birganj), Sunamganj (Chhatok), Satkhira (Tala), Feni (Fulgazi) and Chattogram (Hathazari) during Boro 2019. The entry T27A (R. ck) were not germinated in the site of Feni (Fulgazi) and Chattogram (Hathazari). None of the tested advanced line could give higher yield than the check varieties BRRI dhan58 (Std. ck) 7.19 t ha^{-1} (Table 13). The flowering and maturity of the BR8340-5-6-1 was uniform and had less insect infestation. Main purpose of this ALART was to recommend insect resistant rice genotype which would be more resistant compared to other existing rice varieties. Considering the above results and less disease reaction, farmers' opinion, and special character of insect resistance, BR8340-5-6-1line was found to be suitable for PVT. However, after threadbare discussion in the VDP-meeting, Boro 2019, the house suggested to do a re-ALART in the hotspot area of BPH in coming Boro season since there was no BPH infestation in any of the locations.

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Table 12. Grain yield, growth duration, TGW and plant height of rice genotypes under ALART (BBR-Bio) during Boro 2019.

Genotype	Location Grain yield (t ha^{-1})									GD (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR(Bio)8333-BC5-1-20	6.96	7.12	6.91	7.31	6.82	7.2	7.39	8.35	7.26	157	21.61	97
BR(Bio)8333-BC5-2-16	7.23	6.87	6.12	7.19	6.25	7.41	6.98	7.52	6.94	158	22.53	100
BR(Bio)8333-BC5-2-22	7.53	7.18	5.4	7.19	5.8	7.17	6.79	7.81	6.86	158	22.72	97
IRBB60 (R. ck)	6.11	6.07	4.26	6.16	4.58	6.65	6.73	5.98	5.82	158	24.78	83
BRRI dhan29 (Std ck)	6.64	6.48	6.16	7.77	6.53	7.42	7.12	7.98	7.01	160	22.30	96
LSD ($_{0.05}$)				0.25					0.20	1	0.44	1

L1- Chattogram, L2- Feni, L3- Habiganj, L4- Khulna, L5- Barishal, L6- Rajshahi, L7- Dinajpur, L8-Gazipur.

Table 13. Grain yield, growth duration, TGW and plant height of rice genotypes under ALART (IRR) during Boro 2019.

Genotype	Location								GD (day)	TGW (g)	Plant height (cm)	
	Grain yield (t ha^{-1})											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR8335-10-6-3-10	6.93	3.65	5.57	5.43	7.81	7.34	6.69	6.89	153	157	21.61	98
BR8340-5-6-1	6.93	6.20	7.11	6.17	7.70	6.53	7.49	7.65	154	158	22.72	105
BRRIdhan58 (S. Ck)	7.67	6.75	7.12	6.25	7.55	7.31	7.86	7.02	155	158	24.78	100
T27A (R. CK)	5.88	5.25	5.09	4.92	-	-	6.71	5.5	152	160	22.30	132
LSD ($_{0.05}$)	0.58							0.23	1	0.66	1	

L1- Gazipur, L2- Sunamganj, L3- Sirajganj, L4- Dinajpur, L5- Feni, L6- Chattogram, L7- Satkhira, L8- Natore.

TECHNOLOGY DISSEMINATION

Seed production and dissemination programme (SPDP)

For rapid dissemination of newly released BRRI varieties among the farmers, Adaptive Research Division (ARD) conducted 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, TRB, ASRS and TTFP). In this programme, mainly BRRI varieties are demonstrated in farmers' fields.

SPDP with drum-seeder during Aus under GoB. SPDPs were conducted in Nakla, Sherpur during Aus 2018. BRRI dhan48 and BRRI dhan82 were disseminated in this programme. Total rice production through demonstrations of BRRI dhan48 and BRRI dhan82 were about 17.4 ton and farmers retained 3.90 ton seeds from those varieties for next year cultivation. About 360 farmers gained awareness about the varieties through field visits, discussion and knowledge sharing. About 170 farmers were motivated to cultivate those varieties in next year.

SPDP in T. Aman 2018 under GoB. SPDPs in T. Aman 2018 were conducted in nine districts (Netrakona, Sherpur, Mymensingh, Chattogram, Narayanganj, Jamalpur, Narshingdi, Gazipur and Tangail) and eight modern varieties (BRRI dhan34, BRRI dhan49, BRRI dhan52, BRRI dhan71, BRRI dhan72, BRRI dhan75, BRRI dhan79 and BRRI dhan87) were used in the programme. In total, 28.0 ton seeds were produced from all demonstrations and 6.01 ton quality seeds were retained by the farmers for the next year use. About 3,443 farmers acquired awareness and knowledge about the varieties through field visits, discussion and knowledge sharing. In total, 1,386 farmers were motivated and showed their interest to cultivate these varieties in the next year.

SPDP during Boro 2019 under GoB. Farmers’ participatory on-farm demonstrations were conducted in different agro-ecological regions of the country covering nine upazilas of seven districts such as, Netrakona, Tangail, Cox’s Bazaar, Khulna, Mymensingh, Kishoreganj and Chattogram and seven varieties, BRRI dhan58, BRRI dhan63, BRRI dhan67, BRRI dhan74, BRRI dhan81, BRRI dhan84 and BRRI dhan89 were used. In total, 28.3 ton seeds were produced from all demonstrated plots and farmers retained 4.13 ton quality seeds for the next year use. About 1,605 farmers acquired awareness and knowledge about the varieties and 552 farmers were motivated to cultivate these varieties in the next year.

SPDP during Boro 2019 at Nakla, Sherpur under GoB. Two special SPDP were conducted during Boro 2019 at Nakla upazila in Sherpur district. At one site, BRRI dhan58, BRRI dhan74, BRRI dhan86 and another site BRRI dhan58, BRRI dhan74 and BRRI dhan89 were selected for conducting demonstration. In total, 3367 kg seed was produced from all demonstration and farmers retained 85 kg quality seeds for the next year use.

About 380 farmers acquired awareness and knowledge about the varieties and 85 of them were motivated to cultivate these varieties in the next year.

SPDP during Boro 2019 at Dhanbari, Tangail under GoB. Two SPDPs were conducted during Boro, 2019 at Dhanbari upazila in Tangail district. At one site, BRRI dhan50, BRRI dhan58 and another site BRRI dhan81 and BRRI dhan84 were selected for conducting demonstration. A total of 3,264 kg seeds were produced from all demonstrations and farmers retained 120 kg quality seeds for the next year use. About 320 farmers acquired awareness and knowledge about the varieties and 39 were motivated to cultivate these varieties in the next year.

SPDP in Bagerhat during Boro 2019. SPDPs were conducted during Boro 2019 at Shoronkhola and Morrelganj in Bagerhat district under GoB. BRRI dhan28, BRRI dhan67 and BRRI dhan74 were selected for conducting demonstration. Farmers retained 410 kg quality seeds for the next year use. About 550 farmers acquired awareness and knowledge about the varieties and 90 were motivated to cultivate these varieties in the next year.

SPDP in hilly areas under HNRP. In hilly areas rice is cultivated in *jhum* system as mixed crop by tribal farmers. About 70% crops used in the *jhum* system is local rice. The locally adopted varieties were Benni, Chakmachikon, Borodhan, Gurichina, Gelon and Hamarang having very low grain yield. Productivity in hilly areas can be increased by replacing local varieties using BRRI developed suitable varieties.

SPDP under *Jhum* cultivation during Aus 2018. Demonstration of BRRI dhan48 and BRRI dhan65 were conducted in seven upazilas of three hilly districts (Bandarban, Rangamati and Khagrachari) under SPDP. In total 717 kg seeds were retained for seed purpose for use in the next *Jhum* cultivation. In total 633 farmers gained knowledge from these SPDPs where 154 and 111 farmers were motivated to grow BRRI dhan48 and BRRI dhan65.

Adaptive trial (AT) in valley of hill during T. Aus 2018. Experiments were carried out in 10 upazilas in three hilly districts (Bandarban, Rangamati and Khagrachari) using four high yielding modern rice varieties (BRRI dhan27, BRRI dhan48, BRRI dhan65 and BRRI dhan82) and one local check were planted side by side in one bigha of land. Considering all the situations, BRRI dhan48 and BRRI dhan82 might be suitable for hilly areas. Some newly released varieties might be included in the programme in next season.

SPDP in valley of hills during T. Aus 2018. SPDPs were conducted at the valley of hills in seven upazilas of three hilly districts of Bangladesh (Bandarban, Rangamati, and Khagrachari) in T. Aus 2018. BRRI developed Aus rice varieties BRRI dhan27, BRRI dhan48, BRRI dhan65 and BRRI dhan82 were used in the demonstrations. A total of 2,235 kg seeds were retained for for use in the next Jhum cultivation. Total 705 farmers gained knowledge from these SPDPs of which 314 farmers were motivated to grow these varieties. Considering all the traits BRRI dhan48 would be a very good variety for cultivation in the valley of hill.

AT in *Jhum* during Aus 2018. These experiments were conducted in the farmers' Jhum cultivation field in Khagrachari, Bandarban and Rangamati using four high yielding modern rice varieties BRRI dhan27, BRRI dhan48, BRRI dhan65 and BRRI dhan82 and one local check were planted side by side in one bigha of land. Considering all the situations, BRRI dhan48 and BRRI dhan82 might be suitable for hilly areas.

AT in valley of hill during T. Aman 2018. Experiments were carried out in ten upazilas in three hilly districts (Bandarban, Rangamati and Khagrachari) using five high yielding modern T. Aman rice varieties (BRRI dhan49, BRRI dhan70, BRRI dhan71, BRRI dhan72 and BRRI dhan75) and one local check were planted side by side in one bigha of land. BRRI dhan49 yielded the highest (5.2 t ha^{-1}) followed by BRRI dhan72 (5.1 t ha^{-1}), BRRI dhan71 (4.9 t ha^{-1}) and BRRI dhan75 (4.8 t ha^{-1}) and these varieties might be suitable for hilly areas in T. Aman season.

AT in valley of hill during Boro 2019. Experiments were carried out in 12 upazilas in three hilly districts (Bandarban, Rangamati and Khagrachari) using five high yielding modern Boro rice varieties (BRRI dhan58, BRRI dhan63, BRRI dhan67, BRRI dhan81 and BRRI dhan86) and one local check was planted side by side in one bigha of land. BRRI dhan58 and BRRI dhan67 might be suitable for the hilly areas during Boro season. BRRI dhan63, BRRI dhan81 and BRRI dhan86 were affected by blast disease.

SPDP in valley of hill during Boro 2019. SPDPs were conducted at the valley of hills in three hilly districts of Bangladesh (Bandarban, Rangamati and Khagrachari) in Boro 2019. BRRI developed Aman rice varieties BRRI dhan58 and BRRI dhan67 were used in the demonstration. In total 967 kg seeds were retained for seed purpose for use in the next year cultivation. Total 597 farmers gained knowledge from these SPDPs of which 270 farmers were motivated to grow these varieties.

SPDP during T. Aman 2018 under SPIRA. SPDP were conducted in ten upazilas of six districts (Tangail, Gaibandah, Chapainawabganj, Jashore, Bagerhat and Patuakhali) under SPIRA project during Aman 2018 using eight varieties such as BRRI dhan49, BRRI dhan70, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan76 and BRRI dhan77. About 4,542 farmers acquired awareness and knowledge about the varieties and 970 farmers were motivated to cultivate them. Farmers retained 6,950 kg seeds for next season cultivation.

SPDP during Boro 2019 under SPIRA. SPDP were conducted in five upazilas of four districts (Gaibandah, Dinajpur, Jashore and Bagerhat) under SPIRA project during Boro 2019 using BRRI dhan58, BRRI dhan63, BRRI dhan67 BRRI dhan81 and BRRI dhan86. In total, 20,747 kg seeds were produced and farmers retained 3245 kg seeds for next season cultivation. About 2,045 farmers acquired awareness and knowledge about the varieties and 405 farmers were motivated to cultivate BRRI varieties in next year.

SPDP during T. Aus 2018 under TRB. Eleven SPDPs were conducted in nine upazilas of six districts (Chattogram, Moulvibazar, Mymensingh, Chuadanga, Jashore and Khulna) under TRB during Aus 2018. BRRI dhan48 and 82 was used in the SPDP. A total of 23.9 ton grains were produced and farmers retained 1,565 kg seeds for next season cultivation. About 825 farmers acquired awareness and knowledge about the varieties and 120 farmers were motivated to cultivate BRRI dhan48 and BRRI dhan82 for next Aus season.

SPDP during Aman 2018 under TRB. Twenty SPDPs were conducted in 11 upazilas of eight districts (Netrakona, Mymensingh, Khulna, Naogaon, Bagura, Joypurhat, Bandarban and Cox's Bazar) under TRB project during Aman 2018. BRRI dhan34, BRRI dhan49, BRRI dhan70, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan79 and BRRI dhan80 were used in the SPDPs. Total production of all the varieties was 37.0 tons from which about 6.0 ton was retained by the farmers for next season cultivation. About 2,575 farmers gained awareness and knowledge about the varieties and 533 farmers were motivated to cultivate them.

SPDP during Boro 2019 under TRB. Twenty SPDPs were conducted in 10 districts (Netrakona, Mymensingh, Sherpur, Khulna, Jashore, Chuadanga, Naogaon, Bagura, Bandarban and Cox's Bazar) under TRB project during Boro 2019. BRRI dhan58, BRRI dhan63, BRRI dhan67, BRRI dhan81, BRRI dhan84, BRRI dhan86, and BRRI dhan89 were used in the SPDPs. Total production of all the varieties was about 50 ton from which 6.5 ton was retained as seeds by the farmers for next season cultivation. About 3,738 farmers gained knowledge about the varieties and 485 farmers motivate to cultivate them in future.

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Head to head adaptive trial (HHAT) during Aman 2018. A total of 200 HHAT were conducted under TRB project through public private partnership in T. Aman 2018 throughout the country. BRRI released 14 varieties BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan76, BRRI dhan77, BRRI dhan79, BRRI dhan80 and BRRI dhan87 were used in the HHATs along with check varieties Swarna, Guti Swarna, Suman Swarna, Sada Mota, Khato Babu, BINA dhan7, BINA dhan11 and BINA dhan17. BRRI dhan87 produced the highest mean grain yield 6.34 t ha^{-1} followed by BRRI dhan72 (5.36 t ha^{-1}), BRRI dhan71 (5.20 t ha^{-1}), BRRI dhan52 (5.10 t ha^{-1}) and BRRI dhan49 (5.03 t ha^{-1}). Farmers preferred BRRI dhan87 for its higher grain and straw yield and long slender grain. BRRI dhan71, BRRI dhan75, BRRI dhan49, BRRI dhan52 also performed excellent. Finally farmers preferred BRRI dhan87>BRRI dhan71>BRRI dhan75>BRRI dhan80>BRRI dhan49>BRRI dhan52>BRRI dhan73>BRRI dhan79>BRRI dhan76 for their overall performance.

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HHAT during Boro 2019. A total of 200 HHATs were conducted in Boro (dry season) 2019 under TRB project through public private partnership throughout the country. BRRI released nine varieties (BRRI dhan28, BRRI dhan67, BRRI dhan74, BRRI dhan81, BRRI dhan84 and BRRI dhan86, BRRI dhan29, BRRI dhan58 and BRRI dhan89) were evaluated in the HHATs throughout the country. BRRI dhan29 produced competitive yield along with BRRI dhan89, however it was infected by neck blast disease in some locations. BRRI dhan67 showed potentiality throughout the country although it was released for coastal saline environment. BRRI dhan58 and BRRI dhan81 would be suggested to grow in southwest to north region. BRRI dhan84 performed well with shorter growth duration even two days earlier than BRRI dhan28.

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SPDP during Boro 2019 under ASRS. Twenty adaptive trials were conducted in 60 bigha (8.0 ha) land under adaptation and out-scaling of some selected rice varieties in stress prone environments (ASRS) during Boro 2019. Stress tolerant especially salinity tolerant modern rice variety BRRI dhan67 was used in four upazilas (Koyra, Paikgacha, Dumuria and Batiaghata) of Khulna and two upazilas (Rampal and Fakirhat) of Bagerhat district. BRRI dhan58, BRRI dhan81 and BRRI dhan86 were evaluated in *haor* areas like Kishoreganj (Mithamoin and Karimganj) and Netrakona (Madon and Sadar) districts. Among the tested varieties, BRRI dhan67 performed excellent in the coastal saline environment. A total of 43.14 ton grain were produced in 20 adaptive trials of the varieties from which around 6.3 ton was preserved as seed. Ten field days were conducted on the crop performance of the varieties where around 1,400 participants gained knowledge about the varieties and rice technologies especially seed production and preservation technique.

SPDP during Boro 2019 under TTFP. Block demonstration for BRRI released latest six varieties, BRRI dhan58, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan86 and BRRI dhan89 was established at Bhaluka and Muktagacha upzillas of Mymensingh and Sadar as well as Sarishabari upzilas of Jamalpur under the transfer of agricultural technologies to farmers' level for increasing farm productivity (TTFP) during Boro 2019. NATP-2 is the funding source for this programme. Total seed production from these six rice varieties was 21 ton from which farmers retained three ton for next year cultivation. In total, 3,380 farmers observed the performance of BRRI varieties and among them 562 farmers were motivated for the next year cultivation.

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FARMERS TRAINING AND PROMOTIONAL ACTIVITIES

Farmers' training. During the reporting period, ARD conducted 49 farmers' training programmes at different locations of the country under GoB and different projects (SPIRA, ASRS and TRB) from which 1,520 trainees (1,410 farmers and 110 SAAOs of DAE) participated on modern rice production technologies.

Field day/Farmers' rally. ARD conducted 60 field days at different locations of the country under GoB and different projects (SPIRA, ASRS, TRB and TTFP). Around 8,000 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, which helped rapid dissemination of technologies.

Seed production at BRRI farm. Quality seeds of recently released promising rice varieties were produced in T. Aman 2018 and Boro 2019 seasons during the reporting period under GoB and TRB project. A total of 8.8 tons quality seeds of BRRI varieties were produced. The seeds were used to conduct research activities and seed production and dissemination (SPDP) during the reporting period. Rest of the seeds were distributed to the farmers and stakeholders free of cost as seed support for rapid dissemination newly released promising rice varieties.

Seed support to farmers and stakeholders under TRB project. ARD distributed 5.16 and 4.6 ton truthfully labeled seeds (TLS) of modern rice varieties in Aman 2018 and Boro 2019 respectively, which were distributed to 1,435 farmers and stakeholders free of cost. Around 5000 farmers will be benefitted through getting seed and technologies directly and indirectly.

Establishment of farmers, seed center under TRB and ASRS. A total of 26 farmers, seed centers (FSC) were established at Netrakona, Kishoreganj, Jashore, Khulna, Bagerhat and Bandarban districts under TRB project and ASRS programme. We provided six plastic drums in each FSC. Around 80 kg seeds will be preserved in each drum. Farmers will preserve good quality seed of promising rice varieties for rapid dissemination through seed exchange or selling among the farmers.

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Training Division

SUMMARY

Training Division has conducted 50 training programmes in the reporting year with course duration from one day to two months. Need based course curriculum was developed for these courses. Total number of participants was1,271. The participants were Upazila Agriculture Officers, Agriculture Extension Officers and Sub-Assistant Agriculture Officers (SAAO) of the Department of Agriculture Extension (DAE), scientists of BRRI and BARI, teachers of BSMRAU and Sher-E-Bangla Agricultural University and farmers. The highest number of participants was from the DAE. The overall knowledge improvement for SAAOs in one week Rice Production Training (RPT) was 277% with wide range from 210% to 527%. Knowledge improvement of DAE officers in two month Rice Production Technologies Training course was 214% in theory and 119% in practical evaluation for the first batch and again it was 163% in theory and 143% in practical for the second batch. The results indicate the significance of rice production training for extension personnel. Effectiveness of imparted trainings was determined on the basis of feedback response on different aspects. Most of the trainees expressed positive views about the course content and method of training. However, participants of the one week course suggested for increasing duration of the course from one 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 844 responses on different issues were received from the trainees. Of which 725 from one-week modern rice production training for the SAAOs and 119 from two-month long training on modern rice production technologies for DAE officers. Though the participants were different categories, their expectations were very much similar. To the SAAOs who showed high expectation about insect and disease management followed by seed related issues. Participants from DAE officers also showed similar expectations like SAAO. High expectation of participants, in case of two-month RPT course for DAE officers was on disease, variety and insects related issues followed by rice cultivation and weed management technique (Table 1).

Table 1. Expectations of the SAAO and DAE officers on different subjects in need.

Subject/Issue	SAAO	Rank	Subject/Issue	DAE officer	Rank
	Expectation (%)			Expectation (%)	
Insect	25	1	Disease	21	1
Disease	18	2	Variety	19	2
Seed	10	3	Insect	18	3
Variety	9	4	Cultivation and weed management	10	4
Cultivation and weed management	8	5	Soil and fertilizer management	10	5
Soil and fertilizer	8	5	Seed and Seedbed	8	5
Irrigation	7	6	Irrigation	6	6
Plant Physiology	5	7	Plant Physiology	3	8
Farm Machinery	4	8	Hybrid rice	3	8
Others	6	7	Others	5	7
Total	100		Total	100	
Response no.	725		Response No.	119	

CAPACITY BUILDING AND TECHNOLOGY TRANSFER

Training on rice physiological development through trait discovery

A training programme on 'Rice physiological development through trait discovery' under the project of Physiological Development through Trait Discovery for Boosting Rice Yield in Changing Climatic Conditions was conducted in 2018-19. Duration of the course was one-week. A total of 30 participants were trained through this course. The participants of these courses were Scientific Officers, Senior Scientific Officers and Principal Scientific Officers of BRRI. Table 2 presents knowledge gain, improvement and performance status of the training.

Training on modern rice production technologies

Twenty training courses on modern rice production technologies were conducted during the reporting period. The main objective of the course was to train the grass root level extension workers (SAAO) 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 leading training methods in this course. Duration of the course was one week. A total of 395 SAAOs were trained. Among the participants, 347 and 48 were male and female respectively (Table 3).

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 49% and 277% respectively (Table 4).

Training on rice production technologies for DAE officers

The main objectives of the two-month long course were to train the DAE officers so that they can acquire and enrich knowledge on:

- Modern rice production technologies
- Identification of field problems of rice cultivation and its solutions and
- Quick dissemination of rice production technologies in the field

The course curriculum was designed as per requirement and objectives of the course. Enhanced lectures and talking followed by group discussion, individual presentations, practical session, field visit, review and feedback etc were the predominant training methods in this course. Two batches of training were conducted during the reporting period. Total participants were 60. Of which 49 were male and 11 were female. Table 5 presents the particulars of the participants.

Improvement of knowledge was measured on the basis of marks obtained in the benchmark and final evaluation of individual participant. Knowledge improvement through this training was very attractive. In case of batch one, it was 214% for theory and 119% for skill and in batch two, the knowledge improvement were 163% and 143% in theory and skill respectively (Table 6).

Training on basic molecular biology and disease resistance

A training programme on basic molecular biology and disease resistance was conducted in 2018-19 with the support of 'exploring new source of resistance and pyramiding blast resistant gene(s) into Boro rice' project. Duration of the course was one-week. A total of 49 participants were trained through this course in two batches. The participants of these courses were Scientific Officers, Senior Scientific Officers and Principal Scientific Officers of BRRI and BARI and Assistance Professors of BSMRU and Sher-E-Bangla Agriculture University. Table 7 presents the particulars of the trainings.

Table 2. Knowledge gain, improvement and performance status of rice physiological development through trait discovery training course.

Evaluation score (%)		Gain	Improvement (%)	Performance		
Benchmark	Final			Distinction	Satisfactory	Participatory
28	70	42	164	7	23	0

Table 3. Particulars of one week modern rice production training for SAAO of DAE.

Duration	No. of participants		
	Total	Male	Female
28 Oct-2 Nov, 2018	20	17	3
28 Oct-2 Nov, 2018	20	20	0
9-14 Feb, 2019	20	19	1
16-21 Feb, 2019	20	16	4
23-28 Feb, 2019	20	15	5
2-7 March, 2019	20	16	4
9-14 March, 2019	20	19	1
16-21 March, 2019	20	17	3
16-21 March, 2019	20	20	0
23-28 March, 2019	20	16	4
23-28 March, 2019	19	16	3
30 March-4 April, 2019	20	16	4
30 March-4 April, 2019	19	18	1
6-11 April, 2019	19	19	0
6-11 April, 2019	20	18	2
13-18 April, 2019	20	18	2
13-18 April, 2019	20	15	5
20-25 April, 2019	18	18	0
20-25 April, 2019	20	16	4
27 April-2 May, 2019	20	18	2
Total	395	347	48

Table 4. Knowledge gain, improvement and performance status of one week modern rice production training.

Evaluation score (%)		Gain	Improvement (%)	Performance		
Benchmark	Final			Distinction	Satisfactory	Participatory
16	68	52	325	5	10	5
20	67	47	235	9	10	1
19	62	43	226	0	16	4
20	82	62	310	12	8	0
11	69	58	527	3	17	0
19	76	57	300	8	12	0
19	69	50	263	5	12	3
24	74	50	208	3	16	0
26	72	46	177	3	14	3
15	65	50	333	4	5	10
23	71	48	213	5	12	3
20	67	47	235	4	11	4
16	63	47	293	1	15	4
14	58	44	314	2	11	7
20	63	43	215	5	6	8
21	65	44	210	3	12	5
21	66	45	214	3	14	3
15	68	53	353	4	11	5
18	56	38	211	0	8	10
12	58	46	383	1	9	10
18	67	49	277	80	229	85

Table 5. Two months modern rice production technologies training courses for DAE officers.

Duration	Participants (no.)			Designation
	Total	Male	Female	
5 Nov-3 Jan, 2019	30	24	6	AEO, AO
13 Jan-13 March, 2019	30	25	5	AEO, AO
Total	60	49	11	

Table 6. Knowledge gain, improvement and performance status of two months modern rice production technologies training courses.

Category of evaluation	Bench mark evaluation score (%)			Final evaluation score (%)			Improvement (%)		
	Male	Female	All	Male	Female	All	Male	Female	All
Theory	28	26	27	84	85	85	200	227	214
Skill	36	41	39	84	84	84	133	105	119
Theory	28	29	29	74	76	75	164	162	163
Skill	30	43	37	88	83	86	193	93	143

Table 7. Particulars of basic molecular biology and disease resistance training programme.

Duration	Participants (no.)			Designation	Organization
	Total	Male	Female		
16-21 March 2019	26	14	12	SO, SSO, PSO Lecturer, Assist Professor	BRRI, BARI, BSMRU, Gazipur, Sher-E- Bangla Agril. University, Dhaka
23-28 March 2019	23	13	10		
Total	49	27	22		

Modern rice production and ecofriendly insect management training

In the year 2018-19 two one week training programmes on modernrice production and insect management training was conducted for the Sub-Assistant Plant Protection Officers (SAPPO) and SAAOs of DAE. The training was funded by strengthening eco friendly insect management programme to increase rice yield. The objective of the course was to train the SAPPOs and SAAOs of the project areas so that they could participate in dissemination of rice technology as well as eco friendly insect management by motivating farmers. A total of 35 SAAOs were trained through this course (Table 8). Table 9 shows the knowledge gain, improvement and performance status of the trainees.

Farmers' training

Training Division conducted farmers training in *haor* areas of Bangladesh during the reporting period. Twenty batches of day-long rice production training programme were conducted with the collaboration of DAE in different upazilas of Kishoreganj, Netrakona and Sunamganj districts. In total 600 farmers and 40 SAAOs were trained through these programmes (Table 10).

Table 8. Modern rice production and ecofriendly insect's management training course for SAPPOs and SAAOs of DAE.

Duration	Participants (no.)		
	Total	Male	Female
4-9 May, 2019	17	15	2
4-9 May, 2019	18	15	3
Total	35	30	5

Training on dissemination of BRRI released Aman varieties in northern region of Bangladesh

Three one-day training programmes on dissemination of BRRI released Aman varieties in northern region of Bangladesh were conducted in Pirganj upazila of Rangpur district and Khanshama upazila of Dinajpur district. The main objectives of the training programmes was to replace the Indian rice varieties with BRRI varieties in that areas. The participants were all officers of DAE working at upazila including SAAO. A total of 62 (53 male and 9 female) officers were trained so that they could motivate the farmers to cultivate BRRI developed rice varieties instead of Indian ones in Aman season (Table 11).

Training information of training division

In the reporting period, 50 training programmes have been conducted by the Training Division. Through this training 1,271 participants were trained. Table 12 presents the summaries of the trainings.

Table 9. Knowledge gain, improvement and performance status of modern rice production and ecofriendly insect's management training course.

Evaluation score (%)		Gain	Improvement (%)	Performance		
Benchmark	Final			Distinction	Satisfactory	Participatory
32	68	36	113	3	11	3
27	61	34	126	1	10	6

Table 10. Modern rice production training course for farmers.

District	Training (no.)	Total trainee (no.)	
		Farmer	Saao
Kishoreganj	12	360	24
Netrakona	4	120	8
Sunamganj	4	120	8
Total	20	600	40

Table 11. Training on dissemination of BRRI released Aman varieties in northern region of Bangladesh.

District	Training No.	Participant (no.)		
		Total	Male	Female
Rangpur	2	42	35	7
Dinajpur	1	20	18	2
Total	3	62	53	9

Table 12. Total training conducted by Training Division.

Name of the training	No. of training	Duration	No. of participants			Designation
			M	F	Total	
Modern rice production training	20	1-week	347	48	395	SAAO
Two months rice production training	2	2-month	49	11	60	AEO,AO
Basic molecular biology and disease resistance	2	6-day	27	22	49	SO,SSO,PSO Lecturer,Assist. Professor
Training on rice physiological development through trait discovery	1	6-day	14	16	30	SO,SSO PSO
Modern rice production and ecofriendly insects management training course	2	1-week	30	5	35	SAAO
Dissemination of BRRI released Aman varieties in northern region of Bangladesh	3	1-day	53	9	62	SAAO
Farmers' training	20	1-day	600 40	- -	600 40	Farmers SAAO
Total	49		1160	111	1271	

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 modern rice production were very much helpful for the trainees to build up their capacity for modern rice production activities.

Performance of BRRI speakers

Twenty batches of one-week modern rice production training for SAAOs and two batches of two-month long training on modern rice production technologies for DAE officers were considered for this evaluation. At first, batch wise analysis was done on the basis of five criteria for each speaker. The criteria were: a. presentation style; b. question handling; c. use of training materials; d. time management and e. quality and relevance of handout and its timely supply. Average of five criteria was used to determine the performance of individual speaker in each batch. The overall performances of BRRI's speakers were very good to excellent.

BRRI RS, Barishal

SUMMARY

A total of 12 new crosses were made, 22 crosses were confirmed and 3,660 plant progenies were selected from segregating populations (F2-F5) during the reporting period.

Two PYTs one for BB resistance and the other for favourable Boro, were conducted during Boro 2018-19. Six RYTs in T. Aman 2018, seven RYTs and six AYT's were conducted during Boro 2018-19. One breeding zone trials with 283 IRRI-RLR materials was conducted during T. Aman 2018. One PVT for rainfed lowland rice (RLR) and zinc enriched rice (ZER) during T. Aman 2018 and two PVT's one for salinity tolerant and the other for zinc enriched rice were conducted during Boro 2018-19.

A total of 387 local Aman germplasm were collected and grown in six line plots for characterization, utilization and maintainance.

In the combined trial of golden rice, IR112060-GR2E: 2-7-63-2-96 was compared to BRRI dhan29. Only number of panicle/plant differed significantly (higher in BRRI dhan29) in the confined trial. There were no clear indications of altering disease susceptibility and there also observed no indications that GR2E event was a preferred host for pest insects.

Survey and monitoring of rice diseases in selected areas were conducted during Aman 2018 and Boro 2018-19. Bacterial leaf blight and brown spot was recorded as major diseases.

The management options of blast disease was demonstrated at farmers' field. The yield increase was observed in recommended practice by 20.6% and disease incidence decreased by 81.4% over farmers' practice.

Pests and natural enemies were monitored in BRRI RS, Barishal using light trap. Appearance of insect pests was lower than the previous reporting year. GLH, YSB, BPH, ZLH, and LHC found comparatively in higher number than the other rice insect pests. The highest catch of natural enemies in light trap was recorded STPD, GMB, and CDB.

Under the rice production using no or minimum use of insecticides programme, comparable higher yield was found in researcher practice than farmers' practice in both T. Aman 2018 and Boro 2018-19 seasons. Average number of insect pest was higher in farmers plot than the researcher plot.

Among the four planting dates, comparatively higher yield was achieved in the 1st (5 August) and 2nd (21 August) planting date in T. Aman season. Growth duration reduced by 7-11 days at later two transplanting dates.

To find out the limiting element for tidal flooded soil during T. Aman season, it was observed that N was the most limiting nutrient and for getting higher yield.

A total of 151 km long primary and secondary canals were surveyed in polder 43/1. Total stored volume of water was 74,14,503 m^3 in April and the salinity level was measured 1.0-2.2 dS/m. It was estimated that this amount of water can be irrigated to grow 634 ha rice, 1800 ha maize and 4878 ha sunflower areas.

A total of 7.3 ha of fallow lands were brought under cultivation by BRRI dhan47, BRRI dhan58, BRRI dhan67 and BRRI dhan74. Canal salinity was ranged from 0.2-0.45 dS/m in all three locations.

In Aus season, the highest yield was observed in BRRI dhan82 and the lowest yield was found in BR21. During T. Aman season, the highest yield was obtained in cultivating BRRI hybrid dhan4 and BRRI dhan87 and the lowest yield was found in BR5. During Boro 2018-19 BRRI dhan29, BRRI dhan89 and BRRI hybrid dhan5 produced above 8.0 t/ha grain yield. The lowest grain yield was observed in BR6 (4.93 t ha^{-1}).

During the reporting year, BRRI RS, Barishal has conducted 21 demonstrations in Aus season, 28 demonstrations in Aman season and 114 demonstrations in Boro season which was more than 60 acre by area coverage.

Varietal replacement through head to head trial were coducted with five T. Aman varieties at six locations and nine Boro varieties in eight locations.

BRRI RS, Barishal conducted 10 farmers' trainings and nine field days in different locations of Barishal region. It participated National Development Fair-2018 in two districts during the reporting period and one agriculture fair in Babuganj upazila during the reporting period.

In T. Aman 2018, a total of 17,070 kg and in Boro 2018-19, a total of 27,205 kg breeder seeds were produced. In T. Aman 2018, a total of 10,823 kg and in Boro 2018-19, a total of 28,759 kg TLS of BRRI released varieties were produced.

VARIETY DEVELOPMENT

Development of varieties for tidal submergence

Hybridization and pedigree nursery. To develop improved varieties for tidal submergence ecosystem, 71 plants were selected from 21 F_2 population and 755 plant progenies were selected from eight F_4 generations in T. Aman 2018.

During Boro 2018-19, a total of 66 F_3 plant progenies of 21 crosses were grown and 263 plant progenies were selected for further generation advance as F_4. A total of 693 F_5 plant progenies of eight crosses were grown and 1,960 plant progenies were selected for further generation advance as F_6.

Introgression of Dense and Erect Panicle Gene in Indica Rice (*Oryza sativa* L.) to Improve Plant Architecture

A total of 146 F_1 seeds were obtained from 12 crosses to develop high yielding Boro varieties (Table 1). Out of 38 crosses, 22 crosses were confirmed and registered in BRRI RS, Barishal code BRBa051 to BRBa072 during Boro 2018-19. A total of 120 plant progenies were selected from F_3 generation to develop high yielding varieties with dense and erect panicles during T. Aman 2018. A total of 39 F_3 plant progenies of four crosses were grown and 211 plant progenies were selected for further generation advance as F_4. A total of 111 F_4 plant progenies of four crosses were grown and 280 plant progenies were selected for further generation advance as F_5 during Boro 2018-19 season.

Table 1. List of F_1s seed produced during Boro 2018-2019, BRRI RS, Barishal.

Cross combination	No. of seed
BRRI dhan29/Uri dhan	15
Sumonswarna/Kataribhog	40
BRRI dhan29/Kataribhog	2
BRRI dhan58/BRRI dhan89	3
Sumonswarna /Uri dhan	2
Parija/BRRI dhan58	20
BRRI dhan58/Parija	4
Kataribhog/BRRI dhan28	3
BRRI dhan28/Kataribhog	28
BRRI dhan89/Uri dhan	6
BRRI dhan28/Parija	5
Parija/BRRI dhan28	18
Total	146

Preliminary yield trial (PYT) 2018-19

PYT # 1 for BB, Boro 2018-19. Preliminary yield trial (PYT) consisting of thirteen genotypes along with the BB resistant check IRBB60 and the susceptible check BRRI dhan29 and BRRI dhan58 was evaluated. Growth duration ranged from 148-157 days whereas grain yield ranged from 6.82-8.79 t ha^{-1}. The five genotypes BR9943-16-2-2-2, BR9650-108-2-1, BR9943-35-2-1-2-B2 to BR9943-4-2-3-1 and BR9943-24-3-3 produced above 8.0 t ha^{-1} grain yield that was higher than all the check varieties and growth duration was similar with the checks BRRI dhan58 and BRRI dhan29. The other five genotypes BR9942-1-2-1-2-B2, BR9943-4-2-3-2, BR9943-26-2-3-6, BR9943-26-3-2-1 and BR9650-108-2-3 (7.57-7.95 t ha^{-1}) produced similar grain yield with the check BRRI dhan29 (7.56 t ha^{-1}) but produced the higher grain yield than the checks BRRI dhan58 and IRBB60. The genotype BR9943-7-2-3-1 produced the higher grain yield than the check IRBB60. There was no presence of BB symptom in this trial.

Regional yield trial (RYT) 2018-19

RYT#1 (ZER-1) T. Aman 2018. For the development of zinc enriched rice, 10 genotypes along with two checks BRRI dhan62 and BRRI dhan39 were evaluated. The genotype IR84725-191-2-6-2-1-P2 produced the highest grain yield (4.82 t ha^{-1}) and fertility (92%) than the checks but with 26 days and 10 days longer growth duration than the check BRRI dhan62 and BRRI dhan39 respectively. The lowest grain yield (1.37 t ha^{-1}) was found in the check variety BRRI dhan62.

RYT#2 (ZER-2) T. Aman 2018. Eleven genotypes along with three checks BRRI dhan49, BRRI dhan72 and BRRI dhan39 were evaluated. The genotype BR7528-2R-19-16-RIL-14 produced the highest grain yield (4.95 t ha^{-1}) than the all checks but 9-19 days longer growth duration than the checks. The second highest grain yield was observed in the genotype BR7528-2R-19-16-RIL-28 (4.76 t ha^{-1}) followed by genotype BR8442-12-1-3-1-B7 (4.70 t ha^{-1}). The lowest grain yield (2.14 t ha^{-1}) was found in the genotype BR7528-2R-HR16-9-1-P1-2.

RYT#3 (ZER-3) T. Aman 2018. Three genotypes along with two checks BRRI dhan49 and BRRI dhan72 were evaluated. The genotype BR7528-2R-19-HR16-9-3-P7-2-2 (4.30 t ha^{-1} and 123 days) produced the similar grain yield and growth duration with the check BRRI dhan72 (4.13 t ha^{-1} and 125 days) but gave the higher grain yield than the check BRRI dhan49 (3.65 t ha^{-1} and 135 days). The lowest grain yield (2.39 t ha^{-1}) was found in the genotype IR97641-35-2-2-8-P2.

RYT#4 disease resistant rice (BB), T. Aman 2018. Eleven genotypes along with three checks BRRI dhan39 (Sus. ck), BRRI dhan49 (Std. ck) and IRBB60 (Res. ck) were evaluated. The genotype BR9140-5-22-5-1 produced the highest grain yield (4.97 t ha^{-1}) than all the checks. The genotypes BR9140-8-25-6-3 and BR9138-8-10-5-3 produced the similar grain yield with the checks BRRI dhan39 and BRRI dhan49 but gave the higher grain yield than the check IRBB60. The genotypes BR9636-8-6-10-2 and BR9140-15-20-6-4 produced the similar grain yield with the check BRRI dhan49 but gave the higher grain yield than the check IRBB60. The lowest grain yield (2.07 t ha^{-1}) was found in the check IRBB60. The various level of neck blast (10-40%) was observed in the genotypes IRBB60, BR9140-8-1, BR10392-B-B-12 and BR9636-8-6-10-2.

RYT (Bio)#5 for high yielding rice, T. Aman 2018. Two genotypes along with two checks BRRI dhan49 and BRRI dhan39 were evaluated. Grain yield ranged from 4.82 to 5.76 t ha^{-1}. The genotype BR(Bio) 9777-123-4-6-1 (5.76 t ha^{-1} and 122 days) produced the similar grain yield having growth duration with the check BRRI dhan39. However it produced the higher grain yield than the check BRRI dhan49 with 12 days earlier growth duration. The lowest grain yield (4.82 t ha^{-1}) was found in the genotype BR (Bio) 9777-116-12-2-2 (Table 2).

RYT(Bio)#6 for development of high yielding rice, T. Aman 2018. Three genotypes along with the check BRRI dhan71 were evaluated. The genotypes BR(Bio) 9786-BC2-80-1-1 and BR(Bio) 9786-BC2-161-1-2 produced the highest grain yield but 10 days longer growth duration than the check BRRI dhan71.

RYT#1 for favorable Boro rice. Five entries along with the check BRRI dhan58 were grown during Boro 2018-19. Growth duration ranged from 139-164 days whereas grain yield ranged from 6.15 to 7.84 t/ha. The highest grain yield was found in the genotypes BR9208-8-1-1-1 (7.84 t ha^{-1}) followed by BR8904-28-1-2-2-2 (7.78 t ha^{-1}). The lowest grain yield (6.15 t ha^{-1}) was recorded in the genotype Bikalpa28-DF (Early).

RYT#2 for zinc enriched rice, Boro 2018-19. Two entries along with the three checks BRRI dhan29, BRRI dhan74 and BRRI dhan84 were grown during Boro 2018-19. Growth duration ranged from 147 to 163 days whereas grain yield ranged from 6.90 to 8.02 t ha^{-1}. The genotypes IR99285-1-1-1-P1 and IR99285-1-1-1-P2 produced the similar grain yield but longer growth duration than the zinc enriched check varieties BRRI dhan74 and BRRI dhan84.

RYT#3 PQR, Boro 2018-19. Four genotypes along with the two checks BRRI dhan50 and BRRI dhan63 were grown during Boro 2018-19. Growth duration ranged from 153 to 160 days whereas grain yield ranged from 6.61 to 7.91 t ha^{-1}. The genotype BR8995-2-5-5-2-1 (7.91 t ha^{-1}) produced the highest grain yield than the checks BRRI dhan50 and BRRI dhan63. The other genotypes BR9205-10-1-5-3, BR8862-8-3-4-4-1 and BR8862-29-1-5-1-3 produced similar yield with the checks BRRI dhan50 and BRRI dhan63.

RYT#4 for disease resistant rice (BB), Boro 2018-19. Six genotypes along with three checks BRRI dhan29, BRRI dhan58 and IRBB60 were grown during Boro 2018-19. Growth duration ranged from 157 to 167 days whereas grain yield ranged from 6.04 to 7.84 t ha^{-1}. The genotype BR9651-15-2-1-4 (7.84 t ha^{-1}) produced the highest grain yield followed by BR9943-40-3-2 (7.68 t ha^{-1}) and BR9651-15-2-1-3 (7.34 t ha^{-1}). The lowest grain yield was found in the genotype BR9651-15-4-3-2.

RYT(Bio)#5 for favourable Boro rice, Boro 2018-19. Four advanced breeding lines along with the check BRRI dhan58 were grown during Boro 2018-19. Growth duration was ranged from 155-160 days whereas grain yield ranged from 7.39 to 8.06 t ha^{-1}. The genotype BR(Bio) 9777-116-12-2-5 produced the highest grain yield but five days longer growth duration than the check BRRI dhan58. The genotype BR(Bio) 9777-116-12-2-4 produced the similar grain yield but three days longer growth duration with the check BRRI dhan58 (Table 3).

Table 2. Yield and ancillary characters of RYT#5 (Bio) genotypes, T. Aman 2018, BRRI RS, Barishal.

Designation	Plant height (cm)	Growth duration (day)	1000-grain wt (gm)	Grain yield (t ha^{-1})
BR(Bio)9777-116-12-2-2	103.1	122	25.3	4.82
BR(Bio)9777-123-4-6-1	106.8	122	25.3	5.76
BRRI dhan49 (ck)	108.0	134	20.6	5.54
BRRI dhan39 (ck)	105.2	122	24.6	5.64
LSD at 0.05	5.2	2.7	2.2	0.30
CV (%)	2.5	1.1	4.6	2.80

DS: 9 Jul 2018, DT: 9 Aug 2018, Spacing: 25 cm × 15 cm.

Table 3. Yield and ancillary characters of RYT#5 (FBR) genotypes, Boro 2018-19, BRRI Barishal.

Designation	Plant height (cm)	Growth duration (day)	1000-grain wt (gm)	Grain yield (t ha^{-1})
BR(Bio)9777-116-12-2-4	109.9	158	26.8	7.77
BR(Bio)9777-116-12-2-5	107.9	160	27.1	8.06
BR(Bio)9787-BC2-35-4-2	98.8	155	20.6	7.39
BRRI dhan58 (ck)	101.6	155	21.0	7.56
LSD at 0.05	3.26	1.8	3.1	0.44
CV (%)	1.6	1.6	6.5	2.84

DS: 24 Nov 2018, DT: 25 Dec 2018, Spacing: 25 cm × 15 cm.

RYT(Bio)#6 for bacterial blight resistant rice, Boro 2018-19. A total of five advanced breeding lines along with two check varieties BRRI dhan28 and IRBB60 were grown during Boro 2018-19. Growth duration ranged from 144 to 159 days whereas grain yield ranged from 6.75 to 7.47 t ha^{-1}. The highest grain yield was found in the genotypes BR(Bio) 11447-1-28-14-1 (7.47 t ha^{-1}) followed by BR(Bio) 11447-1-28-14-3 (7.35 t ha^{-1}) and BR(Bio) 11447-1-28-12-3 (7.27 t ha^{-1}) that was similar to the check BRRI dhan28 but produced the higher grain yield than the check IRBB60. The lowest grain yield (6.69 t ha^{-1}) was recorded in the genotype BR (Bio) 11447-1-28-4-6.

RYT(Bio)#7 for cold tolerant rice, Boro 2018-19. The advanced breeding line BR(Bio)9777-124-1-1-2 along with two check varieties BRRI dhan28 and BRRI dhan36 were grown during Boro 2018-19. Growth duration ranged from 143 to 152 days whereas grain yield ranged from 6.45 to 6.89 t ha^{-1}. The genotype BR(Bio) 9777-124-1-1-2 produced the similar grain yield but with three days longer growth duration than the check BRRI dhan28 and six days earlier growth duration than the check BRRI dhan36.

Advanced yield trial (AYT), Boro 2018-19

Six (AYTs) were conducted during Boro 2018-19. Nine, three, 14, 10, 26 and 18 advanced breeding lines in AYT#1, AYT#2, AYT#3, AYT#4, AYT#5, and AYT#6 respectively were evaluated during Boro 2018-19.

AYT#1. Nine genotypes along with BRRI dhan28 and BRRI dhan58 as standard checks was evaluated at two location of BRRI Barishal, one location of BRRI Bhanga and one location of BRRI Satkhira.

Considering the mean grain yield over the location, the genotype BRBa 2-5-31-B-1 (6.56 t ha^{-1}) produced the highest grain yield followed by BRBa 2-9-4 (6.54 t ha^{-1}) than the checks but 3 days and 11 days longer growth duration than the checks BRRI dhan58 and BRRI dhan28, respectively.

AYT#2. Three genotypes along with BRRI dhan28 and BRRI dhan58 as standard checks was evaluated at two locations of BRRI RS, Barishal and one location of BRRI RS, Bhanga. Considering the mean grain yield over the locations, the genotype BRBa 2-2-1 (6.57 t ha^{-1}) produced the highest grain yield but with four days longer growth duration than the check BRRI dhan28.

AYT#3. Fourteen genotypes along with BRRI dhan28 and BRRI dhan58 as standard checks were evaluated at BRRI RS, Barishal. The genotype BRBa 3-2-6 produced similar grain yield (6.62 t ha^{-1}) but with six days longer growth duration than the check BRRI dhan58. The other four genotypes BRBa 3-2-2, BRBa 3-8-2, BRBa 3-1-7 and BRBa 3-1-6 (6.03-6.38 t ha^{-1}) produced the above 6.0 t ha^{-1} grain yield that was higher than the check BRRI dhan28 (5.08 t ha^{-1}). The lowest grain yield (5.65 t/ha) was found in the genotype BRBa 3-4-5 and BRBa 3-4-6.

AYT#4. Ten genotypes along with BRRI dhan28 and BRRI dhan58 as standard checks were evaluated at BRRI RS, Barishal. The genotype BRBa 3-3-3 produced higher grain yield (6.80 t ha^{-1}) followed by BRBa 2-5-3(6.78 t ha^{-1}) and BRBa 1-4-9-2 (6.66 t ha^{-1}) than the checks BRRI dhan28 and BRRI dhan58.

AYT#5. Twenty-six genotypes along with BRRI dhan28 and BRRI dhan58 as standard checks were evaluated at BRRI RS, Barishal. The genotypes IR14L395 and IR16F1198 produced above 5.0 t ha^{-1} grain yield.

AYT# 6. Eighteen genotypes along with BRRI dhan28 and BRRI dhan58 as standard checks were evaluated at BRRI RS, Barishal.

Proposed variety trial (PVT)

PVT#1. RLR and ZER, T. Aman 2018. The proposed RLR genotype BR8492-9-5-3-2 (5.14 t ha^{-1} and 128 days) produced higher grain yield and similar growth duration than the check variety BRRI dhan39 (4.40 t ha^{-1} and 129 days). The proposed ZER genotype BR7528-2R-HR16-2-24-1 (4.80 t ha^{-1} and 125 days) produced higher grain yield and four days earlier growth duration than the check variety BRRI dhan39 (4.40 t ha^{-1} and 129 days) (Table 4).

Table 4. Yield and ancillary characters of PVT (RLR and ZER) genotypes, T. Aman 2018, BRRI RS, Barishal.

Designation	Growth duration (day)	Grain yield (t ha^{-1})
BR8492-9-5-3-2	128	5.14
BR7528-2R-HR16-2-24-1	125	4.80
BRRI dhan39	129	4.40
LSD at 0.05	1.77	0.26
CV (%)	1.62	2.46

PVT, Boro 2018-19

PVT#1, Salt tolerant rice. The three genotypes IR83484-3-B-7-1-1-1, HHZ12-SAL2-Y3-Y2 and HHZ5-DT20-DT2-DT1 along with the sensitive check BRRI dhan28 and the tolerant check BRRI dhan67 was evaluated at on-farm condition of Latifpur, Kalapara. The growth duration of the genotypes ranged from 140-148 days whereas grain yield ranged from 4.08-5.95 t ha^{-1}. The genotype IR83484-3-B-7-1-1-1 produced (5.95 t ha^{-1}) the highest grain yield followed by HHZ12-SAL2-Y3-Y2 (5.69 t ha^{-1}) and HHZ5-DT20-DT2-DT1 (5.40 t ha^{-1}) compared to the checks BRRI dhan28 (4.08 t ha^{-1} with growth duration of 140 days) and BRRI dhan67 (4.47 t ha^{-1} with growth duration of 143 days).

PVT#2 Bio for favourable Boro rice. The advanced breeding line BR(Bio) 9787-BC2-63-2-2 along with the check variety BRRI dhan28 was grown at on-farm condition of Sreerampur, Nalcity. The proposed genotype BR(Bio) 9787-BC2-63-2-2 (6.60 t ha^{-1} and 140 days) produced higher grain yield and two days earlier growth duration than the check variety BRRI dhan28 (5.83 t ha^{-1} and 142 days). The highest fertility (93.6%) and 1000-grain weight (22.6 gm) also found in the proposed genotype BR(Bio)9787-BC2-63-2-2.

Agronomic and phenotypic characterization of event GR2E-5 and non-transgenic control rice, BRRI dhan29, in confined field trials

Confined field trial (CFT) of golden rice in multi environment, Boro 2018-19. One transgenic line IR112060 GR2-E:2-7-63-2-96 and one non-transgenic control as standard check variety BRRI dhan29 were evaluated. The transgenic line IR112060 GR2-E:2-7-63-2-96 performed little bit lower than the control check variety BRRI dhan29 in respect of tiller number, panicle number and grain yield (Table 5).

PEST MANAGEMENT

Screening of chemicals for controlling blast disease of rice

Among the 15 chemicals tested two viz Brio and Iso-R40EC significantly reduced neck blast (NB)

Table 5. Yield and ancillary data of golden rice materials, Boro 2018-19, BRRI RS, Barishal.

Designation	DF	DM	PH	Pan	FLL	FLW	SF	TGW	GY
IR 112060 GR2-E:2-7-63-2-96	113	141	107	15.4	25.6	1.69	73.2	18.45	6.52
BRRI dhan29 (ck)	117	144	109	15.8	24.7	1.67	70.1	18.41	6.72
LSD (0.05)	4.97	2.48	7.92	0.14	3.01	0.05	4.57	0.99	0.59
CV (%)	2.05	1.21	2.05	7.41	3.26	2.54	3.27	1.30	2.94

DS: 7 Jan 2019, DT: 17 Feb 2019, Spacing: 20 cm × 20 cm.
DF=Days to flowering (days), DM=Days to maturity, PH=Plant height (cm), Pan= Number of panicle/plant, PL=Panicle length (cm), FLL=Flag leaf length (cm), FLW=Flag leaf width (cm), SF= Spikelet fertility (%), TGW= Thousand grain weight (gm), GY= Grain yield (t ha^{-1}).

disease and showed reaction similar to Trooper and Nativo. Reduction of neck blast disease incidence by those chemicals ranged from 90.0% to 92% over untreated control (plain water). Other chemicals viz KGT2 CARE 75 WDG, BRAVO, Adtivo, Tabia, Trycyclazole 75WP also reduced neck blast and this reduction ranged from 84 to 88%. Rest of the chemicals was not effective in reducing the blast disease. Further test of those effective chemicals is suggested for the next season.

Survey and monitoring of rice diseases in selected areas

During T.Aman 2018, bacterial leaf blight and brown spot was recorded as major diseases. sheath blight, blast and false smut were also observed as a promising disease. High yielding variety BRRI dhan34, BRRI dhan52 and local variety Chinigura, Montessormota, Sakkhorkhora, Kumragoir, Kalijira, Vushiara, Lalchikon, Sadamota, Moulata were infected by blast disease during the survey period. The incidence of rice blast disease was less in this season (T. Aman 2018) compared to last T. Aman 2017. Out of 27 fields visited during Boro 2018-19 season, blast was found in 20 fields. Rice blast incidence was comparatively lower in this season compared to 2017-18. Among the other diseases BLB was higher in Boro followed by sheath blight and brown spot (Fig. 1). Leaf scald, sheath rot and karnel smut diseases were also recorded in a limited scale.

Demonstration on the management options of blast disease at farmers' field of Barishal region

The demonstration was conducted during Aman 2018 farmers' field of Babuganj, Barishal under natural field condition using blast susceptible rice variety BRRI dhan34. Yield of BRRI dhan34 was significantly higher in recommended practices (4.32 t ha^{-1}) over farmers' practices (3.41 t ha^{-1}). The amount of yield increase of BRRI dhan34 in recommended or research practice over farmers' practice was 20.6%. Disease incidence was 13.6% in RP treatment while it was 73% in control treatment having a reduction of 81.4% over FP.

Pest and natural enemy incidence in BRRI RS, Barishal light trap

Incidence of insect pests was lower than the previous reporting year. Green leafhopper (GLH), yellow stem borer (YSB), brown planthopper (BPH), zigzag leafhopper (ZLH) and long horned cricket (LHC) were found comparatively in higher number than the other rice insect pests. First peak of insect pest was observed at Barishal in November 2018 and 2nd peak in March 2019 throughout the reporting year, July 2018 to June 2019 (Fig. 1). Among (GLH, BPH, YSB and RH) rice insect pest population the highest number was found in September, October and November 2018 and another highest population was observed in March and April 2019.

The highest catch of natural enemies in light trap was staphylinid beetle (STPD), green mired bug (GMB) and carabid beetle (CDB) at Sagordhi farm, Barishal. The GMB was observed higher in November 2018 and February 2019. STPD was observed highest in November 2018 and January to March 2019. CDB was found higher in November 2018 and April 2019. SPD was found higher throughout the year except November 2018.

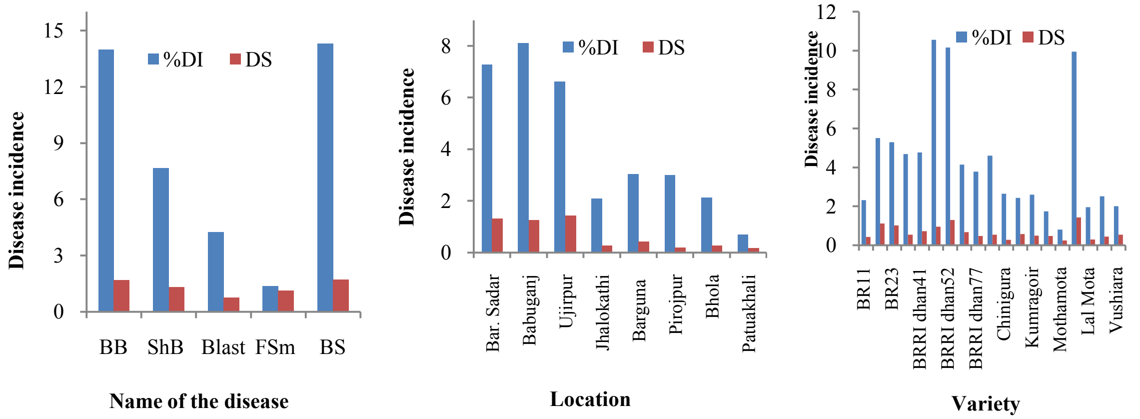

Fig. 1. Incidence and severity of different diseases over different locations and variety, T. Aman 2018.

Rice production with no or minimum use of insecticides

Two treatment, researcher practice (Logo, perching, sweeping, no insecticide upto 30 days of transplanting and need based application of pesticide) and farmers' practice were used in this experiment. Comparable higher yield was recorded in researcher practice than farmers' practice in T. Aman 2018 and Boro 2018-19. During T. Aman 2018, higher yield (5.03 t ha^{-1}) was found in researcher practice than farmers' practice (4.92 t ha^{-1}) plot. Average number of insect pest was higher (6.3) in farmers' plot than researcher plot (5.5) and average number of natural enemies was lower (2.2) in farmers plot than the researcher plot (3.7). Similar trends were observed during Boro 2018-19.

CROP-SOIL-WATER MANAGEMENT

Effect of planting date on growth and yield of BRRI developed varieties in Aman season

In T. Aman 2018, experiment was conducted having four sowing dates and four varieties. Irrespective of variety rice transplanted in 5 August (seeding 1 July, yield 4.7 t ha^{-1}) and 21 August (seeding 16 July, yield 4.7 t ha^{-1}) with 35-day-old seedling produced higher yield than the later two planting times. Average growth duration was 145 and 149 days at those transplanting times respectively. Growth duration reduced by 7-11 days at later two transplanting dates.

Long term missing element trial for diagnosing limiting nutrient in Sagardi, Barishal farm in Aman 2018

The highest grain yield (5.17 tha^{-1}) was found in complete treatment (NPKSZn). Grain yield was significantly lower than the complete treatment due to the omission of N, K, S and Zn. The lowest yield was recorded in -N plot followed by -S plot. Thus the study reveals that N is the most limiting nutrient in tidal flooded soil. Overall findings suggest that all the nutrients (N, P, K, S, Zn) should be applied for getting the higher yield and obviously, N application must be assured for optimum rice yield.

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

In total 151 km long primary and secondary canals were surveyed in polder 43/1. Stored volume of water was 74,14,503 m^3 in April. Among the surveyed canal 11.1 km long canal was affected by salinity ranges from 1-2.2 dS m^{-1}. It shows that 4,878 ha sunflower field can be successfully irrigated with the 74,14,503 m^3 water. On the other hand, irrigation is possible for 1,800 ha and 634 ha land of maize and Boro rice respectively.

Use of less saline water resources for increasing cropping intensity in Barishal region

This experiment was conducted at Bakerganj, Barishal, Nolcity and the Jhalokathi sadar upazila during Boro 2018-19. The water salinity was measured in both locations throughout the period of time and was less than 0.5 dS/m, which is very suitable for irrigation. In Nolcity, Jhalokati, BRRI dhan74 produced the highest yield of 6.3 t ha^{-1} while BRRI dhan67 produced the minimum 5.7 t ha^{-1}. In Jhalokathi sadar, BRRI dhan74 gave the higher yield of 6.1 t ha^{-1} followed by BRRI dhan67 (5.6 t ha^{-1}). In Bakerganj, BRRI dhan 74 performed the best among the four varieties. It gave the highest 6.1 t ha^{-1} grain yield followed by 6.0 t ha^{-1} and 5.7 t ha^{-1} for BRRI dhan67 and BRRI dhan58 respectively. BRRI dhan47 produced the lowest 5.3 t ha^{-1}. In both the sites, yield of each variety was lower than their average yield. This is because of transplanting of aged seedlings.

Sufficient amount of water is available round the year in primary, secondary and tertiary canals of Barishal region. Salinity of these water remains in permissible limit for irrigation. There is a large scope of crop intensification through Boro rice cultivation. But to get desirable yield of Boro rice massive demonstration work and farmers' training is needed because, farmers of this area don't have sufficient knowledge on pest, fertilizer and other agronomic management practices.

SOCIO-ECONOMICS AND POLICY

Stability and adaptability analysis of BRRI developed variety in Aus 2018

In Aus 2018, the highest yield was observed in BRRI dhan82 (5.1 t ha^{-1}) followed by BRRI dhan83 (4.9 t ha^{-1}) and BRRI dhan48 (4.9 t ha^{-1}). The lowest yield was found in BR21 (2.6 t ha^{-1}) due to bird attack. In T. Aman 2018, among the tested SDV, the highest yield was observed in BRRI hybrid dhan4 (5.8 t ha^{-1}) followed by BRRI dhan71 (5.3 t ha^{-1}). The lowest yield was found in BRRI dhan57 (3.8 t ha^{-1}). In medium duration varieties, the highest yield was found in BRRI dhan87 (5.8 t ha^{-1}) followed by BRRI hybrid dhan6 (5.66 t ha^{-1}). The lowest yield was obtained in BR3 (3.83 t ha^{-1}). Finally, in the long duration varieties, the highest yield was in BRRI dhan77 (5.4 t ha^{-1}) followed by BRRI dhan76 (5.3 t ha^{-1}) and the lowest yield was in BR5 (2.9 t ha^{-1}). During Boro 2018-19, grain yield ranged from 4.93-8.40 t ha^{-1}. The three varieties BRRI dhan29, BRRI dhan89 and BRRI hybrid dhan5 produced above 8.0 t ha^{-1} grain yield. The lowest grain yield was observed in the variety BR6 (4.93 t ha^{-1}) followed by BRRI dhan60 (5.04 t ha^{-1}).

TECHNOLOGY TRANSFER

Demonstration, seed production and scaling up of BRRI rice varieties under GOB, SPIRA and other projects.

In the reporting year, BRRI RS, Barishal has conducted 21 demonstrations in Aus 2018, the highest yield (4.97 t ha^{-1}) was recorded from BRRI dhan82 followed by BRRI dhan48 (4.55 t ha^{-1}) while the lowest yield (3.2 t ha^{-1}) was observed in BRRI dhan65. A total of 28 demonstrations in Aman 2018 and the highest yield was recorded from BRRI dhan52 (5.4 t ha^{-1}) followed by BRRI hybrid dhan4 (5.3 t ha^{-1}). A total of 1,114 demonstrations were conducted in Boro season. Among the Boro varieties average yield of three hybrid varieties was 8.18 t ha^{-1} (ranged from 8.01-8.28 t ha^{-1}), which was higher than the seven inbred varieties (average 6.66 t ha^{-1}, ranged from 6.05-7.3 t ha^{-1}). BRRI dhan74, BRRI dhan69 and BRRI dhan58 were liked by the farmers in this region.

Varietal replacement through head to head trial for T. Aman 2018 and Boro 2018-19 under TRB

Varietal replacement through head to head trial with five T. Aman varieties at six locations in Barishal region BRRI dhan72 (4.78 tha^{-1}) and BRRI dhan77 (4.72 tha^{-1}) gave higher yield followed by BRRI dhan76 (4.70 tha^{-1}), BRRI dhan79 (4.66 t ha^{-1}), BRRI dhan52 (4.56 tha^{-1}) and Sadamota (3.5 t ha^{-1}). In Boro 2018-19, trials were conducted under BRRI dhan28 and BRRI dhan29 groups in eight locations. BRRI dhan67 (7.45 tha^{-1}) and BRRI dhan74 (7.33 tha^{-1}) provided the higher yield followed by BRRI dhan81 (6.75 tha^{-1}), BRRI dhan28 (6.42 tha^{-1}), BRRI dhan86 (6.41 t ha^{-1}) and BRRI dhan84 (6.25 t ha^{-1}). In BRRI dhan29 group, BRRI dhan29 (7.63 tha^{-1}) provided the highest yield followed by BRRI dhan58 (7.1 tha^{-1}), BRRI dhan89 (7.05 t ha^{-1}).

Farmers' training/Field day

BRRI RS, Barishal conducted 10 farmers' training (male 251 and female 59, NGO personnel 10 and Imam 10) and nine field days (418 male and 482 female) in different locations of Barishal region during the reporting period.

Breeder seed and TLS production. In T. Aman 2018, a total of 17,070 kg and in Boro 2018-19, a total of 27,205 kg breeder seed were produced. In T. Aman 2018, a total of 10,823 kg TLS and in Boro 2018-19, a total of 28,759 kg seeds of BRRI released varieties were produced.

BRRI RS, Bhanga

SUMMARY

A total of 22,675 progenies were grown in F_2 generation following Field RGA method with single seed descent (SSD) targeting to develop high yielding Boro varieties and 10,395 F_3 progenies were maintained by collecting single panicle from each plant in Boro 2018-19. Two advanced breeding lines such as BR10230-15-27-7B, BR10260-7-19-2B and a check variety Fulkori were evaluated as PVT in two locations in Gopalganj and Faridpur. BR10230-15-27-7B was recommended for release as BRRI dhan91, which is country's first deep water rice high yielding variety. Moreover, BR7528-2R-HR16-2-24-1 (ZER) and BR8492-9-5-3-2 (RLR) gave 0.9 t ha^{-1} and 1.0 t ha^{-1} higher yield respectively than the check variety BRRI dhan39 at Akanbaria village of Bhanga upazila in Faridpur district. The growth duration of BR7528-2R-HR16-2-24-1 (ZER) was six days earlier than the check variety. The growth duration of BR8492-9-5-3-2 (RLR) was similar to check variety BRRI dhan39. In PVT (Boro, 2018-19), BR (Bio) 9787-BC2-63-2-2 produced 0.96 t ha^{-1} higher yield than the check variety BRRI dhan28. The growth duration of BR(Bio)9787-BC2-63-2-2 was four days earlier than the check variety. In RYT (DWR), all seven genotype sproduced higher grain yield than the check variety Hizal-digha. Among all, Lal-Mohon produced higher yield (1.4 t ha^{-1}) in Kendua village of Muksudpur upazila in Gopalganj district in Broadcast Aman (DWR) season. No significant differences in yield among these genotypes were found in Talma village of Nagarkanda upazila in Faridpur district. The growth duration of Sorsoria, Dudlaki, Laxmidigha was almost similar to check. The other four landraces such as Bashiraj, Biladigha, Kipho-digha, Lal-Mohon had higher growth duration than the check variety in both the locations. In multi location testing of Boro-DWR cropping pattern in flood prone areas, existing cropping pattern was replaced by improved cropping pattern Boro-DWR (Laldigha) and about 1.3 t ha^{-1} REY was increased. Seven demonstrations of modern rice varieties during T. Aman 2018 and Boro 2018-19 were carried out in Faridpur, Madaripur and Gopalganj districts funded by BRRI-SPIRA project.

VARIETY DEVELOPMENT

FRGA. In Boro 2018-19, 22675 plants were grown in F_2 generation following Field RGA technique with single seed descent (SSD) targeting to develop high yielding Boro varieties and 10,395 F_3 progenies were maintained by collecting single panicle from each plant (Table 1).

PVT (DWR). Two advanced breeding lines such as BR10230-15-27-7B (BR11 Sub1 / BRRI dhan40), BR10260-7-19-2B (Tilakkachari / BRRI dhan41) and a check variety Fulkori were evaluated as PVT in two locations, Muksudpur upazila in Gopalganj and Bhanga upazila of Faridpur district. BR10230-15-27-7B and BR10260-7-19-2B produced 2.2 t ha^{-1} and 3.2 t ha^{-1} yield, which were higher than the check variety Fulkori (1.4 t ha^{-1}). The growth duration was four and three days shorter than the check variety respectively (Table 2). BR10230-15-27-7B was recommended for release as BRRI dhan91, which is the first deep water rice high yielding variety of the country.

PVT (T. Aman). BR7528-2R-HR16-2-24-1 (ZER) and BR8492-9-5-3-2 (RLR) gave 0.9 t ha^{-1} and 1.0 t ha^{-1} higher yield than the check variety BRRI dhan39 at Akanbaria village of Bhanga upazila in Faridpur district. The growth duration of BR7528-2R-HR16-2-24-1 (ZER) was six days earlier than the check variety. The growth duration of BR8492-9-5-3-2 (RLR) was similar to the check variety BRRI dhan39 (Table 3).

PVT (Boro). BR(Bio)9787-BC2-63-2-2 produced 0.96 t ha^{-1} higher yield than check variety BRRI dhan28. The growth duration of BR (Bio) 9787-BC2-63-2-2 was four days shorter than the check variety.

RYT (DWR). In Kendua village of Muksudpur upazila in Gopalganj district, all the lines produced higher grain yield than the check variety Hizal-digha. Among all, Lal-Mohon produced higher yield (1.4 t ha^{-1}) (Table 4). In Talma village of Nagarkanda upazila in Faridpur district, there is no significant differences in yield among these lines. The growth duration of Sorsoria, Dudlaki, Laxmidigha was almost similar to check variety (Table 4). The other four lines Bashiraj, Biladigha, Kipho-digha, Lal-Mohon has higher growth duration than the check variety in both the locations.

Table 1. Cross combinationand F_3 progenies, development of high yielding Boro rice, BRRI RS, Bhanga.

Cross combination	No. of progenies grown	No. of progenies harvested
D(R)-6 /BRRI dhan67	3125	1670
BRRI dhan75 / WANXIAN7777-P8	3500	1935
IR106449-23-3-AJY1-B-1 / BRRI dhan67	3500	1700
CN6 /AK-6	3500	1700
BRRI dhan29 / BRRI dhan47	1325	Not flowered
HH223-SAL16-DT1-DT1 / BRRI dhan67	3500	1625
IR108175-B-CMU3-2-1 / BRRI dhan47	2625	1165
IR-105459-23-3-AJY1-B-1 /BRRI dhan67	1600	600
Total		10395

Table 2. Performance of proposed lines under PVT-DWR in B. Aman 2018.

Genotype	Location			
	Muksudpur, Gopalganj		Bhanga, Faridpur	
	Yield (t ha^{-1})	Growth duration (day)	Yield (t ha^{-1})	Growth duration (day)
BR10230-15-27-7B	1.1	151	3.5	149
BR10260-7-19-2B	2.1	153	4.5	150
Fulkori (ck)	0.4	155	1.3	155

Table 3. Performance of proposed lines under PVT-RLR and ZER during T. Aman 2018-19 Akanbaria, Bhanga, Faridpur.

Genotype	Yield (t ha^{-1})	Growth duration (day)
BR7528-2R-HR16-2-24-1	7.1	109
BR8492-9-5-3-2	7.2	115
BRRI dhan39	6.2	115

Table 4. Grain yield and agronomic characters of RYT-DWR, in B. Aman 2018 at Kendua, Muksudpur, Gopalganj and Talma, Nagorkanda, Faridpur.

Genotype	Growth duration (day)	Plant height (cm)	Panicle length (cm)	Tiller/hill	Panicle/hill	Yield (t ha^{-1})
			Kendua, Muksudpur, Gopalganj			
Bashiraj	155.67	159.67	24.4	9	7	0.9
Bila-digha	155.67	202.73	24.67	8	6	0.7
Dud-laki	147.67	181.53	23.87	8	6	0.9
Kipho-digha	155.33	192	24.27	7	6	0.6
Lal-Mohon	155.33	146.6	20.8	8	6	1.4
Laxmi-digha	147	187.2	23.13	8	6	0.5
Sorsoria	147.67	187.53	21.73	8	6	0.6
Hizal-digha (ck)	148.67	198.6	22.67	8	6	0.4
LSD ($P < 0.05$)	1.66	26.52	2.54	NS	NS	0.56
			Talma, Nagorkanda, Faridpur			
Bashiraj	160	135.2	20.8	10	7	2.0
Bila-digha	159	158.67	21	10	8	1.5
Dud-laki	148	152.07	18.67	8	7	1.5
Kipho-digha	157	172.73	19.33	8	7	1.9
Lal-Mohon	156	134.27	20.47	10	8	1.3
Laxmi-digha	149	195	20.2	9	8	2.0
Sorsoria	148	201.07	20.87	10	9	2.2
Hizal-digha (ck)	148	183.07	21.67	9	7	2.1
LSD ($P<0.05$)	1.68	44.23	NS	NS	NS	NS

MLT (Aman). The advanced breeding line BR7930-20-2-2-2-2-1 produced similar grain yield (3.9 tha^{-1}) to the check variety BRRI dhan52 with almost 21 days higher growth duration. The other advanced breeding lines produced lower yield with the check variety BRRI dhan52. There were no advanced lines that produced higher yield than the check variety BRRI dhan44. The growth duration of BR8748-19-1 was eight and 15 days earlier than that of the check varieties BRRI dhan52 and BRRI dhan44 respectively (Table 5).

BVE (Breeding value estimation) trial

In Boro 2018-19 season, 161 genotypes were evaluated for breeding value estimation. Initially, 10 genotypes were selected based on yield performance, which will be used as parent in crossing and further evaluation. The genotype BR9006-54-1-3-2 produced higher 5.84 t ha^{-1} yield followed by Sampa Katari (5.79 t ha^{-1}), KARJAT-5 (5.77 t ha^{-1}), PIR26>CO-2410-1-2 (5.75 t ha^{-1}), BR8905-17-2-3-3-1-4 (5.74 t ha^{-1}), BR8562-11-2-6-1-1-1 (5.58 t ha^{-1}), BRRI dhan59 (5.46 t ha^{-1}), BR9011-12-2-1 (5.4 t ha^{-1}), WANXIAN-P10 (5.39 t ha^{-1}), BR8564-32-1-1-6-1-1 (5.32 t ha^{-1}).

Breeding zone trial (BZT)

A total of 60 genotypes were evaluated along with two standard check varieties BRRI dhan58 and BRRI dhan81 for getting initial yield potential in replicated trial following row column design in Boro 2018-19. The genotype IR 106236-B-B-B-PRN B-PRN B-PRN-62 produced higher yield 5.84 t ha^{-1} followed by IR16A2203 (5.08 t ha^{-1}), IR 106236- B-B-B-PRN B-PRN B-PRN 246 (5.05 t ha^{-1}), IR16A2287 (5.02 t ha^{-1}), IR15A3248 (4.94 t ha^{-1}), IR16A1135 (4.78 t ha^{-1}), IR16A1996 (4.60 t ha^{-1}), IR15A3466 (4.59 t ha^{-1}), IR 106236- B-B-B-PRN B-PRN B-PRN 11 (4.56 t ha^{-1}), IR 103314-B-B RGA-B RGA-143-1 (4.54 t ha^{-1}).

INGER-IIRON. Sixty-seven genotypes along with seven local checks were evaluated in Boro, 2018-19 season. Out of 67 lines, 11 lines such as SVIN055, SVIN63, SVIN64, SVIN65, SVIN66, SVIN69, SVIN74, SVIN76, SVIN77, SVIN109 and SVIN117 were selected for using as parent in cross and advanced yield testing

AYT-1 (Boro). The advanced breeding lines such as BR8899-17-1-1-1-1-1 (7.76 t ha^{-1}), IR100008-40-B-3 (7.34 t ha^{-1}), IR100740-89-B-2 (7.2 t ha^{-1}), IR100722-B-B-B-B-16 (6.89 t ha^{-1}), TP30433 (6.77 t ha^{-1}), IR99982-B-B-B-B1 (6.74 t ha^{-1}) produced higher grain yield than both the check varieties (BRRI dhan81 and BRRI dhan28) with longer growth duration. The advanced breeding lines IR99982-B-B-B-B-18 (6.69 t ha^{-1}), BR10296-55-4 (6.66 t ha^{-1}), TP30015 (6.65 t ha^{-1}), IR99982-B-B-B-B-8 (6.61 t ha^{-1}), IR100121-B-B-B-B-67 (6.46 t ha^{-1}) and IR100004-19-B-1 (6.3 t ha^{-1}) produced higher grain yield than the check variety BRRI dhan28 with longer growth duration (Table 6).

AYT-2 (Boro). The advanced breeding lines such as BR8905-17-2-3-3-1-4 (9.26 tha^{-1}) and BR8905-17-2-3-3-1-1 (8.37 t ha^{-1}) produced higher grain yield than the check varieties BRRI dhan58 with longer growth duration. The other seven advanced breeding lines produced lower yield with the check varieties with longer growth duration except TP29654 (Table 7).

PYT (Boro). The advanced breeding lines such as BR10296-27-3-1-1 (8.08 t ha^{-1}), TP 30754 (7.79 t ha^{-1}), TP 30596 (7.73 t ha^{-1}), TP 30606 (7.58 t ha^{-1}), TP 30610 (7.56 t ha^{-1}), TP 30598 (7.19 t ha^{-1}), TP 30597 (6.96 t ha^{-1}) produced higher grain yield than the check varieties (BRRI dhan81 and BRRI dhan28) with longer growth duration and two breeding lines BR9600-22-5-2-1-P3 (6.79 t ha^{-1}), TP 21654 (6.71 t ha^{-1}) produced higher grain yield than the check variety BRRI dhan28 with longer growth duration (Table 8).

RYT (Boro) *haor*. None of the three advanced breeding lines out-yielded the check BRRI variety dhan28. But the growth duration of all the three lines was seven days shorter than the check variety BRRI dhan28 (Table 9).

RYT (Boro) favourable. None of the five advanced breeding lines out-yielded the check variety BRRI dhan58. But the growth duration of three lines was shorter than check variety BRRI dhan58. Based on growth duration, Bikalpa28-DF was 22 days shorter and BR 9208-8-1-1-1 was 18 days shorter than the check variety (Table 10).

RYT (Boro) bacterial blight resistance. None of the six advanced breeding lines out-yielded the susceptible check BRRI dhan29 with shorter growth duration. But BR9651-15-2-1-4 produced slight higher yield than the check variety BRRI dhan58 with similar growth duration. Compared with resistant check IRBB60, BR9651-15-2-1-4 produced higher yield of about 0.24 t ha^{-1} with similar growth duration followed by BR9651-15-2-1-5, BR9651-15-2-1-3, BR9651-15-4-3-2 of about 0.2 t ha^{-1}, 0.19 t ha^{-1} and 0.06 t ha^{-1} respectively (Table 11).

Table 5. Grain yield and agronomic characters of MLT-DWR, in Aman 2018 at Kendua, Muksudpur, Gopalganj.

Genotype	Plant height (cm)	Tiller no./Plant	Panicle no./Plant	Yield (tha^{-1})
BR7930-20-2-2-2-2-1	152.8	11	9	3.9
BR7932-14-2-2-3-1-1-1-16	152.1	12	10	2.7
BR7932-14-2-3-1-1-1-2	153.6	11	9	1.8
BR7932-17-2-1-2-1-1-1-12	152.7	11	9	3.4
BR7932-17-2-1-2-1-2-1-23	141.5	13	11	3.2
BR7932-17-2-1-2-1-2-1-25	134.9	16	13	3.5
BR7934-10-1-1-1-2-2	142.2	10	8	3.0
BR8146-11-2-1-1-2-10-1	140.4	11	8	3.3
BR8146-5-2-2-1-1-1-2	141.8	15	11	3.25
BR8146-6-1-1-2-2-1-21	146.1	10	8	3.25
BR8156-7-1-2-1-1-1-1	134.6	14	12	2.65
BR8159-20-8-5-8-2	134.5	14	11	2.3
BR8748-19-1	123.6	12	10	3.6
BRRI dhan44 (ck)	138.8	13	11	4.95
BRRI dhan52 (ck)	132.4	12	10	3.9
LSD (P<0.05)	7.20	3.77	3.81	2.62
CV(%)	1.26	7.69	9.76	20.03

Table 6. Grain yield and ancillary characters of AYT-1, Boro 2018-19 at BRRI RS, Bhanga

Genotype	Growth duration (day)	Plant height (cm)	Yield ($t\ ha^{-1}$)
BR10296-31-1	152	76.8	5.92
BR10296-55-4	152	94.3	6.66
BR8899-17-1-1-1-1-1	150	73.3	7.76
BR9944-18-1-6	149	92.5	5.65
BR9945-12-1-3	148	90.4	5.51
BR9950-12-2-1	145	99.2	6.14
IR100004-19-B-1	151	85	6.3
IR100008-40-B-3	162	88.7	7.34
IR100121-B-B-B-B-67	157	95.7	6.46
IR100722-B-B-B-B-16	153	94.5	6.89
IR100740-89-B-2	156	91.3	7.2
IR99090-B-B-61-1	156	95.1	6.19
IR99982-B-B-B-B1	153	86.8	6.74
IR99982-B-B-B-B-18	152	84.6	6.69
IR99982-B-B-B-B-8	150	85.3	6.61
TP30015	155	86.5	6.65
TP30433	158	94.5	6.77
BRRI dhan28 (ck)	149	89.3	6.23
BRRI dhan81 (ck)	149	76.7	6.72
LSD (P<0.05)	2.6	1.5	0.87
Heritability (Broad-sense)	0.80	0.95	0.73

Table 7. Grain yield and ancillary characters of AYT-2, in Boro 2018-19 at BRRI RS, Bhanga.

Genotype	Growth duration (day)	Plant height (cm)	Yield ($t\ ha^{-1}$)
BR8905-17-2-3-3-1-4	164	98.9	9.26
BR8905-17-2-3-3-1-1	161	79.2	8.37
BRRI dhan58 (ck)	156	95.8	8.29
BR8902-38-7-1-1-1-1	158	99.2	8.01
TP26717	164	92.9	8.00
BR9945-40-1-3	161	91.7	7.54
TP30022	164	86.6	7.39
BR9945-28-7-3	160	91.9	6.84
TP30430	160	99.4	6.65
TP29654	151	74.8	6.52
LSD (P<0.05)	2.46	2.41	1.06
Heritability	0.96	0.91	0.79

Table 8. Grain yield and ancillary characters of PYT, in Boro 2018-19 at BRRI RS, Bhanga.

Genotype	Growth duration (day)	Plant height (cm)	Yield (t ha^{-1})
BR10296-27-3-1-1	149	85.1	8.08
TP 30754	152	92.5	7.79
TP 30596	156	87.5	7.73
TP 30606	152	98.8	7.58
TP 30610	160	99.8	7.56
TP 30598	152	91.0	7.19
TP 30597	150	91.5	6.96
BR9600-22-5-2-1-P3	158	82.7	6.79
TP 21654	152	87.2	6.71
TP 16228	148	70.2	6.24
BR10296-36-4-1-1	160	92.7	6.06
BRRI dhan81 (ck)	146	89.2	6.83
BRRI dhan28 (ck)	147	95.0	6.39
LSD (P<0.05)	NS	NS	NS
Heritability	-	-	-

Table 9. Grain yield and ancillary characters of RYT-*haor* in Boro 2018-19 at BRRI RS, Bhanga.

Genotype	Growth duration (day)	Plant height (cm)	No. of tillers/hill	No. of panicles/hill	Panicle length (cm)	Yield (t ha^{-1})
BRRI dhan29-SC3-28-16-10-6-HR6 (Com)-HR1 (Gaz)-P4 (Hbj)	142	72.1	13	12	18.7	4.86
BRRI dhan29-SC3-28-16-10-6-HR6 (Com)-HR1 (Gaz)-P8 (Hbj)	142	73.8	12	11	18.7	4.29
BRRI dhan29-SC3-28-16-10-6-HR6 (Com)-HR2 (Gaz)-P11 (Hbj)	142	69.9	12	11	18.3	4.11
BRRI dhan28 (CK)	149	84.7	14	12	23.2	7.93
LSD (P<0.05)	NS	1.24	2.21	1.31	0.61	1.14
Heritability	-	0.70	0.64	0.67	0.89	0.65

Table 10. Grain yield and ancillary characters of RYT- Favourable Boro in Boro 2018-19 at BRRI RS, Bhanga.

Genotype	Growth duration (day)	Plant height (cm)	No. of tillers/hill	Yield (t ha^{-1})
KARJAT-5	141	98.8	15	8.01
BR 9208-8-1-1-1	128	106.1	13	7.96
BR 9675-68-5-1	140	99.4	16	7.95
BR 8904-28-1-2-2-2	139	96.0	18	7.80
Bikalpa28-DF (Early)	124	85.1	13	6.64
BRRI dhan58 (ck)	146	91.5	14	8.47
LSD (P<0.05)	2.64	4.04	1.36	0.69
Heritability	0.90	0.78	0.94	0.87

Table 11. Grain yield and ancillary characters of RYT-BB, in Boro 2018-19 at BRRI RS, Bhanga.

Genotype	Growth duration (day)	Plant height (cm)	No. of tillers/hill	No. of panicles/hill	Panicle length (cm)	Yield (t ha^{-1})
BR9650-99-3-2	126	98.5	12	11	23.6	6.90
BR9651-15-2-1-3	127	87.4	13	12	22.7	7.30
BR9943-40-3-2	130	97.7	13	12	22.9	7.07
BR9651-15-2-1-4	128	85.2	12	12	22.1	7.35
BR9651-15-2-1-5	127	84.5	13	12	22.1	7.31
BR9651-15-4-3-2	130	95.5	13	12	22.9	7.17
BRRI dhan29 (Sus ck)	137	95.1	13	13	23.0	7.56
BRRI dhan58 (Sus ck)	128	92.9	13	12	23.3	7.32
IRBB60 (Res ck)	128	76.6	14	13	22.6	7.11
LSD (P<0.05)	2.13	3.89	2.26	2.36	1.80	0.91
Heritability	0.95	0.97	0.52	0.45	0.52	0.43

RYT (Boro) PQR. All four advanced breeding line such as BR8862-29-1-5-1-3, BR8862-8-3-4-4-1, BR8995-2-5-5-2-1, BR9205-10-1-5-3 produced higher grain yield at about 1.07 tha^{-1}, 1.5 tha^{-1}, 0.8 tha^{-1}, 0.32 tha^{-1} respectively than the check varieties BRRI dhan50 with longer growth duration but lower yield comparing other check variety BRRI dhan63 with longer growth duration also (Table 12).

RYT (Boro) ZER. The advanced breeding lines IR99285-1-1-1-P2 produced higher yield at about 2.26 tha^{-1}, 0.89 tha^{-1}, 0.32 t ha^{-1} over the check varieties BRRI dhan84, BRRI dhan74 and BRRI dhan29 respectively. But IR99285-1-1-1-P2 produced higher grain yield of about 1.73 t ha^{-1}, 0.36 t ha^{-1} than the check varieties BRRI dhan84 and BRRI dhan74 respectively with longer growth duration but lower yield compared to the other check variety BRRI dhan29 with 12 days shorter growth duration (Table 13).

RYT (Boro) cold tolerant-Bio. The advanced breeding line BR (Bio) 9777-124-1-1-2 produced lower yield than the check BRRI dhan28 and BRRI dhan36 with similar growth duration (Table 14).

RYT (Boro) favourable-Bio. Among three advance breeding lines, BR(Bio)9777-116-12-2-5 and BR(Bio)9777-116-12-2-4 produced about 0.27 t ha^{-1} and 0.13 t ha^{-1} higher grain yield respectively with similar growth duration than the check variety BRRI dhan58 (Table 15).

RYT (Boro) bacterial blight resistance-Bio. None of the five advanced breeding lines out-yielded the resistant check IRBB60 with almost similar growth duration. But BR (Bio) 11447-1-28-14-3 produced higher yield at about 0.09 t ha^{-1} over the standard check variety BRRI dhan28 (Table 16).

RICE FARMING SYSTEMS

For identification of potential rice variety in Wheat/Onion-Jute-Relay Aman cropping pattern under shallow deep-water rice ecosystem, the highest rice yield (3.9 t ha^{-1}) was obtained from BRRI dhan39 that was relayed with jute. The highest REY (Rice equivalent yield) was found from T_5 (24.74 t ha^{-1}) cropping pattern followed by T_2 (24.17 t ha^{-1}) and T_4 (22.74 t ha^{-1}) (Table 17).

In validation of improved fertilizer management option in Aman rice relayed with jute at farmers field in shallow flooded area, the highest yield (4.4 t ha^{-1}) was obtained from researcher managed fertilizer practice (Fertilizer rate urea-TSP-MP-gypsum-zinc: 225-105-90-135-7.5 kg ha^{-1} through top dressing at weeding time than farmer practice (Table 18).

In multilocation testing of Boro-DWR cropping pattern in flood prone areas, existing cropping pattern was replaced by improved cropping pattern Boro-DWR (Laldigha) and REY was increased at about 1.3 t ha^{-1} (Table 19).

CROP-SOIL-WATER MANAGEMENT

In effect of nitrogen and potassium management on growth and yield of short duration T. Aman rice, yield of BRRI dhan71 was significantly higher than the others in T_4 (4.6 t ha^{-1}) followed by T_2 (4.3 t ha^{-1}). In respect to yield of BRRI dhan75, no significant difference among treatments was found. In context of plant height no significant difference in two varieties among four treatments was found (Table 20).

SOCIO ECONOMICS AND POLICY

Stability analysis. In long duration Aman varieties, BR22, BRRI dhan41 and BRRI dhan46 produced the highest grain yield (4.1 t ha^{-1}) followed by BRRI dhan44 (3.9 t ha^{-1}) and BR23 (3.6 t ha^{-1}). In short duration Aman varieties, BRRI hybrid dhan4 produced higher yield (4.2 t ha^{-1}) than the others followed by BRRI dhan71 (3.7 t ha^{-1}) and BRRI dhan56 (3.6 t ha^{-1}). BRRI hybrid dhan6 produced the highest grain yield (4.4 t ha^{-1}) in medium duration Aman varieties followed by BRRI dhan70 (4.3 t ha^{-1}) and BRRI dhan73 (4.1 tha^{-1}), BRRI dhan53 (4.1 t ha^{-1}), BRRI dhan49 (4.1 t ha^{-1}). In Boro season, long duration varieties, BRRI dhan89 gave the highest grain yield (6.8 tha^{-1}) followed by BRRI dhan29 (6.4 tha^{-1}) and BRRI dhan35 (6.1 t ha^{-1}). In short duration Boro varieties BRRI hybrid dhan3 yielded higher yield (6.1 t ha^{-1}) followed by BRRI dhan74 (5.7 t ha^{-1}) and BRRI dhan68 (5.5 t ha^{-1}).

Table 12. Grain yield and ancillary characters of RYT-PQR, in Boro 2018-19 at BRRI RS, Bhanga.

Genotype	Growth duration (day)	Plant height (cm)	Yield (t ha^{-1})
BR8862-29-1-5-1-3	162	87	6.49
BR8862-8-3-4-4-1	163	96	6.92
BR8995-2-5-5-2-1	166	97	6.22
BR9205-10-1-5-3	164	102	5.74
BRRI dhan50	157	75	5.42
BRRI dhan63	152	74	7.09
LSD (P<0.05)	1.46	2.03	1.07
Heritability	0.90	0.89	0.75

Table 13. Grain yield and ancillary characters of RYT-ZER, in Boro 2018-19 at BRRI RS, Bhanga.

Genotype	Growth duration (day)	Plant height (cm)	No. of tillers/hill	No. of panicles/hill	Panicle length (cm)	Yield (t ha^{-1})
BRRI dhan29 (ck)	151	95.7	17	16	24.2	8.33
BRRI dhan74 (ck)	136	89.5	12	11	25.1	7.76
BRRI dhan84 (ck)	134	96.2	12	11	24.4	6.39
IR99285-1-1-1-P1	143	99.2	16	15	24.5	8.12
IR99285-1-1-1-P2	139	94.3	15	14	24.5	8.65
LSD (P<0.05)	1.49	1.99	1.69	1.51	1.43	1.43
Heritability	0.90	0.69	0.93	0.84	-	0.45

Table 14. Grain yield and ancillary characters of RYT-Cold tolerant (Bio), in Boro 2018-19 at BRRI RS, Bhanga.

Genotype	Growth duration (day)	Plant height (cm)	No. of tillers/hill	No. of panicle/hill	Panicle length (cm)	Yield (t ha^{-1})
BR(Bio)9777-124-1-1-2	128	73.5	12	11	21.5	6.52
BRRI dhan28	128	93.5	12	12	23.2	7.24
BRRI dhan36	128	71.0	14	13	21.9	7.07
LSD (P<0.05)	0.92	0.91	0.65	0.92	0.57	0.79
Heritability	0.25	0.60	0.93	0.90	0.94	0.42

Table 15. Grain yield and ancillary characters of RYT-Favourable (Bio), in Boro 2018-19 at BRRI RS, Bhanga.

Genotype	Growth duration (day)	Plant height (cm)	No. of tiller/hill	No. of panicle/hill	Panicle length (cm)	Yield (t ha^{-1})
BR(Bio)9777-116-12-2-4	130	100.8	10	10	23.9	7.19
BR(Bio)9777-116-12-2-5	130	100.6	12	11	22.4	7.33
BR(Bio)9787-BC2-35-4-2	131	91.8	10	10	22.3	6.36
BRRI dhan58	130	89.3	11	11	21.5	7.06
LSD (P<0.05)	0.96	1.89	1.09	1.53	0.90	0.43
Heritability	0.52	0.61	0.70	-	0.89	0.87

Table 16. Grain yield and ancillary characters of RYT-BBR (Bio), in Boro 2018-19 at BRRI RS, Bhanga.

Genotype	Growth duration (day)	Plant height (cm)	No. of tillers/hill	No. of panicles/hill	Panicle length (cm)	Yield (t ha^{-1})
BR (Bio) 11447-1-28-12-3	159	83.6	13	12	23.8	6.90
BR (Bio) 11447-1-28-14-1	158	93.6	12	11	24.3	6.93
BR (Bio) 11447-1-28-14-3	157	93.2	13	12	25.6	7.33
BR (Bio) 11447-1-28-4-6	157	87.3	13	13	24.9	6.68
BR (Bio) 11447-3-10-7-1	158	94.2	12	11	24.6	6.92
BRRI dhan28 (Std. ck)	148	84.4	13	13	21.7	7.25
IRBB60 (Res. ck)	158	76.3	15	14	22.4	7.51
LSD (P<0.05)	0.78	1.00	0.85	0.92	0.66	0.57
Heritability	0.59	-	0.92	0.91	0.97	0.51

Table 17. Yield performance for potential rice variety in Onion-Jute-Relay Aman cropping pattern under shallow deep water rice ecosystem, 2018-19.

Treatment	Yield (t ha^{-1})			REY
	Jute	Relay Aman	Onion	
T_1=BRRI dhan34	2.8	1.8	10.13	20.48
T_2=BRRI dhan39	2.9	3.9	11.23	24.17
T_3=BRRI dhan70	3.1	1.8	11.16	22.42
T_4=BRRI dhan71	2.7	3.0	11.15	22.74
T_5=BRRI dhan72	3.2	3.3	11.65	24.74
T_6=BRRI dhan75	2.8	3.4	10.13	22.08

Jute = Tk 43.75/kg, Rice (Paddy) = Tk 20/kg, Onion = Tk 25/kg.

Table 18. Yield performance for BRRI dhan39 relayed with jute in validation of improved fertilizer management option at farmers field in shallow flooded areas.

Variety	Fertilizer management	Yield (t ha^{-1})
BRRI dhan39	Farmer's practice	4.2
	Researcher's practice	4.4
LSD (P<0.05)		0.045
CV(%)		1.19

Table 19. Yield performance of multi-location testing of Boro-DWR cropping pattern in flood prone areas.

Cropping pattern	Yield (t ha^{-1})		REY (t ha^{-1})
	Boro (BRRI dhan29)	DWR (Laldigha)	
Boro-Fallow-Fallow	5.6	-	5.6
Boro-DWR (Laldigha)	5.6	1.3	6.9

Table 20. Yield performance of short duration T. Aman rice BRRI dhan71 and BRRI dhan75 in effect of nitrogen and potassium management.

Treatment	Variety					
	BRRI dhan71			BRRI dhan75		
	Yield (tha^{-1})	Plant height (cm)	Sterility (%)	Yield (t ha^{-1})	Plant height (cm)	Sterility (%)
T1	3.7	109.3	16.3	3.2	95.2	34.5
T2	4.3	109.3	20.3	2.9	95.8	34.3
T3	3.4	110.9	17.9	3.5	95.53	34.5
T4	4.6	109.1	15.7	3.4	96.87	33.4
LSD (P<0.05)	0.7660	NS	NS	NS	NS	NS
CV(%)	11.74	3.58	31.74	11.96	2.42	8.51

T_1= N (1/3rd at basal +1/3rd at 15 DAT+ 1/3rd at 30 DAT) + K as basal (BRRI recommended).
T_2= N (50% at 10 DAT + 30% at 20 DAT+ 20% at 30 DAT) + K (50% at basal + 50% at 30 DAT) and
T_3= N (50% at 10 DAT + 30% at 20 DAT+ 20% at 30 DAT) + K (50% at basal + 30% at 20 DAT + 20 % Spray at 30 DAT).
T_4= N (1/3rd at 10 DAT +1/3rd at 20 DAT+ 1/3rd at 30 DAT) + K (50% at basal + 45% at 30 DAT + 5 % Spray at 7 DAF).

TECHNOLOGY TRANSFER

Demonstrations of modern rice varieties during T. Aman 2018 and Boro 2018-19 were conducted in Faridpur, Madaripur and Gopalganj districts under BRRI RS, Bhanga, Faridpur with the financial assistance of BRRI-SPIRA project. Mean grain yields with growth duration of Aman varieties were: 5.5 t ha^{-1} with 128 days for BRRI dhan71, 5.8 t ha^{-1} with 121 days for BRRI hybrid dhan4 and 5.7 t ha^{-1} with 120 days for BRRI hybrid dhan6. In Boro 2018-19, mean grain yield of BRRI dhan58 was 6.9 t ha^{-1} with growth duration of 155 days, 5.8 t ha^{-1} with 148 days for BRRI dhan74, 6.3 t ha^{-1} with 148 days for BRRI dhan81, 8.2 t ha^{-1} with 162 days for BRRI dhan91. 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 created.

In Aman, 2018 five varietal replacement through head to head trials were conducted in five upazilas of two districts namely Faridpur and Gopalganj under BRRI RS, Bhanga with the financial assistance of BRRI-TRB project. Five BRRI varieties like, BRRI dhan49, BRRI dhan71, BRRI dhan72, BRRI dhan75 and BRRI dhan80 were included in one bigha trial. The highest grain yield in different locations were as follows: 4.5 t ha^{-1} with BRRI dhan49 in Jatrabari, Sadarpur, Faridpur; 4.7 t ha^{-1} with BRRI dhan71 in Dasherhat, Muksudpur, Gopalganj; 5.5 t ha^{-1} with BRRI dhan72 in Jatrabari, Sadarpur, Faridpur; 4.6 t ha^{-1} with BRRI dhan75 in Maniknagar, Nagarkanda, Faridpur and 4.9 t ha^{-1} with BRRI dhan80 in Maniknagar, Nagarkanda, Faridpur.

Similarly in Boro, 2018-19, a total of six varieties like BRRI dhan28, dhan67, dhan74, dhan81, dhan84, dhan86 are included in BRRI dhan28 group while BRRI dhan29, 58, 89 are included in BRRI dhan29 group. The six (three BRRI dhan28 group and three BRRI dhan29 group) varietal replacement through head to head trials were conducted in six upazilas of two districts namely Faridpur and Madaripur under BRRI RS, Bhanga with the financial assistance of BRRI-TRB project. The highest grain yield with growth duration in different locations were as follows: 8.18 t ha^{-1} with BRRI dhan28 in Goalando, Rajbari; 10.08 t ha^{-1} with BRRI dhan67 in Bhanga, Faridpur; 8.03 t ha^{-1} with BRRI dhan74 in Mukshudpur, Gopalganj; 8.65 t ha^{-1} with BRRI dhan81 in Kalkini, Madaripur; 9.83 tha-1 in BRRI dhan84 with Shariatpur Sadar, 9.83 tha^{-1} BRRI dhan86 in Shariatpur Sadar. The trial farmers stored their seeds according to their choice for growing in the next Boro season.

BRRI RS, Bhanga farm produced about 25.0 tons of seeds of which about 10 tons of breeder seed of BRRI dhan28 and BRRI dhan29 and the rest about 15.0 were TLS of short duration Aman varieties e.g. BRRI dhan39, BRRI dhan71, BRRI dhan75, BRRI dhan79 and BRRI dhan87 as well as Boro varieties of BRRI dhan28, BRRI dhan29, BRRI dhan50, BRRI dhan58, BRRI dhan63, BRRI dhan67, BRRI dhan81, BRRI dhan88, BRRI dhan89 during Boro 2018 -19 season.

BRRI RS, Bhanga trained three hundred farmers of greater Faridpur region on modern rice production technologies through 10 training programmes with the cooperation of DAE under the financial assistance of GOB and BRRI-SPIRA project.

Moreover, two technologies developed in coordination with Plant Breeding and RFS Divisions, BRRI Gaipur respectively.

1. Recently BR10230-15-27-7B was released as BRRI dhan91, which is the first high yielding deepwater rice variety of the country. This variety is suitable for shallow deep-water ecosystem of Faridpur region. BRRI RS, Bhanga had an active role during advanced line evaluation stage of varietal development and release process of this variety in hotspot areas.
2. The improved cropping pattern Wheat/Onion-Jute-Relay Aman for Shallow Flood Prone Ecosystems was recommended by Board of Management, BRRI as technology for the farmers' of Faridpur region to increase cropping intensity, crop diversity and total production.

Investigators: M Akhlasur Rahman,Tusher Chakrobarty and M Amir Hossain

BRRI RS, Cumilla

SUMMARY

Altogether 57 crosses were made and 39 crosses were confirmed during T. Aman and Boro seasons at BRRI RS, Cumilla. A total of 758, 306, 86, and 24 plant progenies with desirable plant type and high yield potential were selected from $F_{2,}$ $F_{3,}$ F_4 and F_5 generations respectively. Sixty-one homozygous lines were bulked under the varietal development programme. Thirty-four genotypes were selected from observational trial (OT) having desirable characters and high yield potential. Eight, 3, 4, 4, 2, 4, 3, 3, 8, 2 and 3 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 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), GSR (OYT), GSR (MST) and GSR (SP) respectively, during T. Aman season.

A total of 134 advanced lines were selected from different yield trials in T. Aus, T. Aman and Boro season during 2018-19.

Disease incidence of bacterial blight, sheath blight, neck blast, false smut and brown spot were 5-70, 5-80, 2-90, 1-20 and 5-90% respectively during T. Aman 2018. In Boro 2018-19, the disease incidence of neck blast, bacterial blight, sheath blight and brown spot were 2-100, 2-80, 5-70 and 5-80% respectively. Results of blast management technology demonstration indicate that farmers can save upto 57% and 63% rice yield loss in T. Aman and Boro season respectively. Three genotypes HR (path)-2, HR (path)-10, HR (path)-11 showed no neck blast incidence and yield ranged from 6.79 to 7.39 t ha^{-1} whereas, BRRI dhan28 showed about 81.3% neck blast with 4.61 t ha^{-1} yield in RYT Barura, Cumilla.

BRRI recommended fertilizer dose + 3 t/ha organic manure (CD) produced the significant highest grain yield both in T. Aman and Boro season irrespective of variety.

Optimum seeding time for BRRI dhan75 and BRRI dhan58 is 15 July and 15 November in T. Aman and Boro season respectively in Cumilla region.

BRRI dhan57, BRRI dhan62 and BRRI dhan75 produced 4.89, 4.37 and 5.03 t ha^{-1} grain yield respectively with NPKZnS fertilizers. Omission of N from complete treatment had a significant effect on grain and straw yield of irrespective of varieties.

Eighty kg N ha^{-1} appeared as bestfor grain yield and straw yield on BRRI dhan75 in T. Aman season while120 kg ha^{-1} N showed highest grain yield on BRRI dhan89.

BRRI dhan41 (6.53 t ha^{-1}) and BRRI hybrid dhan3 (8.39 t ha^{-1}) produced highest yield in Aman and Boro season respectively in stability analysis.

Mean yield of BRRI dhan85 and BRRI dhan75 was 4.79 and 4.85 t ha^{-1} with the growth duration of 109 and 116 days respectively in three rice systems under multilocation trial.

Among the rice varieties used in HTH trial and Block demonstration, the yield of BRRI dhan87 showed the highest yield 6.5 to 7.12 t ha^{-1} in Aman season and BRRI dhan74 (8.12-8.61 t ha^{-1}) and BRRI dhan89 (7.86-8.62 t ha^{-1}) showed the highest yield in Boro season. A total of 393 farmers and 27 SAAOs were trained up in modern rice cultivation and blast disease managementfrom 13 farmers training programmes.

VARIETY DEVELOPMENT

All the yield trials including preliminary yield trial (PYT), secondary yield trials (SYT), regional yield trial (RYT), advanced yield trials (AYT) were conducted following RCB designe. In Boro and T. Aman 20 × 20 cm spacing was maintained whereas in T. Aus it was 20 × 15 cm. Replication was 2 or 3 depending on space limitation and number of seedling used.

T. Aus

BRRI RS, Cumilla programme

Under TRB project 10 viz 1, 4, 5, 8, 9, 10, 17, 20, 22 and 25 entries were selected from observational trial based on yield and growth duration (Table 1). Yield range of selected lines was 4.20-5.14 t ha^{-1}. Six lines were selected from both preliminary yield trial (PYT) and regional yield trial (RYT).

Table 1. Yield and agronomic performances of breeding materials from observational yield trial (OYT), T. Aus 2018-19, BRRI RS, Cumilla.

Entrty	Designation	PH (cm)	GD (day)	Yield (t ha^{-1})	Remark
New 1	BR9829-30-3-2-1	112	115	4.60	
New 2	BR9829-46-3-3-1	109	114	4.14	
New 3	BR9829-77-2-1	102	117	3.58	
New 4	BR9829-78-1-2-1	115	121	4.44	
New 5	BR9829-78-1-3-2	105	113	4.28	
New 6	BR9829-79-2-1-1	100	113	4.09	
New 7	BR9829-79-2-3-1	100	113	3.95	
New 8	BR9829-79-2-3-2	96	116	5.14	
New 9	BR9829-79-3-1-1	101	113	4.27	
New 10	BR9829-79-3-1-3	92	115	4.39	T-10%
New 11	BR9829-79-5-3-2	92	113	3.57	
New 12	BR9829-80-2-2-1	92	111	3.11	
New 13	BR9829-80-2-2-2	94	113	3.77	
New 14	BR9829-80-2-4-1	103	117	2.59	
New 15	BR9830-5-2-2-1	101	111	3.04	
New 16	BR9830-5-2-2-2	75	111	2.74	
New 17	BR9830-5-2-2-3	107	112	4.20	T-10%
New 18	BR9830-44-1-2-1	101	110	3.49	
New 19	BR9830-44-1-2-2	105	112	3.47	
New 20	BR9830-44-1-8-1	107	116	4.29	T-40%
New 21	BR9830-44-1-8-2	101	117	3.34	
New 22	BR9830-53-3-5-1	111	116	5.11	T-10%
New 23	BR9830-53-3-5-2	72	109	3.34	
New 24	BR9830-74-2-2-1	95	111	3.18	
New 25	BR9830-74-4-1-1	101	111	4.73	
New 26	BR9830-74-4-3-1	97	111	2.58	T-10%
New 27	BR9830-74-4-3-2	106	117	3.56	
Ck 1	BR 26 (ck)	78	109	4.18	
Ck2	BRRI dhan48 (ck)	84	112	4.77	T-10%
Ck3	BRRI dhan28 (ck)	85	108	4.24	T-25%

DS: 17 Apr 18, DT: 17 May 18.

T. Aman

TRB project. Five lines were selected from observational trial (OYT) with the yield range of 4.23-5.38 t ha^{-1}. From PYT#1 (BB), two line viz. BR10397-3-2-5 and BR10397-4-1-2 were selected (3.95-4.78 t ha^{-1}). Entries namely BR10390-22-2-1-5, BR10393-2-2-2 and BR10393-6-1-2 were selected from PYT#2 (BB) whith yield range of 4.25-4.44 t ha^{-1}. Three lines IR92694-SUB-SUB-36-1-B, IR13F478 and IR13F457 were selected from PYT (RLR).

Breeding zone trial. Fifty-one entries were selected from 864, based on yield (5.51-7.85 t ha^{-1}) and growth duration (98-133 days) in T. Aman season.

BRRI HQ. Among the RYT from BRRI HQ, 3,1,4,2, 2, 1, 2, 1 and 1 lines were selected from RYT#1(RLR), RYT#2(RLR), RYT#1(ZER), RYT#2(ZER), RYT#1 (PQR), RYT#2 (PQR), RYT#3 (PQR), RYT (BB) and RYT (Insect) respectively. No entries were selected from RYT#3(ZER), RYT#1 (Bio) and RYT#2 (Bio).

PVT. In PVT#1 proposed line BR 8210-10-1-2 produced 0.08 t ha^{-1} higher yield with eight days shorter growth than BRRI dhan49. On the other hand, in PVT#2 proposed line BR-7528-2R-HR16-2-24-1 produced 0.22 t ha^{-1} higher yield than BRRI dhan39 with four days shorter growth duration. In PVT#3 proposed line BR8535-2-1-1produced 1.31 t ha^{-1} higher yield than BRRI dhan34 with 15 days shorter growth duration. In PVT#4 proposed line BR10230-15-27-7B and BR10260-7-19-2B produced 1.10 t/ha and 2.07 t ha^{-1} higher yield than Fulkori with 16 and 26 days shorter growth duration respectively.

BRRI RS, Cumilla breeding programme. From the observational trial (OYT-Com), 12 lines were selected on the basis of yield and growth duration from 92 genotypes along with six check varieties viz., BRRI dhan39, BRRI dhan49, BRRI dhan56, BRRI dhan57, BRRI dhan71 and BRRI dhan75. Forty-four lines were selected having good phenotypic acceptability and yield potential as well as earliness from multi-parent advanced generation intercross lines. From different PYT and SYT trials 11 and two entries were selected respectively. In AYT trials eight entries were selected based on their yield performance, growth duration and desirable phenotypic characters.

Boro

Under TRB project, four genotypes BR10296-27-3-1-2, BR10296-31-1-P1, TP30597 and TP30610 were selected from preliminary yield trial (PYT) for their high yield potential (6.56-7.11 t ha^{-1}). Genotypes BR10296-31-1, TP30433, IR99982-B-B-B-B-18 and IR100722-B-B-B-B-16 gave the higher yield (5.89-7.12 t ha^{-1}) compared to the checks with similar growth duration (148-161 days) of the check varieties in AYT#1 (FB) and BR8905-17-2-3-3-1-1, BR8905-17-2-3-3-1-4, TP30430 and TP26717 gave the higher yield (6.35-7.45 t ha^{-1}) compared to the checks with similar growth duration (158-161 days) of the check varieties in AYT#2 (FB) (Table 2).

Table 2. Yield and agronomic performances of breeding materials from advanced yield trial (AYT#1 and AYT#2), Boro (Favourable) 2018-19, BRRI RS, Cumilla.

Designation	PH (cm)	Panicle/m^2	Tiller/m^2	GD (day)	Yield (t ha^{-1})
		AYT#1 (FB)			
BR10296-31-1	94	268	289	151	5.89
BR10296-55-4	97	275	291	150	4.91
BR9944-18-1-6	110	278	296	147	4.84
BR9945-12-1-3	106	262	284	149	4.31
BR9950-12-2-1	104	290	309	152	5.24
BR8899-14-4-1-2-2-1	84	272	289	151	5.68
BR8899-17-1-1-1-1-1	95	258	278	150	5.65
TP30433	86	259	278	161	7.12
TP30015	92	288	310	152	5.69
IR99982-B-B-B-B-18	102	275	298	148	5.99
IR99982-B-B-B-B-8	92	412	304	148	5.62
IR100004-19-B-1	111	286	281	146	5.72
IR100740-89-B-2	93	282	303	152	5.27
IR100008-40-B-3	90	259	281	156	5.06
IR100121-B-B-B-B-67	96	260	280	151	5.16
IR999822-B-B-B-B-1	97	273	290	149	5.35
IR100722-B-B-B-B-16	99	289	305	151	5.89
IR99090-B-B-61-1	99	272	290	152	4.80
BRRI dhan28 (ck)	96	269	283	145	5.50
BRRI dhan81 (ck)	92	255	283	148	5.35
LSD (5%)	2.07	7.98	7.55	1.38	0.24
		AYT#2 (FB)			
BR9945-28-7-3	103	286	304	152	5.13
BR9945-40-1-3	103	267	289	152	5.89
BR8902-38-7-1-1-1-1	104	276	300	151	5.46
BR8905-17-2-3-3-1-1	99	273	297	159	7.45
BR8905-17-2-3-3-1-4	101	279	298	161	7.06
TP29654	78	272	288	149	5.36
TP30022	88	280	302	154	5.93
TP30430	102	246	272	160	6.35
TP26717	94	257	279	158	7.03
BRRI dhan58 (ck)	94	256	277	154	6.14
LSD (5%)	5.07	9.33	8.98	2.51	0.50

* DS: 30 Nov 2018, DT: 18 Jan 2019. ** DS: 30 Nov 2018, DT: 18 Jan 2019.

Breeding zone trial. Sixty entries were selected from 432 based on yield (7.02-8.79 t ha^{-1}) and growth duration (125-135 days).

Breeding value estimation. Forty-three entries were selected from 148 based on yield (7.01-9.03 t ha^{-1}) growth duration (132-147 days).

BRRI HQ. In RYT#1 (RLR), BR8521-30-3-1, BR8841-38-1-2-2 and IRIIL433 was selected for higher yield (4.42-5.54 t ha^{-1}) and shorter growth duration (125-129 days) than BRRI dhan39 (125 days) and BRRI dhan49 (133 days). BR8526-L8 was selected from RYT#2 (RLR) for higher yield (2.22 t ha^{-1}) than it's check BRRI dhan49. From RYT#1 (ZER), four lines viz. BR8427-2-3-2-P1-2, BR8444-37-2-3-1-1-B3, IR99269-33-4-1 and BR8442-9-5-8-1-1 were selected for higher yield (3.69-4.06 t ha^{-1}) while two lines namely, BR7528-2R-19-16-RII-28 and BR7528-2R-19-16-RII-14 were selected from RYT#2 (ZER) for better performance than the standard checks. Two entries BR9178-7-2-4-4, BR8528-2-2-3-HR 1 from RYT#1 (PQR), one entry BR8882-30-2-5-2 from RYT#2 (PQR) and two entries BR8526-2-1-4-HR3-HR3 and BR8526-38-2-1-HR1 from RYT#3 (PQR) were selected based on better yield and other agronomic characteristics than checks. Entries BR10390-16-2-1 and BR9143-55-3-2-1were selected from RYT (BB) and RYT (Insect) respectively based on their yield performances. No genotypes were found promising in respect of yield performance, growth duration, lodging tolerance and other agronomic characters from RYT#3 (ZER), RYT#1 (Bio) and RYT#2 (Bio).

PVT. The proposed line BR (Bio) 9787-BC2-63-2-2gave 2.55 t ha^{-1} higher yield with same growth duration of BRRI dhan28 (Table 3).

BRRI RS, Cumilla breeding programme. Twenty-two genotypes (entry# 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21 and 23) were selected from 38 genotypes from OT based on high yield performance and other good agronomic characters. Twenty lines viz BRC426-4-2-1, BRC426-13-1-1, BRC427-9-1-3, BRC427-10-2-1, BRC428-3-1-1, BRC428-3-1-2, BRC428-3-1-3, BRC428-11-1-1, BRC428-14-1-3, BRC428-15-1-2, BRC430-16-1-2, BRC489-4-2-4-2, BRC489-8-1-1-2B, BRC394-1-1-1-2, BRC394-1-1-1-5A, BRC398-4-1-1-1B, BRC398-14-2-2-1, BRC401-1-1-1-1B, BRC365-23-1-2-1-2 and BRC365-23-2-2-2-2 were selected from PYT (SD) for higher yield (5.02-6.51 t ha^{-1}) as compared with standard checks. In PYT (LD), based on high yield performance (6.19-6.99 t/ha) and growth duration (143-149 days), seven lines viz. BRC427-9-1-1, BRC427-9-1-2, BRC428-2-2-1, BRC366-2-1-2-1-3, BRC366-2-2-4-2-1, BRC366-2-2-4-2-2 and BRC366-2-2-4-2-3 were selected for better yield than the checks (6.53-7.62 t ha^{-1}) with lesser growth duration. In SYT (SD), BRC333-2-2-1-1-2, BRC333-2-2-1-2-1, BRC333-2-2-1-3-2, BRC345-5-2-2-1-1 and BRC345-5-2-2-1-2 were selected for higher or similar yield (4.70-6.68 t ha^{-1}) performance and growth duration (143-145 days) compared with the checks. From SYT (MD), BRC364-1-2-1-1, BRC328-6-2-2-1-2, BRC328-6-2-2-3-1, BRC328-6-2-3-2-2, BRC331-1-2-1-2-1-2-1-1, BRC331-1-2-2-1-1 and BRC337-3-2-2-1-3 were selected for higher or similar yield (4.64-5.52 t ha^{-1}) and growth duration (142-153 days) than the checks. From SYT (LD), BRC325-11-1-1-1, BRC335-1-3-2-1-1 and BRC335-1-3-2-2-1 were selected for higher or similar yield (5.49-6.22 t ha^{-1}) and growth duration (139-147 days) than the checks. In AYT (Com), all the genotypes were selected for higher yield (5.86-6.67 t ha^{-1}) with almost similar growth duration (139-148 days) as compared with the checks (4.98-5.57 t ha^{-1}) and growth duration (137-144 days) (Table 4).

Table 3. Yield and agronomic performance of promising materials in PVT Boro 2018-19, Cumilla region.

PVT	Location	Line and check	Growth duration	Grain yield (t ha^{-1})
1.	Kurchap Dewidwar Cumilla	1. BR(Bio)9787-BC2-63-2-2	147 days	7.42
		2. BRRI dhan28 (ck)	147 days	4.87

Table 4. Yield and agronomic performance of breeding materials of AYT Boro 2018-19, BRRI RS, Cumilla.

Designation	PH (cm)	GD (Day)	Yield (t ha^{-1})
BRC297-15-1-1-1	101	145	5.96
BRC302-1-4-4-4	96	143	6.67
BRC302-2-1-2-1	105	143	6.33
BRC269-15-1-1-3	95	148	6.53
BRC298-18-2-3	103	148	6.09
BRC302-18-1-2-1	102	139	5.86
BRRI dhan28 (Ck)	98	137	5.17
BRRI dhan58 (Ck)	93	144	5.57
BRRI dhan81 (Ck)	91	141	4.98
LSD (5%)	3.29	2.32	0.44

DS: 8 Dec 2018, DT: 21 Jan 2019.

PEST MANAGEMENT

Survey and monitoring of rice diseases in selected areas in 2018-19. Disease survey was conducted in nine upazilas of Cumilla district during T. Aman and Boro 2018-19 to know the present status of different rice diseases under various climatic conditions. Disease incidence and disease severity data of major rice diseases were recorded following SES, IRRI 2013. On average, disease incidence of bacterial blight, sheath blight, neck blast, false smut and brown spot were 5-70, 5-80, 2-90, 1-20 and 5-90% respectively during T. Aman 2018 season. In Boro 2018-19 season, the disease incidence of neck blast, bacterial blight, sheath blight and brown spot were 2-100, 2-80, 5-70 and 5-80% respectively. This year severe neck blast disease was found in BRRI dhan28.

Validation of neck blast disease management at farmers level in Cumilla region. During T. Aman and Boro 2018-19 season, 14 field demonstrations on rice blast disease management following BRRI and farmers' practices were conducted in the selected blast prone areas to validate the technology of neck blast disease management and build up farmers' awareness on its management and minimize yield loss. The BRRI developed technology is additional application of 5 kg of MOP/*bigha* during last top dress of urea and fungicide Trooper (Tricyclazole) or registered Tricyclazole group fungicide @ 1 g/L water was sprayed two times as preventive measures during late booting and flowering stages in the evening. Farmers practice refers to the application methods those farmers locally adopted. During T. Aman 2018, neck blast disease affected severely 44-82% in BRRI dhan34 at farmers' practice compared to BRRI recommended practices (1-7%) in the demonstration trial where yield was saved up to 57% by managing neck blast disease. During Boro 2018-19 season, the highest neck blast disease infection (80%) was recorded in Barura and Cumilla sadar in the farmers' practice but the lowest neck blast incidence was recorded in the BRRI practice ranged from 0.1 to 5% and yield was saved up to 63% by using BRRI technology.

Regional yield trial for blast disease resistant lines during Boro 2018-19. A regional yield trial (RYT) consisting 10 blast disease resistant genotypes along with susceptible checks BRRI dhan28, BRRI dhan29 and BRRI dhan58 was conducted in severe blast prone area Chandipur under Barura upazila of Cumilla during Boro 2018-19 season to evaluate specific and general adaptability of the advanced blast resistant breeding lines in the farmers field condition. Three genotypes HR (path)-2, HR (path)-10, HR (path)-11 showed no neck blast incidence and yield ranged from 6.79 to 7.39 t ha^{-1} whereas, BRRI dhan28 showed about 81.3% neck blast infection with 4.61 t ha^{-1} yield. Lodging was observed about 60% only in HR (path)-11 due to higher plant height during hard dough stage.

Screening of blast, BB and tungro resistant monogenic lines in disease hot spot in Cumilla during Boro 2018-19. A field trial consisting 95 rice genotypes along with checks BRRI dhan28, BRRI dhan29, BRRI dhan58 and BRRI dhan74 was conducted in disease hot spot Chandipur, Barura, Cumilla during Boro 2018-19 season to evaluate rice genotypes against major diseases such as blast, BB and tungro in the farmers` field condition. No disease was observed in 15 genotypes (Entry # 41, 43, 45, 48, 61-67, 76-77, 83, 90) including BRRI dhan74 (Entry # 29, 53, 82). Only entry # 80 showed tungro disease with 80% DI and severity 5. Ten genotypes including BRRI dhan74 showed more than 6 t ha^{-1} yield. Twelve entries showed 70-100% neck blast disease infection with lower yield. Ten genotypes including BRRI dhan74 produced more than 6 t ha^{-1} yield. Twelve entries showed 70-100% neck blast disease with lower yield.

Varietal reaction and recovering ability of BRRI released T. Aman varieties. An experiment was conducted under natural infection of rice tungro disease during Aman 2018 season to know the varietal reaction and its recovering ability against tungro disease of rice. Percent disease incidence and disease severity data were collected following standard evaluation system (SES), IRRI 2013. Yield loss assessment was taken from severity score following SES scale as well as yield data. Some BRRI released varieties have recovering ability against tungro disease loss upto 10%. Twelve rice varieties showed 20-60% yield loss. Some BRRI varieties BR3, BR10, BR11, BRRI dhan51, BRRI dhan57, BRRI dhan62 showed 100% yield loss due to high severity of rice tungro disease.

CROP-SOIL-WATER MANAGEMENT

Yield maximization of Aman rice through nutrient management

Yield maximization trial of Aman rice through nutrient management was conducted in BRRI RS, Cumilla during 2018 following RCB design with three replications. Twenty-one-day-old seedling was transplanted with 20 × 20 cm spacing. Plot size was 3 m × 2 m. Treatments were T_1= STB fertilizer dose, T_2= BRRI recom. fertilizer dose, T_3= 20% over T_2, T_4= 70% over T_2 + 3 t ha^{-1} organic manure (CD), T_5= BRRI recom. fertilizer dose + 3 t ha^{-1} organic manure (CD) and T_6= Control. Fertilizers were applied @ 68-10-41-11 kg ha^{-1} N-P-K-S respectively for BRRI recommended fertilizer dose. All fertilizers except N were applied during final land preparation. Nitrogen was applied as top dress in equal splits at 15, 30 and 45 DAT. Other standard management practices were followed as and when necessary.

Among the treatments, T_5 (BRRI recommended fertilizer dose + 3 t ha^{-1} organic manure (CD) produced the significantly the highest grain yield in BRRI dhan75 (4.95 t ha^{-1}) and BRRI dhan71 (4.30 t ha^{-1}) compared to control treatment T_6 (Table 5).

Effect of seeding time on yield of Aman rice varieties

The experiment was conducted at BRRI RS, Cumilla during Aman 2018 to find out appropriate seeding time of newly released Aman varieties. Seeding was started from 15 June to 15 August. Three rice varieties were BRRI dhan32, BRRI dhan71 and BRRI dhan75. Twenty-one-day-old seedling was transplanted with 20 × 20 cm spacing at 15 days intervals. The experiment was laid down in spilt-plot design, where planting date was in the main plot and the varieties were in the sub-plot with three replications. 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 as top dress in equal splits at 15, 30 and 45 DAT (day after transplanting). Other standard management practices were followed as and when necessary. Irrespective of variety, 15 July appeared as the best seeding time for significantly higher yield (Table 6).

Table 5. Effect of nutrient management on Aman rice.

Treatment	Yield (t ha^{-1})	
	BRRI dhan71	BRRI dhan75
T_1	3.77	4.50
T_2	3.80	4.47
T_3	4.05	4.73
T_4	4.19	4.81
T_5	4.30	4.95
T_6	2.76	2.88
CV (%)	3.91	
LSD (0.05)	0.27	

DS: 20 Jun 2018, DT:11 Jul 2018.

Table 6. Effect of seeding time on yield (t/ha) and growth duration (day) of selected varieties in T. Aman 2018, BRRI RS, Cumilla.

Variety	Yield (t ha^{-1})				
	15 Jun	30 Jun	15 Jul	30 Jul	15 Aug
BRRI dhan71	4.90 (115)	5.21 (114)	5.26 (114)	4.82 (115)	4.01 (119)
BRRI dhan75	4.92 (113)	5.36 (114)	5.46 (114)	5.01 (115)	4.00 (120)
BRRI dhan32 (ck)	3.98 (129)	4.18 (130)	4.30 (130)	4.02 (131)	3.05 (135)
CV%			4.04		
LSD (0.05)			0.30		

Figures in the parenthesis indicate growth duration.

Yield maximization of Aman rice through nutrient management

A yield maximization of Aman rice through nutrient management trial was conducted in BRRI RS, Cumilla to maximize yield during Boro 2018 following RCB design with three replications. Thirty-five-day-old seedling was transplanted with 20 × 20 cm spacing. Plot size was 3 m × 2 m. Treatments were T_1= STB fertilizer dose, T_2= BRRI recom. fertilizer dose, T_3= 20% over T_2, T_4= 70% over T_2 + 3 t ha^{-1} organic manure (CD), T_5= BRRI recommended fertilizer dose + 3 t ha^{-1} organic manure (CD) and T_6= Control. BRRI recommended fertilizers were applied @ 120-30-50-15-3 kg ha^{-1} N-P-K-S respectively. All fertilizers except N were applied during final land preparation. Nitrogen was applied as top dress in equal splits at 20, 35 and 50 DAT. Other standard management practices were followed as and when necessary.

Among the treatments, T_5 (BRRI recom. fertilizer dose + 3 t ha^{-1} organic manure (CD) produced the significantly the highest grain yield in BRRI dhan81 (5.66 t ha^{-1}) and BRRI dhan86 (5.64 t ha^{-1}) compared to control treatment (Table 7).

Effect of seeding time on yield of Boro varieties

The experiment was conducted at BRRI RS farm, Cumilla during Boro 2018 to observe appropriate seeding time of newly released Boro varieties in Cumilla. Seeding was started from 15 November to 15 February. Three rice varieties namely BRRI dhan58, BRRI dhan81 and BRRI dhan86 were selected. Thirty-five-day-old seedling was transplanted with 20 × 20 cm spacing at 15 days intervals. The experiment was laid down in spilt-plot design, where seeding date was in the main plot and the varieties were in the sub-plot with three replications. Fertilizers were applied 120-30-50-15-3 kg ha^{-1} N-P-K-S respectively. All fertilizers except N were applied during final land preparation. Nitrogen was applied as top dress in equal splits at 20, 35 and 50 DAT. Other standard management practices were followed as and when necessary.

Table 7. Effect of nutrient management on Boro rice.

Treatment	Yield (t ha^{-1})	
	BRRI dhan81	BRRI dhan86
T_1	5.09	5.17
T_2	5.23	5.32
T_3	5.05	5.15
T_4	4.80	4.97
T_5	5.66	5.64
T_6	3.71	3.56
CV (%)	8.34	
LSD (0.05)	0.64	
DS: 25 Dec 2018, DT: 30 Jan 2019.		

Figures in the parenthesis indicate growth duration.

Table 8. Effect of seeding time on yield (t ha^{-1}) and growth duration (days) of varieties in T. Aman 2018, BRRI RS, Cumilla.

Variety	Yield (t ha^{-1})				
	15 Nov	30 Nov	15 Dec	30 Dec	15 Jan
BRRI dhan81	5.64 (142)	5.34 (142)	3.80 (143)	3.98 (145)	3.93 (149)
BRRI dhan86	4.80 (141)	5.33 (141)	3.83 (140)	3.68 (145)	3.73 (147)
BRRI dhan58	6.51 (151)	5.66 (150)	3.66 (153)	3.65 (156)	3.86 (158)
CV (%)			8.93		
LSD (0.05)			0.67		

Figures in the parenthesis indicate growth duration.

In Cumilla, BRRI dhan58 and BRRI dhan81 produced significantly the highest grain yield on 15 November seeding with shorter growth duration. BRRI dhan86 produced significantly the highest grain yield on 30 November seeding with shorter growth duration (Table 8).

Long-term missing element trial for diagnosing the limiting soil nutrient

Long-term missing element trial was initiated to determine nutrient deficiency problems in soil through missing elements techniques and to see long-term yield trend of rice under different nutrients managements.

The experiment was initiated on a permanent layout at BRRI RS, Cumilla since Boro 2014. Field trial was conducted at BRRI RS, Cumilla (AEZ 15) during T. Aman 2018 and Boro 2018-19. Different types of BRRI released short duration rice varieties such as BRRI dhan57, BRRI dhan62 and BRRI dhan75 were evaluated in T. Aman and BRRI dhan84, BRRI dhan86 and BRRI dhan88 in Boro. Six fertilizer treatments viz. T_1= N omission (-N), T_2= P omission (-P), T_3= K omission (-K), T_4= S omission (-S), T_5= Zn omission (-Zn) and T_6= NPKZnS (STB) were imposed in the subplots and rice varieties in the main plots following a split-plot design with three replications. Fertilizer doses were NPKZnS @ 110-15-42-9-1.5 kg ha^{-1} for T. Aman and 145-31-77-13-1.5 kg ha^{-1} for Boro. Twenty-five and forty-day-old seedlings were transplanted during T. Aman and Boro respectively at 20 cm × 20 cm spacing. Standard management practices were followed for growing the crops. All plots were surrounded by 100 cm soil levees to avoid contamination between plots. At maturity, the crop was harvested (5 m^2 area) manually at 15 cm above ground level for yield estimation and 16 hills were harvested at the ground level for straw yield computation from each plot. Grain yield was adjusted at 14% moisture content and straw yield as oven dry basis.

T. Aman 2018. BRRI dhan57, BRRI dhan62 and BRRI dhan75 produced 4.89, 4.37 and 5.03 t ha^{-1} grain yield respectively with NPKZnS fertilizers. However, yield differences of K missing plots were found significant among the tested three varieties viz. BRRI dhan57, BRRI dhan62 and BRRI dhan75. On the other hand, N omission from complete treatment had a significant effect on grain and straw yield of tested varieties indicating that a soil test based fertilizer dose is enough for these varieties.

Boro 2018-19. BRRI dhan84, BRRI dhan86 and BRRI dhan88 produced 6.79, 8.53 and 8.64 t ha^{-1} grain yield respectively with NPKZnS fertilizers. In case of BRRI dhan58, grain yield was drastically reduced due to omission of Potassium. On the other hand, N omission from complete treatment had a significant effect on grain yield and straw yield of tested varieties indicating that a maintenance dose of fertilizer is enough for these entries.

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Effect of N rates on the yield of BRRI dhan87 during T. Aman 2018 and BRRI dhan89 during Boro2018-19

An experiment was conducted in BRRI RS, Cumilla to determine the N response behaviour of BRRI dhan87 and BRRI dhan89.

The experiment was conducted in T. Aman 2018 and Boro 2018-19. Thirty and forty-five-day-old seedlings were transplanted respectively in T. Aman 2018 and Boro 2018-19 at 20 cm × 20 cm spacing. The trial was conducted under six N doses viz 0, 40, 60, 80, 100 and 120 kg ha^{-1} in T. Aman 2018 and 0, 40, 80, 120, 160 and 200 kg ha^{-1} in Boro 2018-19. The experiment was laid out in a RCB design with three replications. Nitrogen was applied in three splits i.e. 34% at basal, 33% at 25 days after transplanting (DAT) and the rest 33% at seven days before panicle initiation (PI) stage. A blanked dose of P, K, S and Zn was applied as soil test based (STB) at the time of final land preparation. Standard management practices were followed for growing the crop. All plots were surrounded by 100 cm soil levees to avoid contamination between plots. At maturity, the crop was harvested (5 m^2) manually at 15 cm above ground level for yield estimation and 16 hills were harvested at the ground level for straw yield computation from each plot. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis.

T. Aman 2018. Among the nitrogen doses, N_{80} produced higher grain and straw yield which was statistically similar with the observed yield of 60,100 and 120 kg ha^{-1} N doses.

Boro 2018-19. Among the nitrogen doses, N_{160} produced higher grain and straw yield. On the other hand, yield of 40, 80, 120 and 200 kg ha^{-1} N doses were statistically similar.

Investigators: F H Khan, M M Rashid, A Sultana, M A Muttaleb and M R Islam

Evaluation of bio-organic fertilizer in the soil plant system

An evaluation trial of bio-organic fertilizer in the soil plant system was conducted in BRRI RS, Cumilla to evaluate efficiency of bio fertilizer to promote rice plant growth and yield as well as to improve soil biology.

The experiment was conducted in BRRI RS, Cumilla, Bangladesh (AEZ-15, land type-MHL) during T. Aman 2018 and Boro 2018-19. BRRI dhan75 and BRRI dhan89 were the test variety in T. Aman and Boro season respectively. Six fertilizer treatments were T_1 = Bio fertilizer (2 t ha^{-1}), T_2 = NPKS (100%), T_3 = N (70%) + KS (100%) + Biofertilizer (2 t ha^{-1}), T_4 = N (70%) +PKS (100%), T_5 = NPKZnS (100%) and T_6 = Control. The treatments were assigned in RCBD with three replications. The unit plot size was 4 m × 3 m. Forty-five-day-old seedlings were transplanted at 20 cm × 20 cm spacing. No insecticide was used in the field. Irrigation and weed control were done when necessary.

Soil samples were collected from 0-15 cm depth for pH and organic carbon content analysis. Available S and Zn were determined by extracting 0.16 M calcium dihydrogen phosphate [$Ca(H_2PO_4)2$] solution and 0.005 M diethylene-triamine-pentaacetic acid (D/TPA) solution respectively. The S and Zn contents in the digested and extracted solutions were quantified using inductively coupled with plasma-optical emission spectrophotometer. Total N and exchangeable K were determined through Micro- Kjeldahl method and ammonium acetate extraction method respectively. Grain and straw yield and yield components were recorded following standard protocol.

T. Aman 2018. Among the treatments, T_5 = NPKZnS (100%) produced the highest grain yield. However, T_1 = Bio fertilizer (2 t ha^{-1}), T_2 = NPKS (100%) and T_4= N (70%) + PKS (100%) had insignificant differences on grain and straw yield.

Boro 2018-19. The treatments were T_3 = N (70%) + KS (100%) + Bio fertilizer (2 t ha^{-1}) produced the highest grain and straw yield. However, T_1 = Bio fertilizer (2 t ha^{-1}), T_2 = NPKS (100%), T_4= N (70%) + PKS (100%) and T_5 = NPKZnS (100%) had insignificant differences on grain yield.

Investigators: F H Khan, M M Rashid, A Sultana, U A Naher and Rafiqul Islam

SOCIO-ECONOMICS AND POLICY

Stability analysis of BRRI varieties. In Aman season, among the 42 varieties, BRRI dhan41 (6.53 t ha^{-1}) produced the highest yield followed by BR10 (6.24 t ha^{-1}), BRRI dhan77 (6.12 t ha^{-1}), BRRI dhan44 (5.92 t ha^{-1}) and BRRI dhan44 (5.80 t ha^{-1}). Growth duration of these varieties ranged from 144 to 150 days. BRRI dhan70, BRRI dhan62 and BRRI dhan57 were the low yielding varieties withthe yield of 2.16, 4.42 and 2.62 t ha^{-1} respectively. Rest of the varieties gave yield ranged from 3.05 to 5.74 t ha^{-1}.

In Boro, considering the yield performance the top five varieties were BRRI hybrid dhan3 (8.39 t ha^{-1}), BRRI hybrid dhan5 (8.06 t ha^{-1}), BRRI dhan69 (7.98 t ha^{-1}), BRRI hybrid dhan2 (7.82 t ha^{-1}) and BR9 (7.64 t ha^{-1}). Observed yield of these five varieties were ranged from 8.39 to 7.64 t ha^{-1} with growth duration of 136-155 days. BR17 yielded the lowest grain yield (4.41 t ha^{-1}).

RICE FARMING SYSTEMS

Multi-location trial of BRRI dhan85 and BRRI dhan75 in selected cropping patterns of Cumilla region

Twenty multi-location trials (one *bigha* each) of newly released Aus variety BRRI dhan85 while 10 multi-location trials of BRRI dhan75 were implemented under three rice systems in T. Aus and T. Aman 2018 season respectively in two districts of Cumilla region. Mean yield of BRRI dhan85 was 4.79 t ha^{-1} with the growth duration of 109 days in three rice systems. On the other hand, mean yield of BRRI dhan75 was 4.85 t ha^{-1} in three rice systems with the growth duration of 116 days. About 0.40 and 0.56 t ha^{-1} additional yield were found in Aus and T. Aman season respectively. Thus, additional 0.96 t ha^{-1} were found by inclusion of aforesaid varieties in Aus and T. Aman season in three rice systems. Farmers' preferred both BRRI dhan85 and BRRI dhan75 for higher yield, fine rice and higher market price. Some farmers reported slight aroma in cooked rice of BRRI dhan75. On the other hand, some farmers reported that cooked rice of BRRI dhan75 cannot keep daylong.

TECHNOLOGY TRANSFER

Varietal replacement through head to head (HTH) trial during T. Aman and Boro 2018-19

Five newly released rice varieties BRRI dhan71, BRRI dhan72, BRRI dhan75, BRRI dhan80 and BRRI dhan87 were selected for HTH trial in 10 locations of Cumilla, Chandpur and B. Baria district having one *bigha* of land each during Aman 2018 to evaluate the adaptability of modern rice varieties at farmers` field and to investigate performance of the newly released promising rice varieties compared to the popular mega variety BRRI dhan49. In Boro 2018-19, six field trials were conducted for the adaptability and replacement of newly released rice varieties BRRI dhan67, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan86, BRRI dhan58 and BRRI dhan89 were compared with mega rice varieties like BRRI dhan28 and BRRI dhan29. Among the rice varieties used in this study, BRRI dhan87 produced the highest yield up to 7.12 t ha^{-1}. Farmers' acceptance of BRRI dhan87 and BRRI dhan71 also produced higher than the other varieties. BRRI dhan74 (8.61 t ha^{-1}) showed the highest yield followed by BRRI dhan67 (5.29 t ha^{-1}), BRRI dhan86 (5.17 t ha^{-1}), BRRI dhan84 (4.85 t ha^{-1}) and BRRI dhan81 (4.77 t ha^{-1}). The yield of BRRI dhan89 (8.62 t ha^{-1}) was significantly higher than BRRI dhan29 followed by BRRI dhan58 (7.70 t ha^{-1}).

Block demonstration, dissemination and quality seed production of rice varieties during Aman 2018 and Boro 2018-19 (SPIRA project)

Three block demonstrations using new rice varieties BRRI dhan75 and BRRI dhan79 and BRRI dhan87 during T. Aman 2018 and four block demonstrations using BRRI dhan74, BRRI dhan81, BRRI dhan88 and BRRI dhan89 during Boro 2018-19 were conducted to investigate the performance and dissemination of newly released promising rice varieties in the farmers` field levels. In T. Aman 2018, the average yield of BRRI dhan75, BRRI dhan79 and BRRI dhan87 was about 5.4, 5.78 and 6.5 t ha^{-1} respectively. In all the blocks, the highest yield was obtained from BRRI dhan87 with the range of 5.83 to 7.16 t ha^{-1}. During Boro 2018-19, the average yield of BRRI dhan74, BRRI dhan81, BRRI dhan88 and BRRI dhan89 were 8.12, 4.84, 6.27 and 7.86 t ha^{-1} respectively. Demo farmers as well as the neighbouring farmers also showed interest to cultivate BRRI dhan87 in T. Aman and BRRI dhan74 as well as BRRI dhan89 in Boro season.

Field demonstration of BRRI rice varieties. Four field demonstrations (above one *bigha* each) of newly released BRRI dhan80 and BRRI dhan87 was conducted in Burichong, Barura, Adarsha Sadar, Cumilla and B. Baria sadar during T. Aman 2018 season. The yield of BRRI dhan80 and BRRI dhan87 was 4.35-4.63 and 6.01-6.86 t ha^{-1} respectively. Farmer's acceptance of BRRI dhan87 was found very high in those respective areas for its grain size, panicle length and high yield. A total of 15 field demonstrations (above one *bigha* each) of

BRRI dhan69 were conducted in Cumilla district during Boro 2018-19. The yield of BRRI dhan69 was in all the locations varied from 7.14 to 8.62 t ha^{-1}. Farmers' expressed their disliking about this variety due to sticky cooked rice, bold grain and not suitable for keeping the cooked rice daylong.

Training/Field day/Agricultural fair

Training on blast disease management and modern rice cultivation. Seven farmers' training programmes were conducted in different locations of Cumilla region and 210 farmers were trained up in modern rice cultivation. Three trainings on management of blast disease for enhancing rice production in relation to climate change were conducted during 2018-19 in three upazilas (Bramanpara, Barura and Burichong) of Cumilla district funded by GOB, BARC, MoA. A total of 75 farmers and 15 SAAOs were able to understand about the devastating rice disease blast and its management practices through the training. Three farmers' training programmes funded by BRRI SPIRA project were conducted for modern rice cultivation and dissemination of newly released rice varieties in Cumilla, Chandpur and B. Baria districts in 2018-19. A total of 108 farmers and 12 SAAOs were trained up and they improved their knowledge about newly released rice varieties and their management practices from these trainings.

Field days. One field day was conducted at Burichong upazila in Cumilla district on rice blast disease management and build up farmer's awareness to this devastating disease in the presence of extension personnel funded by GOB project during T. Aman 2018 season. About 150 farmers participated on the field day. Farmers were very much interested to participate and learn about the devastating blast disease management techniques for aromatic rice BRRI dhan34. Seven field days were conducted in the block demonstration areas of Cumilla, Chandpur and B. Baria districts to demonstrate the newly released BRRI varieties during Aman and Boro 2018-19 seasons funded by SPIRA-BRRI project. About 1,100 farmers as well as extension personnel attended the field days. Most of the farmers got interested to cultivate new rice varieties in their areas specially BRRI dhan87, BRRI dhan88 and BRRI dhan89. BRRI RS, Cumilla also participated in Krishi mela, agriculture fair and development fair etc.

Breeder and TLS seed production. In T. Aman and Boro 2018-19 seasons 33.35 tons breeder seeds of different BRRI varieties were produced and sent to GRS Division, BRRI HQ, Gazipur. However, 36.75 tons of TLS of BRRI developed rice varieties were produced and sold to the farmers.

BRRI RS, Habiganj

SUMMARY

The genotype BR8236-2B-4-1 produced higher grain yield (3.23 t ha^{-1} and 92 days) which is about 0.21- 0.99 t ha^{-1} higher than the check varieties BRRI dhan43 (ck), BRRI dhan65 (ck), BRRI dhan82 (ck) and BRRI dhan83 with shorter growth duration in B. Aus 2018.

BR9011-62-2-1-2 among 15 genotypes, produced higher grain yield (4.96 t ha^{-1} and 107 days) which is about 0.26-1.18 t ha^{-1} higher than check varieties with shorter growth duration in T. Aman 2018.

In the PVT, B. Aman 2018, the proposed line BR10230-15-27-7B produced significantly higher grain yield and 14 days earlier growth duration than the check variety Fulkori.

Two proposed lines, BR7528-2R-HR-16-2-24-1 (ZER) and BR8492-9-5-3-2 (RLR) gave higher yield than the check variety BRRI dhan39. The proposed line BR7528-2R-HR-16-2-24-1 (ZER) was four days earlier and BR8492-9-5-3-2 (RLR) was seven days later growth duration than the check variety in PVT, T. Aman 2018

The ZER line IR99285-1-1-1-P2 produced higher grain yield with all the check varieties BRRI dhan29, BRRI dhan74 and BRRI dhan84 in Boro 2018-19.

None of the genotype (BRRI dhan29-SC3-28-16-10-6-HR6 (Com)-HR1(Gaz)-P4(Hbj), BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR1(Gaz)-P8(Hbj), BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR1(Gaz)-P11(Hbj)) performed better yield than the check BRRI dhan28, but all the tested lines were five days earlier in Boro 2018-19.

The PQR genotype BR8862-29-1-5-1-3 produced higher grain yield than all the check varieties but 8-10 days later than the checks BRRI dhan50 and BRRI dhan63 in Boro, 2018-19.

The BB resistant line BR (Bio) 11447-3-10-7-1 showed nine days earlier growth duration than the check IRBB60 with almost similar yield (5.6 t ha^{-1}).

The genotype IR100723-B-B-B-B-10 produced the highest grain yield than the check varieties (BRRI dhan28 and BRRI dhan88) with same growth duration in AYT (CTR), Boro 2017-18.

In the RYT (Cold), Boro 2018-19, the genotype BR (Bio) 9777-124-1-1-2 produced the highest grain yield than the check varieties BRRI dhan28 and BRRI dhan36 with same growth duration.

BR8904-28-1-2-2-2 produced the highest yield among the entries and about 0.6 t ha^{-1} higher yield than the check BRRI dhan58 with same growth duration in RYT (FB), Boro 2018-19.

In the RYT (FB-Bio), Boro 2018-19, the genotypes BR (Bio) 9777-116-12-2-5 produced the highest grain yield among all the lines and shown similar growth duration with the check variety BRRI dhan58.

FBR (short duration) PVT was conducted on farmer's field at Balikhal, Baniachong, Habiganj. The proposed line BR (Bio) 9787-BC2-63-2-2 produced almost similar yield (5.06 t ha^{-1}) with the check BRRI dhan28 (5.29 t ha^{-1}), although seven days earlier growth duration than the check.

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.

Vermicompost (VC) organic manure during Aus, T. Aman and Boro rice cultivation could be very useful of atmospheric and soil management strategy to decreased CH_4, N_2O flux and global warming potential (GWP) and increased rice productivity.

The strip tillage reduce about 26-53% GWP than conventional tillage under T. Aman-Mustard-Boro rice cultivation.

VARIETY DEVELOPMENT

RYT, B. Aus 2018

Nine genotypes along with four standard check BRRI dhan43, BRRI dhan65, BRRI dhan82 and BRRI dhan83 were evaluated at BRRI farm Habiganj. The genotype BR8236-2B-4-1 produced higher grain yield (3.23 t ha^{-1} and 92 days) which is about 0.21-0.99 t ha^{-1} higher than the check varieties with shorter growth duration. Advanced line BR8235-2B-13-3 also gave more than 0.5 t ha^{-1} higher yield than the check variety BRRI dhan83 with similar growth duration (Table 1).

Table 1. Yield and ancillary characters of RYT genotypes, B. Aus 2018, BRRI RS, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR9640-2B-9-1	83	95	1.5
BR9640-2B-14-2	88	98	1.7
BR9643-2B-19-1	100	95	2.0
BR9101-2B-1-2-1	83	93	2.5
BR9101-2B-5-3-1	84	98	2.7
BR8235-2B-4-4	98	96	2.6
BR8235-2B-12-4	99	101	2.2
BR8235-2B-13-3	100	103	2.8
BR8236-2B-4-1	105	92	3.2
BRRI dhan43 (ck)	105	97	2.7
BRRI dhan65 (ck)	73	98	3.0
BRRI dhan82(ck)	100	95	2.3
BRRI dhan83(ck)	99	101	2.2
$LSD_{(5\%)}$	5.5	1.8	0.3

DS: 10 May 2018

RYT, T. Aus 2018

BR9011-62-2-1-2, among 15 genotypes, produced higher grain yield (4.96 t ha^{-1} and 107 days) which is about 0.26- 1.18 t ha^{-1} higher than check varieties with shorter growth duration. Advanced line BR9039-12-2-1 and HHZ5-DT20-DT20-DT1 also gave more than about 0.16-1.08 t ha^{-1} higher than the check varieties with similar growth duration (Table 2).

Table 2. Yield and ancillary characters of RYT genotypes, T. Aus 2018, BRRI RS, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR9029-51-3-1	90	106	4.5
BR9029-51-3-5	89	106	4.6
BR9011-25-4-1-1	88	110	4.1
BR9011-25-4-1-1-3	89	106	4.8
BR9011-62-2-1-2	96	107	4.9
BR9039-20-2-2-1	92	110	4.5
BR9039-20-2-2-2	91	110	4.5
BR9039-21-1-1-1	93	112	4.2
HHZ5-DT20-DT20-DT1	98	112	4.8
BR9039-12-2-1	93	113	4.7
BR9011-12-2-1	93	110	4.4
BR8773-9-1-3	94	111	4.0
SP21-1-4	89	90	0.0
BR9029-51-3-12	92	106	4.8
BR9039-30-1-1	91	116	4.0
BR26 (ck.)	90	112	4.3
BRRI dhan28 (ck)	87	112	3.8
BRRI dhan48 (ck)	95	108	4.7
$LSD_{(5\%)}$	1.3	2.5	0.5

DS: 18 Apr 2018, DT: 15 May 2018.

PVT, B. Aman 2018

The genotype BR10230-15-27-7B along with check Fulkori were evaluated. The proposed line BR10230-15-27-7B produced significantly higher grain yield and 14 days earlier growth duration than the check variety Fulkori (Table 3).

PVT, T. Aman 2018

Two proposed lines BR7528-2R-HR-16-2-24-1 (ZER) and BR8492-9-5-3-2 (RLR) produced higher yield than the check variety BRRI dhan39. The proposed line BR7528-2R-HR-16-2-24-1 (ZER) was four days earlier and BR8492-9-5-3-2 (RLR) was seven days later growth duration than the check variety (Table 4).

RYT (ZER), Boro 2018-19

Five genotypes along with three checks BRRI dhan29, BRRI dhan74 and BRRI dhan84 were evaluated. The genotype IR99285-1-1-1-P2 produced higher grain yield with all the check varieties (Table 5).

RYT (short duration), Boro 2018-19

Three genotypes along with one check BRRI dhan28 were evaluated at nine locations (Habiganj(3), Sathkhira, Rangpur, Bhanga and Cumilla. None of the genotype performed better yield than the check BRRI dhan28, but they showed five days earlier growth duration (Table 6).

Table 3. Yield and ancillary character of PVT, B. Aman 2018, Balikhal, Baniachong, Habiganj

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR10230-15-27-7B	148	150	1.6
BR10260-7-19-2B	100	154	damage
Fulkori (ck)	-	164	0.6

DS: 9 Jun 2018

Table 4. Yield and ancillary character of PVT, T. Aman 2018 at Chunarughat, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR7528-2R-HR-16-2-24-1 (ZER)	94	117	3.5**
BR8492-9-5-3-2 (RLR)	94	128	3.6*
BRRI dhan39 (ck)	84	121	2.5***
$LSD_{(5\%)}$	6.3	6.3	0.7

DS: 27 Jul 2018; DT: 27 Aug 2018, *Have shattering tendency, ** Tungro and sheath rot, *** Tungro.

Table 5. Yield and ancillary character of ZER materials, Boro 2018-19, BRRI RS, Habiganj.

Designation	Plant height (cm)	Growth duration (days)	Yield (t ha^{-1})
IR99285-1-1-1-P1	96	173	7.3
IR99285-1-1-1-P2	88	174	8.3
BRRI dhan29	91	176	7.7
BRRI dhan74	84	167	6.8
BRRI dhan84	90	156	5.6
$LSD_{(5\%)}$	3.8	7.1	0.9

DS: 10 Nov 2018, DT: 27 Dec 2019.

Table 6. Yield and ancillary character of short duration lines, Boro 2018-19, BRRI RS, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRRI dhan29-SC3-28-16-10-6-HR6(com)-HR1(Gaz)-P4(Hbj)	82	145	4.9
BRRI dhan29-SC3-28-16-10-6-HR6(com)-HR1(Gaz)-P8(Hbj)	82	146	4.7
BRRI dhan29-SC3-28-16-10-6-HR6(com)-HR1(Gaz)-P11(Hbj)	81	145	4.7
BRRI dhan28	94	151	6.2
$LSD_{(5\%)}$	6.1	2.8	0.7

RYT (PQR), Boro 2018-19

Four genotypes along with two checks BRRI dhan50 and BRRI dhan63 were evaluated. The genotype BR8862-29-1-5-1-3 produced higher grain yield than all the check varieties but it was 8-10 days later than the checks (Table 7).

RYT (BB resistant), Boro 2018-19

Six genotypes along with check variety IRBB60 were evaluated. None of the genotype produced higher yield than the check IRBB60. But the genotype BR (Bio) 11447-3-10-7-1 showed nine days earlier growth duration than the check IRBB60 with almost similar yield (5.6 t ha^{-1}) (Table 8).

AYT (CTR), Boro 2017-18

Eight genotypes along with two checks; BRRI dhan28 and BRRI dhan88 were evaluated. The genotype IR100723-B-B-B-B-10 produced the highest grain yield than the check varieties with same growth duration. All the other genotypes produced more or less same yield with the checks (Table 9).

Table 7. Yield and ancillary character of PQR lines, Boro 2018-19, BRRI RS, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR8862-29-1-5-1-3	84	171	6.5
BR8862-8-3-4-4-1	90	172	4.3
BR8995-2-5-5-2-1	89	168	5.7
BR9205-10-1-5-3	99	174	5.8
BRRI dhan50	74	163	6.1
BRRI dhan63	74	161	6.1
$LSD_{(5\%)}$	7.8	4.2	0.6

DS: 10 Nov 2018, DT: 24 Dec 2019

Table 8. Yield and ancillary character BB lines, Boro 2018-19, BRRI RS, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR(Bio)11447-1-28-4-6	90	158	4.5
BR(Bio)11447-1-28-12-3	88	159	4.4
BR(Bio)11447-1-28-14-1	102	163	3.5
BR(Bio)11447-1-28-14-3	91	157	4.5
BR(Bio)11447-3-10-7-1	92	157	4.1
BR(Bio)11447-3-10-7-1	91	156	5.6
IRBB60	75	165	5.9
$LSD_{(5\%)}$	5.9	2.5	0.6

DS: 17 Nov 2018, DT: 23 Dec 2019.

Table 9. Yield and ancillary character of CTR lines, Boro 2018-19, BRRI RS, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
IR100723-B-B-B-B-10	92	160	6.7
IR100723-B-B-B-B-61	100	162	5.5
BR9989-23-CS1-1-CS2-16-2-4	101	164	6.3
IR100752-B-B-B-B-1	90	163	5.8
IR99073-B-B-B-80	93	161	6.4
IR100722-B-B-B-B-11	99	162	5.6
BR8909-B-12-2-CS1-4-CS2-P5-4-5	90	167	5.5
IR100723-B-B-B-B-43	94	168	6.5
BRRI dhan28 (ck)	100	160	6.3
BRRI dhan88 (ck)	77	162	6.0
$LSD_{(5\%)}$	4.5	1.7	0.3

DS: 17 Nov 2018, DT: 5 Jan 2019.

RYT (Cold), Boro 2018-19

One genotype along with two checks BRRI dhan28 and BRRI dhan36 were evaluated. The genotype BR (Bio) 9777-124-1-1-2 produced the highest grain yield than the check varieties BRRI dhan28 and BRRI dhan36 with similar growth duration (Table 10).

RYT (FB), Boro 2018-19

Four genotypes along with check BRRI dhan58 were evaluated. BR8904-28-1-2-2-2 produced the highest yield among the entries and about 0.6 t ha^{-1} higher yield than the check BRRI dhan58 with similar growth duration (Table 11).

RYT (FB-Biotechnology), Boro 2018-19

Three advanced lines along with the check BRRI dhan58 were evaluated. The genotypes BR(Bio)9777-116-12-2-5 produced the highest grain yield than all the lines and the check variety BRRI dhan58 with similar duration. Another two lines, BR (Bio) 9777-116-12-2-4 and BR (Bio) 9787-BC2-35-4-2 also showed similar yield and growth duration with BRRI dhan58 (Table 12).

PVT(FBR), Boro 2018-19

FBR (short duration) PVT was conducted along with check variety BRRI dhan28 at Balikhal, Baniachong, Habiganj. The proposed line BR (Bio) 9787-BC2-63-2-2 produced almost similar yield (5.06 t ha^{-1}) with the check BRRI dhan28 (5.29 t ha^{-1}), but seven days earlier growth duration than the check (Table 13).

CROP-SOIL-WATER MANAGEMENT

Long-term missing element trial for diagnosing the limiting nutrient in soil

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.

Table 10. Yield and ancillary character of cold lines, Boro 2018-19, BRRI RS, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR(Bio)9777-124-1-1-2	93	160	6.8
BRRI dhan28	100	159	6.2
BRRI dhan36	71	160	5.4
$LSD_{(5\%)}$	17.1	0.7	0.8

DS: 18 Nov 2018, DT: 29 Dec 2019.

Table 11. Yield and ancillary character of FBR lines, Boro 2018-19, BRRI RS, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR8904-28-1-2-2-2	94	157	6.6
Karjat-5	78	168	6.2
BR9675-68-5-1	105	165	5.8
BR9208-8-1-1-1	92	158	6.1
BRRI dhan58	99	156	6.0
$LSD_{(5\%)}$	8.8	4.7	0.3

DS: 30 Nov 2018, DT: 4 Jan 2019.

Table 12. Yield and ancillary character of FBR lines (Biotech.), Boro 2018-19, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR (Bio) 9777-116-12-2-4	100	160	7.2
BR(Bio)9777-116-12-2-5	98	162	7.8
BR(Bio)9787-BC2-35-4-2	90	164	6.9
BRRI dhan58	91	162	7.1
$LSD_{(5\%)}$	4.9	1.6	0.4

DS: 18 Nov 2018, DT: 29 Dec 2019.

Table 13. Yield and ancillary character of PVT (FBR-short duration), Boro 2018-19, Baniachong, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR(Bio)9787-BC2-63-2-2	86	142	5.06
BRRI dhan28 (ck)	98	149	5.29

DS: 20 Nov 2018, DT: 8 Jan 2019.

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 11th 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 dhan89 was used as a test crop. Complete treatment (NPKSZn) significantly increased grain yield and yield parameters of rice. The highest panicle m^{-2} was obtained with balanced fertilized (T_1) plot followed by K, NP, NK omission plot (T_4, T_7). The highest grain yield was obtained in T_1 (7.21 t ha^{-1}) followed by T_4 (4.98 t ha^{-1}). The K omission treatment (T_4) produced significantly lower yield (4.98 t ha^{-1}) than the other treatments. From the experiment it may be concluded that, besides NK, K is the most yield limiting nutrient element in BRRI RS, Habiganj farm (Table 14).

Greenhouse gas emission and global warming potential under triple rice cropping systems

Field experiment was conducted at BRRI HQ experimental farm (23°85.9'N and 90°82.4' E, elevation 12m), Gazipur, Bangladesh in the 2018-2019. Treatments imposed were: chemical fertilizers (NPKSZn), Cow dung (CD), Poultry manure (PM), and Vermicompost (VC) as integrated plant nutrient system (IPNS) based inorganic fertilizations. The static closed-chamber method were used to measure CH_4, CO_2 and N_2O emission rates during T. Aman, Boro and Aus rice season respectively. Result reveals that VC fertilization treatment showed decrease of GHG and GWP than CD and PM treatments. The CD and PM significantly increased total CH_4, N_2O and GWP by around 15-67%, 9-118% and 15-65% of VC fertilization with triple rice cropping system (Table 15). There was also significant difference of rice yield between organic amendment and chemical fertilization systems in Aus and T. Aman and Boro season (Table 16). In conclusion, the VC organic manure during Aus, T. Aman and Boro rice cultivation could be very useful of atmospheric and soil management strategy to decreased CH_4, N_2O flux and GWP and increased rice productivity.

Table 14. Effects of nutrient element omission from the complete treatment on grain yield of BRRI dhan89, Boro 2018-19, Habiganj.

Treatment	Panicle m^{-2}	Grain yield (t ha^{-1})
T_1	368	7.21
T_2	288	5.11
T_3	349	6.96
T_4	340	4.98
T_5	350	6.99
T_6	348	6.78
T_7	302	5.20
T_8	199	4.10
$LSD_{(5\%)}$	20.73	0.35

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 15. Total GHG and GWP with Aus-T. Aman-Boro rice seasons under organic amended rice soil.

Treatment	Total greenhouse gas emission (kg ha^{-1})		Global warming potential (kg CO_2 eq. ha^{-1})
	CH_4	N_2O	
	Aus		
NPKSZn	307	0.07	8615
Cowdung with IPNS	406	0.143	11406
Poultry manure with IPNS	508	0.212	14280
Vermicompost with IPNS	344	0.110	9661
Control	243	0.038	6814
$LSD_{0.05}$	8.06	0.01	337
	T. Aman		
NPKSZn	326	0.247	9193
Cowdung with IPNS	564	0.422	15904
Poultry manure with IPNS	679	0.556	19159
Vermicompost with IPNS	490	0.254	13787
Control	240	0.170	6765
$LSD_{0.05}$	9.44	0.02	476
	Boro		
NPKSZn	232	0.265	6566
Cowdung with IPNS	439	0.350	12385
Poultry manure with IPNS	568	0.530	16044
Vermicompost with IPNS	345	0.320	9745
Control	147	0.110	4145
$LSD_{0.05}$	10.07	0.02	313

Table 16. Grain yield with Aus-T. Aman-Boro rice season under organic amended rice soil.

Treatment	Grain yield (t ha^{-1})		
	Aus	T. Aman	Boro
NPKSZn	3.76	3.54	6.58
Cowdung	4.08	4.03	7.19
Poultry manure	4.00	4.02	7.03
Vermicompost	4.98	4.26	7.25
Control	2.69	2.63	2.51
$LSD_{0.05}$	0.17	0.20	0.39

Comparison of greenhouse gas emission under conventional and strip tillage with T. Aman-Mustard-Boro cropping systems

The experiment was conducted at BARI Joydebpur in 2018-19 to evaluate the effects of tillage on greenhouse gas emission, global warming potential (GWP) and crop yields in the T. Aman-Mustard-Boro cropping systems. Two tillage practices such as T_1: conventional tillage (CT) and T_2: strip tillage (ST) under 100% of recommended N-fertilizer dose (RND) with three replications. The CH_4, N_2O and CO_2 emission were significantly increased in between CT and ST tillage practice. The ST reduces about 26-53% GWP than CT practice. The crop yields also significantly increased under ST than CT agriculture practice (Table 17).

Table 17. Total GHG, GWP and yield under different tillage system.

Parameter (kg ha^{-1})	Tillage system		$LSD_{0.05}$
	Conventional tillage	Strip tillage	
	T. Aman		
Methane (CH_4)	326	202	43
Carbon di-oxide (CO_2)	964	1436	222
Nitrous oxide (N_2O)	1.25	1.75	0.12
Global warming potential	10423	7555	534
Grain yield	4320	4690	220
	Mustard		
Methane (CH_4)	0	0	0
Carbon di-oxide (CO_2)	793	367	20.89
Nitrous oxide (N_2O)	0.12	0.068	0.02
Global warming potential	823	385	32.19
Grain yield	780	1080	158
	Boro		
Methane (CH_4)	187	122	11
Carbon di-oxide (CO_2)	585	774	45
Nitrous oxide (N_2O)	0.28	0.33	0.02
Global warming potential	5895	4277	423
Grain yield	6450	6780	210

BRRI RS, Rajshahi

SUMMARY

In Aus season, 24 breeding lines from two regional yield trial (RYT) were evaluated of which five entries appeared promising for further evaluation. In hybridization programme in T. Aman season, 883 F_1 seeds were produced from seven crosses. Thirteen RYTs were conducted in T. Aman in which 81 breeding lines were evaluated and 14 entries were found promising for further advancement.

In proposed variety trial (PVT), the breeding lines for RLR, BR-RS(Raj)-PL4-B, BR-SF (Rang)-PL1-B and BR8210-10-3-1-2 produced higher grain yield than the check BRRI dhan49 whereas RLR line BR8492-9-5-3- produced 1.64 t ha^{-1} higher grain yield than the check BRRI dhan39. ZER line BR7528-2R-HR16-2-24-1 also produced higher yield with 10 days earlier growth duration than the check BRRI dhan39. The tested PQR line BR8535-2-1-2 produced higher yield with 26-30 days earlier growth duration than the check variety BRRI dhan34.

In OYT, AYT and PVS trials, 25 genotypes were selected from 101 breeding drought lines under STRASA project for further evaluation in T. Aman season. A validation trial (Ec-IFAD), BRRI dhan71 produced higher grain with 30 days shorter growth duration than local Sumonswarna. A total of 251 breeding lines were evaluated in GSR project during T. Aman in which 56 tested entries produced higher grain yield than the check variety.

In Boro season, 975 F_1 seeds were produced from 10 crosses. In Boro, eight RYTs with 31 breeding lines were conducted of which eight lines found promising for further advancement. The BBR genotype BR (Bio) 11447-3-10-7-1 performed similar grain yield with the check variety BRRI dhan28. The two ZER genotypes IR99825-1-1-1-P2 and IR99825-1-1-1-P1 produced significantly higher grain yield than the check varieties. The PQR line BR8995-2-5-5-2-1 produced significantly higher grain with 2-10 days longer growth duration than the check varieties. The tested DRR genotype BR9651-15-2-1-5 produced higher grain yield with six days shorter growth duration than the check varieties.

In PVT Boro, the proposed line BR(Bio)9787-BC2-63-2-2 produced 0.28 t ha^{-1} higher grain yield with days shorter growth duration than the check variety BRRI dhan28. In IIRON (Irrigated nursery), 135 advanced lines were evaluated. Among them, 14 genotypes produced higher grain yield than the check varieties. Out of 336, a total of 67 tested lines were selected from OYT, PYT and SYT of GSR programme during Boro.

USG treated plots produced significantly higher grain of BRRI dhan71 than PU treated (@ 90 kg N ha^{-1}) plot.

Puddled and unpuddled rice cultivation produced similar grain yield at each level of fertilizer application. Unpuddled Boro rice required 25% additional fertilizer to recommended dose.

In T. Aus 2018, omission of N, P and Zn significantly reduced the grain production at BRRI RS, farm Rajshahi (AEZ11). In T. Aman 2018, omission of N, P, S and Zn significantly reduced the grain yield at the same location.

In Boro 2018-19, N was found yield limiting nutrients in calcareous soils of BRRI Rajshahi RS, farm while NPKSZn were the yield limiting nutrients at Barind tract soil in Boro season.

AEZ (Agro-ecological Zone) based fertilization was the best tool for Boro rice cultivation in Barind Tract. Farmers' practice and RCM (Rice crop manager) performed equally in T. Aman while RCM performed the lowest in Boro season.

Recommended fertilizer dose (RD) and NPK Combo fertilizer used @ 680 kg ha^{-1} (with equivalent nutrients of RD) produced identical rice grain. Use of 300 kg ha^{-1} ACI NPKS compound fertilizer (Ratna) saved 50 kg urea, whole dose of P, K, S and Zn.

Bamboo made trap found very efficient in trapping rat compared to pressure trap and box type of trap.

Compared with conventional, the gross margin was slightly higher (1-5%) in all other conservation tillage and crop establishment options. Incorporation of 30% wheat, 30% rice and 100% mungbean straw had a significant contribution in crop yield as well as gross margin of maize-mungbean-rice system.

Urea applicator and urea broadcasting produced almost similar rice yields in BRRI dhan29, BRRI dhan58 and BRRI dhan81.

In Aman season, BRRI dhan72 ranked top in terms of yield followed by BRRI dhan49. In Boro,

the top three varieties were BRRI dhan89, BRRI hybrid dhan2, BRRI dhan29. Considering three seasons, 22 and 14 tons of breeder and TLS seeds were produced respectively.

VARIETY DEVELOPMENT

Regional yield trial (RYT), T. Aus 2018

Fifteen genotypes along with checks BR26, BRRI dhan48 and BRRI dhan28 were evaluated at BRRI RS, Rajshahi farm. Five tested entries produced higher grain than the check varieties (3.26-3.60 t ha^{-1}). The genotype BR9039-20-2-2-1 (4.47 t ha^{-1}) gave the highest grain yield with 6-8 days longer growth duration than the check varieties followed by BR9011-25-4-1-1(4.44 t ha^{-1}).

Observational yield trial (OYT), T. Aus 2018

In total, 257 advanced breeding lines along with the standard check BRRI dhan48 were evaluated at two locations i.e. Lalpur, Natore and Tanore, Rajshahi. Out of 257 tested entries, 57 genotypes produced higher grain (2.90-4.23 t ha^{-1} and 98-128 days) than the check variety BRRI dhan48 (2.88 t ha^{-1} and 119 days) at Lalpur site. At Tanore site, all the genotypes were severely affected by stem borer and rat infestation. As a result, grain yield was drastically reduced.

Hybridization, T. Aman 2018

A total of 883 F_1 seeds were produced from seven crosses using seven parents in T. Aman 2018 season.

Regional yield trial (RYT), T. Aman 2018

A total of 81 breeding lines were evaluated in 13 different RYT three for zinc enriched rice-ZER, one for disease resistance rice-DRR, two for rainfed lowland rice-RLR, three for premium quality rice-PQR, one for Insect resistance rice-IRRI and three for high yielding rice-2 Biotechnology, one Breeding materials) at BRRI RS farm Rajshahi against 15 different standard checks (BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan39, BRRI dhan49, BRRI dhan62, BRRI dhan71, BRRI dhan72, Bina dhan-13, IRBB60, Kalizira, Kataribhog, Radhunipagol, Krishnobhog and Chinigura). Among them, one entry BR(BIO)9786-BC2-161-1-2 (5.61 t ha^{-1}) produced higher yield in RYT-high yielding rice (Biotechnology), four entries showed higher yield in RYT-ZER, one genotype BR9396-2-6-2B produced higher yield in RYT-high yielding rice (Breeding), eight genotypes showed higher yield in RYT-PQR.

Proposed variety trial (PVT), T. Aman 2018

Three PVTs, one rainfed lowland rice (RLR), one zinc enriched rice (ZER) and one premium quality rice (PQR), were conducted against the three standard checks (BRRI dhan34, BRRI dhan39 and BRRI dhan49) in farmers' field of Rajshahi district. The proposed RLR line BR-RS (Raj)-PL4-B, BR-SF (Rang)-PL1-B and BR8210-10-3-1-2 (5.31-5.61 t ha^{-1} and 126-131 days) produced higher grain yield than the check BRRI dhan49 (4.19 t ha^{-1} and 130 days). BRRI dhan49 was highly infested by false smut. The other RLR line BR8492-9-5-3-2 produced higher grain yield (6.43 t ha^{-1}) but with two days longer growth duration than the check variety BRRI dhan39 (4.79 t ha^{-1} and 115 days). The ZER line BR7528-2R-HR16-2-24-1 produced similar yield (4.87 t ha^{-1}) with 10 days earlier growth duration than the the check variety BRRI dhan39 (4.79 t ha^{-1} and 115 days). The PQR line BR8535-2-1-2 produced higher yield (5.05 t ha^{-1} and 114 days) and 30 days earlier growth duration than the check variety BRRI dhan34 (3.11 t ha^{-1} and 144 days).

Observational yield trial (OYT) of STRASA drought lines, T. Aman 2018

A total of 45 advanced lines with nine checks (IR64, SWARNA, Vandana, BRRI dhan66, BRRI dhan71, BRRI dhan28 and BRRI dhan29) were tested under both stress and control conditions. Thirty-four genotypes produced higher grain yield than the checks (2.35-3.99 t ha^{-1}) in controlled condition. Among them, 17 tested entries gave more than 5 t ha^{-1} grain yield. On the other hand, 38 genotypes produced higher grain yield than all the checks (2.17-4.40 t ha^{-1}). Among them, 26 genotypes gave more than 5 t ha^{-1} grain in stressed condition.

Advanced yield trial (AYT) of STRASA drought lines, T. Aman 2018

Thirty-five advanced lines with five checks (BRRI dhan66, BRRI dhan71, Swarna, BRRI dhan28 and BRRI dhan29) were tested under both stress and control condition. Among them only six genotypes produced higher yield than all the checks (3.33-5.61 t ha^{-1}) in controlled condition and 18 genotypes produced higher yield than all the checks (3230-4720 kg ha^{-1}).

Donor materials, STRASA, T. Aman 2018

A total of 11 advance lines with the check BRRI dhan71 was tested under both stress and control conditions. The highest grain (5.01 kg ha^{-1} and 112 days) was found in the entry IR11N313.

Validation trial, STRASA, T. Aman 2018

Non-replicated trials were conducted in farmers' fields at Paba, Tanore and Nachol upazilas of Rajshahi region. Four treatments e.g. local variety (Sumonswarna) + farmers' management (T_1), local variety (Sumonswarna) + improved management (T_2), improved variety (BRRI dhan71)+farmers' management (T_3), improved variety (BRRI dhan71) + improved management (T_4) were tested. Grain yield of both the varieties were higher in improved management practices. Moreover, BRRI dhan71 produced higher grain (5.20-4.72 t ha^{-1}) with 30 days shorter growth duration than the local Sumonswarna (4.95-4.66 t ha^{-1}). So, improved variety along with improved management practices should be followed by farmers to achieve higher yield.

Green super rice (GSR), T. Aman 2018

OYT. A total of eight OYT (OYT#1, OYT#2, OYT#3, OYT#4, OYT#5, OYT#6, OYT#7 and OYT#8) were conducted at Puthia, Rajshahi under the supervision of BRRI RS, Rajshahi. Among eight OYTs consist of 182 genotypes, 31 entries performed higher grain than the check varieties BRRI dhan49 and BRRI dhan71.

PYT. A total of 25 genotypes along with four checks BRRI dhan49, BRRI dhan71, BRRI dhan73 and BRRI dhan75 were evaluated at on-farm condition of Paba and Puthia. Out of 25, eight genotypes produced higher yield than the check varieties.

SYT. Two SYTs (SYT#1 and SYT#2) were conducted at on-farm condition of Paba and Puthia. In this trial, 44 entries were evaluated and among them 17 genotypes produced higher grain than the check varieties.

Hybridization, Boro 2018-19

A total of 975 F_1 seeds were produced from ten crosses using seven parents in Boro 2018-19 season.

Regional yield trial (RYT), Boro 2018-19

RYT#4 (ZER). Two advanced lines along with three check varieties BRRI dhan29, BRRI dhan74 and BRRI dhan84 were evaluated. Two genotypes IR99825-1-1-1-P2 and IR99825-1-1-1-P1 produced significantly higher grain yield (6.06-6.24 t ha^{-1} and 164 days) than the check varieties (4.65-5.56 t ha^{-1} and 151-171 days).

RYT#6 (PQR). Four genotypes along with two check varieties BRRI dhan50 and BRRI dhan63 were evaluated. The PQR line BR8995-2-5-5-2-1 produced significantly higher grain (6.34 t ha^{-1}) with 2-10 days longer growth duration than the check varieties (5.43-5.73 t ha^{-1}). The tested genotype BR9205-10-1-5-3 produced higher grain yield (6.14 t ha^{-1}) than the check variety BRRI dhan50 (5.43 t ha^{-1}).

RYT#7 (DRR). Six advanced breeding lines along with three checks BRRI dhan29, BRRI dhan58 as susceptible checks and IRBB60 as resistant check were evaluated. The tested genotype BR9651-15-2-1-5 produced higher grain yield (6.21 t ha^{-1}) and with six days shorter growth duration than the check varieties (3.93-5.98 t ha^{-1} and 161-165 days).

Proposed variety trial (PVT), Boro 2018-19

One advanced line along with the standard check BRRI dhan28 was evaluated at Alimganj, Paba, Rajshahi. The proposed line BRRI BR (Bio) 9787-BC2-63-2-2 produced higher grain yield and three days shorter growth duration (6.88 t ha^{-1} and 145 days) than the check variety BRRI dhan28 (6.60 t ha^{-1} and 148 days).

International Irrigated Rice Observational Nursery (IIRON), Boro 2018-19

A total of 135 genotypes along with nine checks; BRRI dhan28, BRRI dhan36, BRRI dhan58, BRRI dhan63, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan86 and BRRI dhan89 were evaluated. Out of 135, 14 genotypes produced higher grain yield (6.48-8.90 t ha^{-1} and 155-170 days) than the check varieties (4.87-6.43 t ha^{-1} and 151-162 days).

Green super rice (GSR), Boro 2018-19

OYT. Nine OYTs (OYT#1, OYT#2, OYT#3, OYT#4, OYT#5, OYT#6, OYT#7 and OYT#8) were conducted at Paba, Rajshahi. Nine OYTs consist of 246 genotypes, among them 41 entries performed higher grain than the check varieties BRRI dhan28, BRRI dhan58, BRRI dhan67 and BRRI dhan69.

PYT. Three PYTs (PYT#1, PYT#2 and PYT#3) were conducted at on-farm condition of Paba and Durgapur. In these trials, 66 entries were evaluated, among them 18 genotypes produced higher grain than the check varieties BRRI dhan28, BRRI dhan58, BRRI dhan67 and BRRI dhan69.

SYT. A total of 24 genotypes along with three checks BRRI dhan28, BRRI dhan58 and BRRI dhan69 were evaluated at on-farm condition of Paba and Durgapur. Out of 24, eight genotypes produced higher yield than the check varieties. The genotype 7 FBR-222 (8.14-8.36 t ha^{-1}) performed better in both the locations.

CROP-SOIL-WATER MANAGEMENT

Nitrogen management in BRRI dhan71 at drought prone areas, T. Aman 2018

Nitrogen management in BRRI dhan71 was evaluated under drought condition. The treatments were T_1-prilled urea (PU) application (90 kg N ha^{-1}), T_2- application of USG (1.8g) at 3-5 days after transplanting, and T_3-control (No urea) were assigned. USG treated plots produced significantly higher grain (5.13 t ha^{-1}) than PU treated (@ 90 kg N ha^{-1}) plot (4.75 t ha^{-1}).

Suitable and profitable nutrient management for rice in Barind Tract soils

BRRI dhan71 in Aman season and BRRI dhan81 in Boro season were evaluated with three fertilizer recommendation tools e.g., FRG 2012 (AEZ based), RCM and farmer's practice. Among them AEZ based fertilization in T. Aman and Boro rice was found the best regarding rice grain yield (Table 1). FP and RCM performed equally in T. Aman season while RCM performed the lowest in Boro season.

Determination of yield limiting nutrients in soils by omission plot technique in T. Aus, T. Aman and Boro season at north-west Bangladesh

The experiments were conducted at BRRI RS farm Rajshahi and farmer's field of Rajshahi in T. Aus 2018, T. Aman 2018 and Boro 2018-19 seasons to identify the nutrient(s) that limit the rice yield in soils. Treatments for the experiment were Native nutrients, Recommended dose of NPKSZn, PKSZn (-N), NKSZn (-P), NPSZn (-K), NPKZn (-S) and NPKS (-Zn). Treatments were compared under randomized complete block design with three replications.

Omission of different nutrients from the recommended NPKSZn dose significantly affected the rice yield over the locations and seasons (Table 2). Native nutrients always produced the lowest rice grain and recommended NPKSZn application resulted in the highest grain yield. In T. Aus 2018, omission of N, P and Zn significantly reduced the grain production at BRRI RS farm Rajshahi (AEZ11). In T. Aman 2018, omission of N, P, S and Zn significantly reduced the grain yield at the same location. In Boro 2018-19, omission of only N nutrients significantly affected the rice yield of BRRI dhan63. In the farmer's field at Paba Rajshahi (AEZ26), omission of N, P, K, S and Zn significantly reduced the grain yield of BRRI dhan63. Nitrogen was the most limiting nutrient followed by P.

Table 1. Yield performance of T. Aman (BRRI dhan71) and Boro (BRRI dhan81) rice under different fertilizer management tools at Paba, Rajshahi, 2018-19.

Treatment	Tiller no./m^2		Panicle no./m^2		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
	T. Aman	Boro	T. Aman	Boro	T. Aman	Boro	T. Aman	Boro
AEZ	246	280	244	278	5.18	5.75 a	4.74	7.06
FP	233	287	230	270	4.89	5.33 b	4.36	6.38
RCM	235	279	233	268	4.65	4.72 c	5.25	5.69
LSD (0.05)	NS		NS		0.29		NS	
CV		7.05		4.63		3.25		9.49

Means with the same letter are not significantly different.

Table 2. Effect of omission of macro and micro nutrients on grain yields of rice, Rajshahi 2018-19.

Treatment	Grain yield (t ha^{-1})		
	T. Aus 2018	T. Aman 2018	Boro 2018-19
T_1 = native nutrients	1.56 d	2.46 c	5.10 a
T_2 = npkszn	4.23 a	5.46 a	3.08 d
T_3 = pkszn (-n)	2.25 cd	3.01 c	3.78 c
T_4 = nkszn (-p)	3.09 bc	4.41 b	4.38 b
T_5 = npszn (-k)	3.44 ab	5.01 ab	4.56 b
T_6 = npkzn (-s)	3.28 ab	4.74 b	4.48 b
T_7 = npks (-zn)	3.19 bc	4.59 b	3.07
Cv (%)	11.26	5.76	2.92 d

Means with the same letter are not significantly different.

Nutrient management under conservation agriculture (CA) in double rice cropping system

This experiment was conducted to identify the nutrient requirement of crop under conservation agriculture and to improve soil health under conservation agriculture practice in Boro-Fallow-T. Aman cropping patterns. Treatments details are given below. Design is split-split plot with three replications. Experiment was initiated in Boro 2018-19 seasons with BRRI dhan81 rice variety.

Main plots Crop establishment methods	Sub-plots Residue management	Sub-sub-plots Fertilizer doses
M_1: Unpuddled	S_1: Retention of 20 cm crop residue of rice	N_1: 125% nutrients for all crops
M_2: Puddled	S_2: Removal of crop residue of all crops	N_2: 100% nutrients for all crops
		N_3: 75% nutrients for all crops
		N_4: 50% nutrients for all crops

The results show that the puddled and unpuddled rice cultivation produced similar amount of grain at each level of fertilizer application (Table 3). Unpuddled Boro rice required 25% additional fertilizer to recommended dose.

Performance of NPK Combo compound fertilizer on Boro rice (BRRI dhan63)

The experiment was conducted at BRRI RS farm, Rajshahi in Boro season to evaluate the efficacy of NPK Combo compound fertilizer for Boro rice production. Treatments for the experiment were T_1 = Recommended dose of NPKSZn @ 150-24-67-13-1.3 kg ha^{-1}, T_2 = NPK @ 150-24-67 from NPK Combo (680 kg ha^{-1}) + S and Zn from straight fertilizer, T_3 =25% less of recommended NPK from straight fertilizer + S and Zn from straight fertilizer, T_4 =NPK Combo @ 510 kg ha^{-1} (25% less from rec. NPK) + S and Zn from straight fertilizer. Treatments were compared under randomized complete block design with four replications.

Grain yields in the all fertilized plots were statistically identical. Recommended fertilizer dose (RD) (6.23 t ha^{-1}) and NPK Combo fertilizer used @ 680 kg ha^{-1} (with equivalent nutrients of RD) (6.25 t ha^{-1}) produced identical rice grain. Use of NPK Combo compound fertilizer keeps away from the use of urea, TSP and MoP fertilizer. Farmers may be relieved from the N top dress.

Table 3. Interaction effect of crop establishment method on grain yield (t ha^{-1}) of Boro rice (BRRI dhan63), Paba, Rajshahi, 2018-19.

Fertilizer dose	Crop establishment method	
	Unpuddled	Puddled
125%	5.70 aA	5.02 aA
100%	4.62 bA	5.00 aA
75%	4.07 cA	4.46 bA
50%	3.70 dA	3.99 cA
CV (%)	1.97	

Means with the same letter are not significantly different.

Performance of ACI NPKS compound fertilizer (Ratna) on Boro rice (BRRI dhan63)

The experiment was conducted at BRRI RS farm Rajshahi in Boro season to evaluate the efficacy of NPKS compound fertilizer for Boro rice production. Treatments for the experiment were T_1 = Recommended dose of NPKSZn @ 150-24-67-13-1.3 kg/ha, T_2 = ACI NPKS @ 300 kg/ha + 2 N top dress (100 kg ha^{-1}) + 43 kg K ha^{-1} + 1.3 kg Zn ha^{-1}, T_3 = ACI NPKS @ 300 kg ha^{-1} + 2 N top dress (100 kg ha^{-1})+ 43 kg K ha^{-1} and T_4 = ACI NPKS @ 300 kg ha^{-1} + 2 top dress of N (100 kg ha^{-1}). Treatments were compared under randomized complete block design (RCBD) with four replications.

Use of 300 kg ha^{-1} ACI NPKS compound fertilizer with 100 kg N ha^{-1} as two top dress seems better than recommended dose of straight fertilizer in terms of grain yield of BRRI dhan63 a good variety of Boro season. This treatment saved 50 kg urea, whole dose of P, K, S and Zn. This study was conducted at BRRI RS farm soil (AEZ 11) of Rajshahi.

PEST MANAGEMENT

Effect of different trap design for the management rat

This experiment was conducted at BRRI RS Rajshahi farm during Boro season. Three different types of trap design, viz, bamboo made traps, pressure traps and box type traps were evaluated in this experiment. Every type of trap was set in the rice field area at the beginning of the day. The traps were set in the field following RCBD with six replications. The traps were monitored at 24-hours interval. The trapped rats were removed from the traps and their number was counted and recorded. These trap designs were operated 35 days in the field. The results showed that the highest number of rats were trapped in the bamboo made trap and it was significantly different from other trap design. Lowest number of rats were trapped in the pressure trap.

RICE FARMING SYSTEMS

Effects of tillage with crop establishment methods and residue management under Aman rice-wheat-mungbean system

The trial was conducted at BRRI RS, Rajshahi during 2018-19 in split-plot design with three replications. The tillage and crop establishment 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. Un-puddled transplant Aman rice by transplanter, wheat and MB by ST, T_4. Un-puddled transplanting Aman rice by transplanter, wheat and MB by BP, T_5. Farmers' practice. The residue management options were S_1: Retention of 30% residue of rice and wheat and 100% of mungbean, S_2: Removal of residue of rice and wheat and retention of 100% of MB and S_3: Removal of residue of all crops. BRRI and BARI recommended crop and fertilizer management practices were followed for all treatments.

The grain yield of rice affected significantly by tillage and crop establishment options. The grain yield of rice remained higher in T_5 (conventional) (5.12 t ha^{-1}) which was statistically similar with all other treatments except T_2 (4.44 t ha^{-1}). In contrast, grain yield of wheat was found lower in T_5 (3.53 t ha^{-1}) which was statistically similar with rest of the treatments except T_4 (4.02 t ha^{-1}). The grain yield of mungbean was not influenced by the tillage and crop establishment methods and the higher seed yield was also found in T_5 followed by T_3 and T_4 treatments. The higher cost of cultivation was found in T_5 followed by T_3 while the lower cost of cultivation was found in T_1. The highest gross return was found in T_5 followed by T_3 while the lowest gross return was found in T_1. The gross margin was found lower in T_5 although the gross return remained higher in this treatment. The highest gross margin was found in T_4 (Tk 1,19,500) followed by T_1 treatment (Tk 1,17,000). Compared with conventional, the gross margin was considerably higher (1-5%) in all other tillage and crop establishment options.

Irrespective of tillage management option, the higher rice yield was found in S_1 (4.97 t ha^{-1}) followed by S_2 (4.70 t ha^{-1}) while the lowest yield was found in S_3 (4.60 t ha^{-1}). Similar trend was observed in case of wheat yield. In case of seed yield of mungbean, there was insignificant effect due to crop residue management options. The REY, gross return and gross margin were remained significantly higher in S_1 treatment compared with S_3 treatment indicating that incorporation 30% wheat and 30% rice and 100% mungbean straw had a significant contribution in crop yield as well as gross margin of the system.

Effects of urea application techniques on different Boro varieties in Barind region

The trial was conducted at BRRI regional station, Rajshahi during Boro season in split-plot design with three replications. The urea application methods were T_1: Urea control, T_2: Urea broadcast, T_3: Urea by applicator and the rice varieties were V_1: BRRI dhan29, V_2: BRRI dhan58, V_3: BRRI dhan81. The grain yields of rice varieties were affected significantly by urea application methods and the higher yields were found in urea applicator (5.74, 5.55 and 5.61 t ha^{-1} respectively in BRRI dhan29, BRRI dhan58 and BRRI dhan81) closely followed by urea broadcast (5.58, 5.38 and 5.57 t ha^{-1} respectively in BRRI dhan29, BRRI dhan58 and BRRI dhan81).

SOCIO-ECONOMICS AND POLICY

Stability analysis of BRRI developed T. Aman rice varieties

Forty Aman rice varieties were evaluated at BRRI RS Rajshahi farm. Among them, BRRI dhan72 ranked top in terms of yield (6.07 t ha^{-1}) followed by BRRI dhan49 (5.65 t ha^{-1}). Variety BRRI dhan5, BRRI dhan37, BRRI dhan38 were found low yielding varieties and the yield ranging from 2.45 to 2.86 t ha^{-1}.

Stability analysis of BRRI developed Boro rice varieties

Forty-one Boro varieties were evaluated at BRRI RS Rajshahi farm. Top three varieties were BRRI dhan89 (5.88 t ha^{-1}), BRRI hybrid dhan2 (5.67 t ha^{-1}), BRRI dhan29 (5.65). BRRI dhan67 and BRRI dhan55 were the low yielding varieties and the grain yield ranged from 3.49 to 3.60 t ha^{-1}.

TECHNOLOGY TRANSFER

Farmers training and seed distribution

Farmers' training is an important tool to train up farmers on updated information for rice cultivation. BRRI RS, Rajshahi arranged 12 training programmes at different upazilas of of Rajshahj Division. In total, 390 participants attended the training programme. Among them, 285 were male and 105 were female farmers. Most of the farmers were very much impressed by taking this rice production training.

Demonstration of BRRI released varieties

Field demonstrations were carried out at different locations of Rajshahi region during T. Aus, T. Aman and Boro seasons. A total of 55 demonstrations with latest developed BRRI varieties at Rajshahi region were conducted during the reporting period. The farmers of Rajshahi areas were very much interested about the newly released BRRI varieties.

Truthfully leveled and breeders seed production

Nucleus seed stock was collected from GRS Division of BRRI HQ. 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), 22 and 14 tons of breeder and TLS seed were produced respectively.

Advisory services

Any serious problem related to rice production at farmers' field was addressed duly in collaboration with the Department of Agricultural Extension (DAE), Bangladesh Agricultural Development Corporation (BADC), Barind Multipurpose Development Authority (BMDA), Seed Certification Agency (SCA) and different NGO's. Field visits were mainly to address different problems on insect and disease attack, seed sterility at flowering time etc.

BRRI RS, Rangpur

SUMMARY

To develop suitable modern rice varieties for Rangpur region, 8,564 progenies were advanced through field RGA nurseries in T. Aman and Boro seasons. A total of 180 plants were selected from observational yield trial (OYT). Eight advanced genotypes of BRRI dhan49 NILs were selected from preliminary yield trial (PYT). From secondary yield trial (SYT), ten genotypes of BRRI dhan49 NILs were also selected and two genotypes (BR8189-10-2-3-1-5 and BR10238-5-1) were selected for ALART in RLR ecosystem. BR9011-25-4-1-1 produced 0.8 t ha^{-1} yield advantage over BRRI dhan48 with similar growth duration in T. Aus season. BR8521-30-3-1 and BR8841-38-1-2-2 produced 0.91 and 0.85 t ha^{-1} yield advantage respectively over the check variety BRRI dhan39 in Aman season. IR84725-191-2-6-2-1-P2 and BR8143-4-3-3-6-2-4 produced about 1.6 t ha^{-1} higher yield over the check variety BRRI dhan39 in Aman season. BR8493-3-5-1 (Com) produced 2.4 t ha^{-1} higher yield over BRRI dhan34 with similar growth duration in Aman season. In IRR trial, BR9143-55-3-2-1 gave slightly higher yield than BRRI dhan49 with two weeks earlier in Aman season. In DRR trial, BR9636-8-6-10-2 and BR9140-8-1 produced 1.1 t ha^{-1} and 0.20 t ha^{-1} higher yield than the check variety, BRRI dhan49 in Aman season. In HYR-1 trial, BR(Bio)9777-116-12-2-2 produced high yield over the check variety BRRI dha39 with similar growth duration and BR(Bio)9786-BC2-161-1-2 yielded 0.76 t ha^{-1} higher over BRRI dhan71 with similar growth duration in Aman season. In FBR trial, KARJAT and BR9208-8-1-1-1 performed better than the check varieties BRRI dhan28 and BRRI dhan58. In ZER Boro, IR99285-1-1-1-P2 performed better than the check varieties, BRRI dhan74 and BRRI dhan84 but with higher growth duration. In PQR Boro, BR8862-29-1-5-1-3 produced about 1.6 t ha^{-1} and 1.1 t ha^{-1} higher yield than BRRI dhan50 and BRRI dhan63, respectively. In DRR Boro, BR(Bio)11447-1-28-14-3 produced about 0.6 t ha^{-1} and 2.0 t ha^{-1} higher yield than the check BRRI dhan28 and IRBB60 respectively. In DRR (blast) Boro, advanced line Path2442 produced more than 7.0 t ha^{-1} yield which was higher than all check varieties and having no neck blast disease. A total of 65 varietal demonstrations were conducted at different locations of Rangpur region during T. Aus 2018, T. Aman 2018 and Boro 2018-19. In T. Aus, BRRI dhan48; in T. Aman, BRRI dhan66, BRRI dhan71, BRRI dhan75 and BRRI dhan87; and in Boro, BRRI dhan74, BRRI dhan81, BRRI dhan89 and BRRI hybrid dhan5 were used. Farmers showed keen interest about those newly released varieties.

VARIETY DEVELOPMENT PROGRAMME (VDP)

Development of rice varieties suitable for T. Aman and Boro seasons in Rangpur region

Ten single crosses were made using twelve parents. Eight F_1s were grown for confirmation. In total, 14 F_2 populations and five F_3 generations were advanced through field RGA. A total of 8,564 individual plants were selected from field RGA (Tables 1 and 2). And 180 plants were selected from observational yield trial (OYT). Eight advanced genotypes of BRRI dhan49 NILs were selected from preliminary yield trial (PYT) (Table 3). Moreover, ten genotypes of BRRI dhan49 NILs were selected from secondary yield trial (SYT) for further evaluation (Table 4). Two genotypes (BR8189-10-2-3-1-5 and BR10238-5-1) were selected for ALART in RLR ecosystem.

BREEDING ZONE TRIAL (TRB)

This trial was conducted with 790 advanced breeding lines at BRRI RS, Rangpur during T. Aman 2018 season using partially replicated (P-rep) design. The tested entries were the first release of RGA derived population under TRB breeding concept. Among the tested breeding lines, IR107971-B-B RGA-B RGA-313 produced the highest yield of 7.90 t/ha followed by IR100707-B-B RGA-B RGA-B RGA-285 (7.88 t ha^{-1}), IR108000-B-B RGA-B RGA-163 (7.86 t ha^{-1}), IR107982-B-B RGA-B RGA-359 (7.85 t ha^{-1}), IR 108000-B-B RGA-B RGA-18-1 (7.84 t ha^{-1}), IR 103306-B-B RGA-B RGA-396 (7.82 t ha^{-1}) and IR 103314-B-B RGA-B RGA-171 (7.72 t ha^{-1}). These lines will be further evaluated.

Table 1. List of selected progenies from F_2 polpulations, T. Aman 2018-19.

BR No.	Designation	Selected progenies
BRrang6	BR9159-8-5-40-13-52/Swarna5	475
BRrang7	BR9159-8-5-40-13-52/Nania	451
BRrang8	BR9159-8-5-40-13-52/Gooty Swarna	522
BRrang9	BR9159-8-5-40-13-57/Swarna5	575
BRrang10	BR9159-8-5-40-13-57/Gooty Swarna	457
BRrang11	BRRI dhan52/ Lal Swarna	621
BRrang12	BRRI dhan52/ Gooty Swarna	532
BRrang13	Nania/Swarna5	475
BRrang14	Nania/Lal Swarna	351
BRrang15	Swarna5/Minikit	554
BRrang16	Sonamukhi/BRRI dhan52	658
BRrang17	Shompa katari/BR9159-8-5-40-13-52	587
BRrang18	BRRI dhan58/BR7812-19-6-1-P2	658
BRrang19	BRRI dhan63/BR7812-19-6-1-P2	598
Total		7514

Table 2. List of F_3 genetation, T. Aman 2018-19.

Item	Designation	P/S
BRrang1	Lal Gooty Swarna/Lambra	193
BRrang2	Lal Gooty Swarna/Akundi	285
BRrang3	Swarna5/Kalarata	230
BRrang4	Swarna5/FL478	192
BRrang5	Gooty Swarna/Jamaibabu	150
Total		1050

Table 3. List of selected materials (BRRI dhan49 NILs), PYT in T. Aman 2018-19.

Designation	MAT (day)	PHt (cm)	Yield (t ha^{-1})
BR10050-32-181-344-10-9	115	114	5.45
BR10050-27-2-3-7	115	109	5.71
BR10050-32-42-3	116	94	5.16
BR10050-32-172-224-11-21	115	100	5.0
BR100-50-32-172-224-12-26	113	104	5.06
BR10050-32-181-310-1-2	113	108	5.73
BR10050-7-1-1-1	116	110	5.35
BR10050-47-1-4-3	129	112	4.71
BRRI dhan49 (ck)	135	111	4.38
BRRI dhan75 (ck)	111	100	5.24
LSD (0.05)	5.9589	1.1803	0.982

Table 4. List of selected materials (BRRI dhan49 NILs), SYT, T. Aman 2018-19.

Designation	MAT (day)	PHt (cm)	Yield (t ha^{-1})
BR10050-32-172-224-12-26	114	105	5.51
BR10050-32-181-257-2-10	116	103	5.43
BR10050-10-1-4-5	115	110	5.91
BR10050-27-2-1-2	115	106	4.97
BR10050-48-3-7-11	116	109	5.23
BR10050-32-181-257-1-5	116	111	5.62
BR10050-32-181-257-2-8	125	110	4.95
BR10050-32-181-299-1-1	113	105	5.32
BR8470-1-2-4-2-Rang1-5	116	112	5.51
BRRI dhan49 (ck)	132	110	4.94
BRRI dhan75 (ck)	109	104	4.93
LSD (0.05)	0.8498	1.7259	0.8078

Regional yield trial (RYT), T. Aus 2018

Sixteen genotypes along with two standard checks; BRRI dhan48 and BRRI dhan28 were evaluated. BR9011-25-4-1-1 and BR9011-62-2-1-2 was found to be suitable against standard check variety BRRI dhan48. BR9011-25-4-1-1 produced 0.8 t ha^{-1} yields advantage over BRRI dhan48 with similar growth duration.

Regional yield trial (RYT), T. Aman 2018

Thirteen RYTs were conducted under T. Aman season: two rainfed lowland (RLR), three premium quality (PQR), three zinc enriched rice (ZER), one insect resistant rice (IRR), one disease resistant rice (DRR), one high yielding rice (HYR) from Plant Breeding Division, two HYR from Biotechnology Division under lowland (RLR) Biotechnology against standard check varieties.

RYT#1 (RLR-1). Five genotypes along with two checks; BRRI dhan39 and BRRI dhan49 were evaluated. One genotype BR8521-30-3-1 and BR8841-38-1-2-2 having 0.91 and 0.85 t ha^{-1} yield advantage respectively over the check variety BRRI dhan39.

RYT#2 (RLR-2). Seven genotypes along with standard check; BRRI dhan49 were evaluated. None of the tested genotypes were found high yielder over the check variety.

RYT#3 (ZER-1). Twelve genotypes along with two checks; BRRI dhan62 and BRRI dhan39 were evaluated. The highest yield was observed in genotypes IR84725-191-2-6-2-1-P2 followed by BR8143-4-3-3-6-2-4 over the check varieties.

RYT#4 (ZER-2). Eleven genotypes were tested along with three checks; BRRI dhan49, BRRI dhan72 and BRRI dhan39. None of the tested genotypes performed better over the check varieties.

RYT#5 (ZER-3). Three genotypes were tested along with two checks; BRRI dhan49 and BRRI dhan72. None of the tested entries were found better than the check varieties.

RYT#6 (PQR-1). Ten genotypes and four checks viz. BINA dhan13, BRRI dhan34, Kataribhog and Radhunipagol were evaluated. BR8493-3-5-1 (Com) and BR8528-2-2-3-HR2 performed better then the check varieties. BR8493-3-5-1 (Com) produced 2.4 t ha^{-1} high yield over BRRI dhan34 with similar growth duration.

RYT#7 (PQR-2). Four genotypes along with four standard checks; Krishnobhog, BRRI dhan34, BRRI dhan37 and Kalizira were evaluated. One genotype BR9051-1-1-2-3 produced higher yield over the check varieties.

RYT#8 (PQR-3). Non aromatic BR8526-2-1-4-HR3-HR2 (Com) produced higher yield followed by BR8526-1-4-HR3-HR3 (Com) over the check varieties (Kalizira and BRRI dhan37).

RYT#9 (IRR). Four genotypes were tested along with two checks; BRRI dhan33 (Resistant ck) and BRRI dhan49 (Susceptible ck). BR9143-55-3-2-1 performed better than BRRI dhan49 with two weeks earlier growth duration.

RYT#10 (DRR). Eleven genotypes were tested along with three checks BRRI dhan39, BRRI dhan49 and IRBB60 (Resistant ck). BR9636-8-6-10-2 produced the highest yield followed by BR9140-8-1 than BRRI dhan49. BR9140-8-1 gave 0.20 t ha^{-1} over BRRI dhan39 with four days earlier growth duration.

RYT#11 (HYR). None of the tested genotypes found high yielder over the check variety BRRI dhan49.

RYT#12 (HYR-1, Bio). Two genotypes were tested along with two checks; BRRI dhan39 and BRRI dhan49. BR (Bio) 9777-116-12-2-2 produced high yield over the check variety BRRI dha39 with similar growth duration.

RYT#13 (HYR-2, Bio). BR (Bio) 9786-BC2-161-1-2 yielded 0.76 t ha^{-1} advantages over the BRRI dhan71 with similar growth duration.

Regional yield trial (RYT), Boro 2018-19

A total of 11 RYTs were conducted during Boro season including four cold tolerant rice (CTR), two favourable Boro rice (FBR), one zinc enriched rice (ZER), one premium quality rice (PQR) and three disease resistant rice (DRR) against the standard check varieties.

RYT# 1-3 (CTR# 1, 2 and 3). Five genotypes along with two checks; BRRI dhan28 and BRRI dhan36 were evaluated. None of the tested entries performed better than the checks.

RYT#4 (CTR, Bio). One genotype was tested along with BRRI dhan28 and BRRI dhan36. BR (Bio) 9777-124-1-1-2 was not performed better than the check varieties.

RYT#5 (FBR, Bio). Three genotypes were tested against BRRI dhan58. None of the tested entries performed better than the check variety.

RYT#6 (FBR). Five genotypes were tested along with BRRI dhan58. KARJAT and BR9208-8-1-1-1 performed better than the check variety.

RYT#7 (ZER). Two genotypes were evaluated along with the checks; BRRI dhan29, BRRI dhan74 and BRRI dhan84. IR99285-1-1-1-P2 performed better than the check varieties.

RYT#8 (PQR). Two genotypes BR8862-29-1-5-1-3 and BR8995-2-5-5-5-2-1 were evaluated along with the checks; BRRI dhan50 and BRRI dhan63.

RYT#9 (DRR). Six genotypes were tested with the check varietis, BRRI dhan29, BRRI dhan58 and IRBB60. None of the tested entries performed better than the check variety.

RYT#10 (DRR, Bio). Five genotypes were evaluated against BRRI dhan28 and IRBB60. BR (Bio) 11447-1-28-14-3 performed better than the check variety.

RYT#11 (BLAST, Plant Path). Ten genotypes along with BRRI dhan28, BRRI dhan29 and BRRI dhan58 were evaluated. Path2442 performed better over the check varieties with no neck blast disease.

Proposed variety trial (PVT)

A total of five PVTs were conducted under T. Aman and Boro seasons. In T. Aman season, three PVT's were performed to develop rice varieties promising for premium quality, rainfed lowland rice and, zinc enriched rice as well as a short duration PVT for favourable Boro (Table 5).

Table 5. Yield and other parameters of proposed variety trial (PVT) at T. Aman 2018 and Boro 2018-19.

Tested entry	PHt (cm)	Days to flowering (50%)	Mat (day)	Yield (t ha^{-1})
T. Aman 2018				
PVT#1, PQR (Mondolpara, Rangpur)				
V_1= BR8535-2-1-2	106	92	115	4.64
V_2= BRRI dhan34 (ck)	135	113	138	4.12
DS:10 Jul, 2018, DT: 6 Aug, 2018				
PVT#2, RLR (Roshidpur, Mithapukur, Rangpur)				
V_1= BR-RS(Raj)-PL4-B	110	109	137	5.91
V_2= BR-RS(Rang)-PL1-B	104	108	137	5.76
V3=BR8210--10-3-1-2	115	96	125	4.98
V4=BRRI dhan49 (ck)	98	101	131	4.43
DS:10 Jul, 2018, DT: 1 Aug, 2018				
PVT#3, RLR (Chirirbondor, Dinajpur)				
V_1= BR-RS(Raj)-PL4-B	98	107	136	5.73
V_2= BR-RS(Rang)-PL1-B	97	105	136	5.46
V3=BR8210-10-3-1-2	110	95	124	4.75
V4=BRRI dhan49 (ck)	96	102	130	3.77
DS:10 Jul, 2018, DT: 5 Aug, 2018				
PVT#4, ZER (Roshidpur, Mithapukur, Rangpur)				
V_1= BR8492-9-5-3-2	109	93	121	5.38
V_2= BR7528-2R-HR16-2-24-1I	113	86	113	3.37
V3=BRRI dhan39 (ck)	122	95	122	4.26
DS:10 July, 2018, DT: 01 Aug, 2018				
Boro 2018-2019				
PVT#1, FBR (Dorshona, Rangpur)				
V_1= BR(Bio)9787-BC2-63-2-2	96	132	154	5.87
V_2= BRRI dhan28 (ck)	98	129	150	5.98
DS: 3 Dec, 2018, DT: 17 Jan, 2019				

Confined field trial (CFT) of golden rice in multi-environment, Boro 2018-19

One transgenic line IR112060 GR2-E:2-7-63-2-96 and one non-transgenic control as standard check variety BRRI dhan29 were evaluated with single seedling hill^{-1} at a spacing of 20 × 20 cm in RCB design with three replications. The tested transgenic line IR112060 GR2-E:2-7-63-2-96 produced little bit higher yield than the check variety BRRI dhan29.

CROP-SOIL-WATER MANAGEMENT

Effect of organic (Vermicompost and mustard oilcake) and inorganic fertilizer on premium quality fine rice (PQFR) at Rangpur region in T. Aman and Boro season

The experiment was conducted at BRRI RS, Rangpur during T. Aman and Boro seasons to find out the effect of varmicompost for the improvement of yield and quality of fine rice. The experiment was laid down in randomized complete block design (RCBD) with three replications. The treatment were as: T_1 = Control, T_2 = BRRI recommended fertilizer (T. Aman N=90, P=10, K= 33, S=6.5 and Zn = 2 kg ha^{-1}; Boro N=135, P=14, K= 50, S= 6.5 and Zn = 2 kg ha^{-1}), T_3 = Soil test based BARC 2012 fertilizer recommendation (T. Aman N= 96.75, P= 10.87, K = 27.17, S= 5.83 and Zn = 1.33 kg ha^{-1}; Boro N=140, P=10.87, K= 41, S= 5.83 and Zn = 1.78 kg ha^{-1}), T_4 = 1/2 T_2 + 1.0 t ha^{-1} vermi compost, T_5 = 1/2 T_3 + 1.0 t ha^{-1} vermicompost, T_6 = Only 1.0 t ha^{-1} vermicompost, T_7 = Only 2.0 t ha^{-1} vermicompost, T_8 = Only 3.0 t ha^{-1} varmicompost, T_9 = Only 4.0 t ha^{-1} varmicompost and T_{10} = T_2 + 75 kg mustard oil cake. Tested varieties were BRRI dhan70 in T. Aman and BRRI dhan50 in Boro season. The higher grain yield was obtained from T_3 and T_2 than $T_{10.}$ The highest yield of BRRI dhan50 (7.77 t ha^{-1}) obtained from applying BRRI recommended fertilizer dose and BRRI dhan70 yielded 5.34 t ha^{-1}, which was found by applying soil test based BARC 2012 fertilizer recommendation dose. Only the application of vermi compost is negatively correlated with grain yield.

SOCIO-ECONOMIC

Stability analysis of BRRI varieties at BRRI RS, Rangpur in T. Aman and Boro season during 2018-19

Sixty-three BRRI developed varieties were evaluated during T. Aman (42) and Boro (21) season at BRRI RS farm following RCBD with three replications. BRRI recommended management practices were followed. In T. Aman, the highest grain yield was observed in BRRI dhan33 (5.26 t ha^{-1}) followed by BRRI dhan71 (5.15 t ha^{-1}) from short duration group. Under medium growth duration group, BRRI dhan87 produced the highest yield of 7.15 t ha^{-1} followed by BRRI dhan73 (6.90 t ha^{-1}) and BRRI dhan72 (6.80 t ha^{-1}). BR11 produced the highest yield of 6.24 t ha^{-1} among long duration group followed by BRRI dhan54 (5.75 t ha^{-1}), BRRI dhan30 (5.65 t ha^{-1}), BR10 (5.60 t/ha) and BRRI dhan44 (5.2 t ha^{-1}). In Boro season, BRRI dhan88 produced the highest yield of 5.05 t ha^{-1} among short duration group followed by BRRI hybrid dhan2 (5.03 t ha^{-1}) and BRRI dhan74 (4.86 t ha^{-1}). Among long duration group BRRI dhan29 produced the highest yield.

TECHNOLOGY TRANSFER

Technology dissemination workshop

BRRI RS, Rangpur organized two workshops for T. Aman and T. Aus seasons in reporting period. The aim of the workshop was sustainable rice production in this region through adoption of BRRI developed technologies. Around 220 participants attended the workshops. Additional secretary of MoA, The DG, directors and senior scientists of BRRI, the DG and directors of DAE, AD, DD, UAO, RSCO, DSCO of Rangpur-Dinajpur region, scientists from NARS, BADC and BMDA personnel, different NGO extension personnel, farmers, electronic and print media personnel attended the workshop.

Promotional activities for the former enclave's farmer

BRRI RS, Rangpur conducted 13 varietal demonstration programmes for the dissemination of BRRI developed latest varieties in Dashiarchora, Fulbari, Kurigram (former enclave). Moreover, BRRI RS Rangpur also provided four farmers training on modern rice production technologies where 120 farmers participated. These programmes will be continued in future.

Demonstration (variety/technology)

A total of 94 demonstrations under different projects (GoB-66; GSR-15; TRB-5; SPIRA-7 and Entomology Division-1) were conducted in Rangpur-Dinajpur region during the reporting period.

RS Rangpur (GOB). A total of 66 varietal demonstrations were conducted at different locations of Rangpur-Dinajpur region. In T. Aus, BR26 and BRRI dhan48; in T. Aman, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan75, BRRI dhan80 and BRRI dhan87; and in Boro, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan86, BRRI dhan89 and BRRI hybrid dhan5 were used. Farmers were very much interested about these newly released BRRI varieties.

Green super rice (GSR). BRRI dhan69 were used under this programme. Fifteen demonstrations were conducted and farmers were very happy to cultivate BRRI dhan69 due to its high yield potential (Yield range: 6.8-7.7 t ha^{-1}).

TRB project. Five varietal demonstrations were conducted in five upazilas under four districts in Rangpur-Dinajpur region during Boro 2018-19. Six varieties viz BRRI dhan28, BRRI dhan67, BRRI dhan74, BRRI dhan81, BRRI dhan84 and BRRI dhan86 were used under this programme. BRRI dhan67, BRRI dhan74, BRRI dhan81 and BRRI dhan84 were choosen by the farmers in every location due to grain appearance, high yield and less infection of neck blast disease (Table 6).

SPIRA project. Seven demonstrations were conducted in seven locations during T. Aman and Boro season 2018-19. Eleven varieties viz BRRI dhan52, BRRI dhan58, BRRI dhan63, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan75, BRRI dhan80, BRRI dhan81, BRRI dhan87 and BRRI dhan89 were tested (Table 7 and 8). In T. Aman, BRRI dhan87 produced highest yield (7.40 t ha^{-1}) followed by BRRI dhan80 (7.00 t ha^{-1}). On the other hand, yield performance of BRRI dhan89 was the highest (8.03 t ha^{-1}) followed by BRRI dhan52 (7.76 t ha^{-1}) in Boro season.

Table 6. Grain yield of head to head trials under TRB project in Rangpur region, Boro 2018-19.

Location	Grain yield (t ha^{-1})					
	BRRI dhan28	BRRI dhan67	BRRI dhan74	BRRI dhan81	BRRI dhan84	BRRI dhan86
Kurigram sadar	7.38	6.5	7.4	7.7	7.7	6.8
Thakurgaon sadar	6.25	7.56	8.05	7.23	6.3	7.56
Birganj, Dinajpur	6.08	5.63	6.3	5.59	5.58	5.57
Boda, Panchagrah	5.81	6.44	7.5	6.67	6.46	6.99
Nawabganj, Dinajpur	5.25	5.65	6.18	5.37	5.98	5.08

Table 7. Grain yield of varietal demonstration under SPIRA project in Rangpur region, T. Aman 2018.

Location	Grain yield (t ha^{-1})						
	BRRI dhan52	BRRI dhan66	BRRI dhan70	BRRI dhan71	BRRI dhan75	BRRI dhan80	BRRI dhan87
Joldhaka, Nilphamari	-	5.19	-	4.68	4.56	-	6.80
Parbortipur, Dinajpur	-	-	6.4	-	-	7.00	7.40
Dorshona, Rangpur	5.80	-	-	-	-	-	-

Table 8. Grain yield of varietal demonstration under SPIRA project in Rangpur region, Boro, 2018-19.

Location	Grain yield (t ha^{-1})			
	BRRI dhan58	BRRI dhan63	BRRI dhan81	BRRI dhan89
Dorshona, Rangpur	7.76	-	-	7.28
Chirirbandar, Dinajpur	-	6.69	7.64	8.03
Sundarganj, Gaibandha	-	-	-	7.57
Fulbari, Kurigram	-	-	7.44	-

Strengthening of environment friendly insect pest research for increasing yield (Entomology project). During Boro season, a technology was demonstrated for insect pest management (BRRI management and farmers' practices) using BRRI dhan81. It was found that BRRI management (6.50 t ha^{-1}) performed better than the farmers' practices (6.10 t ha^{-1}).

Training, field day and fair. Twenty farmers' training programmes (GoB-17; SPIRA-03) on modern rice production technology were conducted at different upazilas of Rangpur-Dinajpur region in collaboration with DAE. A total of 620 farmers were trained through these programmes. Among the participants, 94 and 524 were female and male respectively. These training programmes were very much helpful to minimize knowledge gap on modern rice production technologies. A total of 12 in-house trainings were arranged at the BRRI RS to improve the capability in office management of office staff. Fifteen field day (GoB-12; SPIRA-03) were conducted at different demonstration sites in collaboration with DAE during this reporting period. A total of 1,500 farmers, local leaders and DAE personnel attended in those field day programmes. Moreover, BRRI RS, Rangpur also participated 'Krishi Projokti Mela' and 4th development fair held in Rangpur region.

Seeds and seedling distribution among the flood affected farmers

BRRI RS, Rangpur took special programme for the flood affected farmers. A total of 199 kg seeds and seedlings from 50 kg seeds of different photosensitive varieties viz. BR22, BRRI dhan34 and BRRI dhan46 were distributed among the flood affected farmers in Domar and Dimla of Nilphamari.

Seed production and dissemination in July 2018-June 2019

A total of 2,841 kg 10,191 kg TLS was produced in T. Aus season and Aman season, respectively. 3,825 kg breeder seed (BRRI dhan52 and BRRI dhan71) was produced in T. Aman and 5,530 kg TLS was produced in Boro season. Moreover, 3,760 kg breeder seed of BRRI dhan81 was produced and sent to GRS Division, BRRI HQ. In T. Aus and T. Aman seasons, 1684 kg TLS was distributed among the farmers for dissemination in Rangpur-Dinajpur region. Table 9 presents the data related to variety wise production and distribution.

Table 9. Variety wise seed production and distribution during T. Aus 2018, T. Aman, 2018 and Boro 2018-19, BRRI RS, Rangpur.

Variety	Amount (kg)		Sold (TLS- kg)	Send to GRSD (Breeder-kg)	Distribution of TLS (kg)
	TLS	Breeder seed			
		T. Aus 2018			
BR24	55	-	2	-	-
BR26	245	-	27	-	12
BRRI dhan48	1898	-	1756	-	142
BRRI dhan65	136	-	12	-	-
BRRI dhan82	445	-	358	-	6
BRRI dhan83	62	-	42	-	20
Total	2,841	-	2,197	-	180
		T. Aman 2018			
BR22	236	-	46	-	42
BRRI dhan34	1027	-	893	-	115
BRRI dhan46	200	-	-	-	42
BRRI dhan49	630	-	267	-	10
BRRI dhan52	1992	2,775	1525	2,775	5

Continued Table 9.

Variety	Amount (kg)		Sold (TLS- kg)	Send to GRSD (Breeder-kg)	Distribution of TLS (kg)
	TLS	Breeder seed			
BRRI dhan66	230	-	214	-	5
BRRI dhan70	298	-	222	-	55
BRRI dhan71	824	1,050	725	1,050	99
BRRI dhan72	216	-	193	-	5
BRRI dhan75	898	-	645	-	253
BRRI dhan80	610	-	263	-	236
BRRI dhan87	3030	-	2,387	-	637
Total	10,191	3,825	7,380	3,825	1,504
		Boro, 2018-19			
BR16	280	-	-	-	-
BRRI dhan50	400	-	-	-	-
BRRI dhan58	560	-	-	-	-
BRRI dhan63	610	-	-	-	-
BRRI dhan74	370	-	-	-	-
BRRI dhan81	-	3,760	-	3,760	-
BRRI dhan84	300	-	-	-	-
BRRI dhan86	640	-	-	-	-
BRRI dhan88	900	-	-	-	-
BRRI dhan89	1470	-	-	-	-
Total	5,530	3,760	-	3,760	-
Grand total	18,562	7,585	9,577	7,585	1,684

BRRI RS, Satkhira

SUMMARY

A total of 188 progenies were selected from 42 crossing populations from F_3 to F_5 during T. Aman 2018. In rapid generation advance (RGA), 857 and 120 panicles were collected from $14F_3$, and $3F_5$ populations respectively. In LST, 1,750 entries were collected from 27 crossing populations during Boro 2018-19. Under breeding zone trial, 432 lines were tested under advanced yield trial (AYT) and observational yield trial (OYT), where 10 to 15 promising lines were selected.

In T. Aman 2018, IR15T1376 and TP30649 line performed better over check varieties under preliminary yield trial (PYT) whereas IR92831-22-BAY3-1-1-3-AJY1 showed yield advantage in secondary yield trial (SYT). BR10187-1-5-11, TP30649, IR15T1375 and TP10275 line had higher yield tested in PYT while BR9620-2-7-1-1 line was good yielder in AYT during Boro 2018-19.

Green super rice (GSR) trial in Boro 2018-19, tested line of 7FBR-404, 7FBR-340 and 7FBR-102 yielded higher in OYT. In PYT, 7FBR-222' line showed better performance where some breeding lines had yield advantage tested in SYT and AYT.

Regional yield trial (RYT) was conducted at BRRI RS farm, Satkhira during T. Aman 2018 with respective check variety(ies). Higher yield was found from BR8841-38-1-2-2 and BR8521-30-3-1 entries in RYT for RLR. Tested entries of BR8887-26-8-2-3, BR8528-2-2-3-HR2, BR8526-38-2-1-HR2 and BR8526-2-1-4-HR3-HR2(Com) gave higher yield in RYT for PQR. Most of the tested entries showed better performance in RYT for ZER. BR9140-8-25-6-3, BR8545-5-5-2-7-2 and BR9140-15-20-6-4 produced higher yield in RYT for DR. In Boro 2018-19, BR8862-8-3-4-4-1 and BR8995-2-5-5-2-1 yielded better in RYT for PQR as well as BR(Bio)9777-124-1-1-2 and some lines showed promising in RYT for CTR and RYT for BRR, respectively.

BR8727-B-2-1-1, BR8729-B-7-3-2, BRRI dhan54 and BRRI dhan73 ranked 1st positive at Koyra, Debhata, Kaliganj and Assasuni, respectively tested in participatory variety selection (PVS) during T. Aman 2018. Farmers choosed genotypes of IR103499-B-2-AJY1, IR104002-CMU 28-CMU1-CMU3 and BR9625-B-1-4-6 in PVS tested under high salinity environment at Koyra, Debhata, Kaliganj and Assasuni during Boro 2018-19.

In proposed variety trial (PVT), BR8535-2-1-2 yielded more than 45% higher over BRRI dhan34 (3.49 t ha^{-1}) and this line has already been released as a new variety BRRI dhan90 for T. Aman season. Tested three entries of HHZ5-DT20-DT2-DT1, HHZ12-SAL2-Y3-Y2 and IR83484-3-B-7-1-1-1 performed better in all tested locations even under high salinity level, where check varieties were completely damaged during Boro 2018-19.

The yield performance of golden rice (6.6 t ha^{-1}) was significantly lower than BRRI dhan29 (7.3 t ha^{-1}) with similar growth duration (144-145 days) under a confined trial conducted at BRRI farm during Boro 2018-19.

Balanced fertilizer application is the means to harvest maximum yield where N is the most critical nutrient element as well as K and P is the second most critical nutrient. About 25% higher N dose (155 kg ha^{-1}) could increase the yield level in saline environment.

BRRI dhan27 and BRRI dhan83 among the Aus varieties; BRRI dhan49, BRRI dhan87, BR10, BRRI dhan33, BRRI hybrid dhan6, BRRI dhan71, BRRI dhan75 and BRRI dhan52 among T. Aman varieties; BRRI hybrid dhan2, 3, 5 among Boro varieties appeared a good yielder in stability analysis at the BRRI RS farm. Hybrid rice IT showed more tolerance against salinity tested at Faridpur, Kaliganj, Satkhira. BRRI dhan73 and BRRI dhan67 performed better especially in saline affected areas in T. Aman and Boro season respectively.

Overall 101 demonstrations (Aus, Aman and Boro) were conducted during 2018-19 under SPDP programme. Twelve farmers training (390 farmers) and 14 field days were arranged and we attended two agricultural fairs in this year as well participated in different respective and technical activities.

A total of 28.397 ton breeder seeds of BRRI rice varieties were produced and sent to GRS Division. Moreover, 24.039 ton truthfully level seed of BRRI rice varieties were produced, stored as well as sold and distributed to the farmers, NGOs and DAE.

Result of climate resilient farming systems research and development activities under PBRG, NATP-2 project conducted at Bishnupur union, Kaliganj, Satkhira showed that Mustard-BRRI dhan81/86-BRRI dhan75 increased the total

productivity as much as of 40% higher rice equivalent yield over the existing Fallow-BRRI dhan28-BRRI dhan49 cropping pattern (10.42 t ha^{-1}). Homestead areas become more productive with adopting vegetable production round the year. Inclusion of vegetable production on *gher* bund increased the productivity at significant level. Sonali chicken and Turkey rearing under scavenging system is adopted quickly by the farm families and it contributes to increase farm income as well as family consumption of egg and meat also. Average gross margin of 147,588 Tk ha^{-1} was found in the fish poly-culture of saline gher system.

VARIETAL DEVELOPMENT

Selection from pedigree nursery (F_3-F_5)

A total of 87 progenies were selected from $12F_3$ populations tested at Raghurampur, Kaliganj, Satkhira during T. Aman 2018. Similarly, 101 progenies were selected from $12F_4$ populations and 86 lines were bulked from F_5 populations at Tuardanga, Assasuni, Satkhira.

Rapid generation advance (RGA)

A total of 46,599 panicles were collected from $16F_2$, $4F_4$ and $7F_5$ generations in 27 crossing populations during T. Aman 2018. And 977 panicles were composed from $14F_3$ and $3F_5$ populations in 17 crossing progenies during Boro season 2018-19.

Line stage trial (LST)

A total of 1,750 entries were collected from 27 crossing populations where 92, 357 and 1301 entries were collected from 1,040, 3,062 and 5,086 progenies respectively during Boro 2018-19 tested at BRRI farm, Satkhira.

Observational trial (OT)

In T. Aman 2018, a total of 31 and 25 entries were selected from 78 entries at Asssasuni and at Koyra site, respectively. In Boro season, all entries were damaged due to high level of salinity at Assasuni site, while, 12 and 18 entries from 67 and 88 tested progenies were selected at Koyra site respectively. Figure 1 presents water salinity of the experimental plots.

Preliminary yield trial (PYT)

PYT-1. In T. Aman 2018, BR100045-15-23-5 and BR9747-13-2-8 performed better followed by BR9747-5-3-11, BR10061-B-1-2-1 among 18 lines against BRRI dhan54 and BRRI dhan73 tested at Assasuni, Debhata, Kaliganj, Koyra and BRRI RS farm. Figure 1 presents water salinity of the experimental plots.

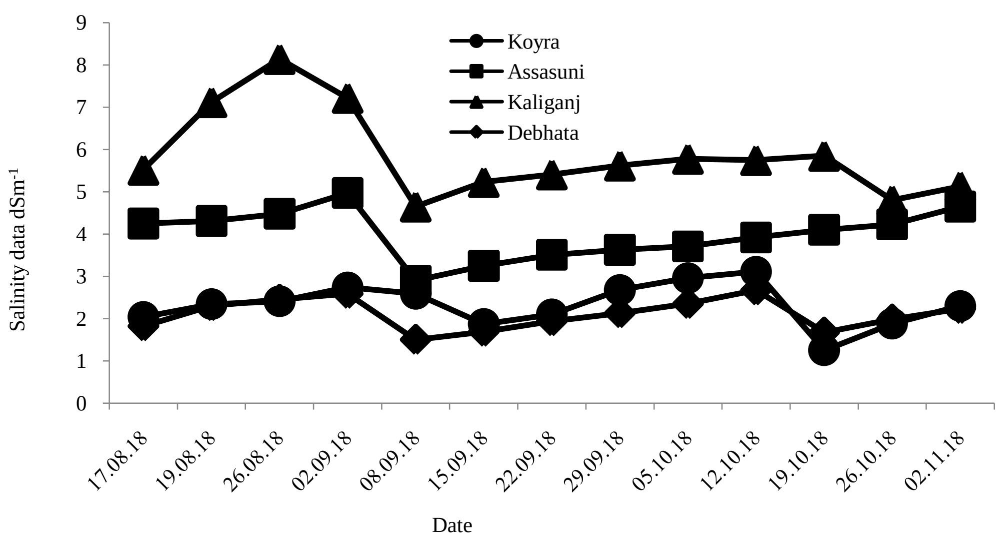

Fig. 1. Water salinity of PYT-1 experimental plot at Koyra (Khulna), Kaliganj, Assasuni and Debhata (Satkhira) during T. Aman 2018.

In Boro 2018-19, BR10187-1-4-12, BR9911-4-2-4, BR9901-1-3-10, BR10182-5-4-2, BR9915-1-2-4 and BR9903-3-2-6 yielded higher among the tested 26 entries than the check varieties of BRRI dhan28, BRRI dhan67 and Bina dhan-10 at Koyra site. None of the entries performed better than Bina dhan-10 at Debhata site, where BR10187-1-5-11, BR9904-1-3-3, BR9899-5-2-15 and BR9918-10-4-5 produced higher yield than BRRI dhan67. Figure 2 presents water salinity of the experimental plots.

PYT-2. Among the 17 entries, IR15T1469 and IR15T1305 produced higher yield over the check varieties (BR11, BR23, BRRI dhan54 and BRRI dhan73) tested at Debhata, Assasuni and Kaliganj sites during T. Aman 2018 while BRRI dhan73 performed better under saline condition.

Among the tested 27 lines, no entries performed better than Bina dhan-10 conducted at Debhata and BRRI RS farm, but TP30649 (6.38 t ha^{-1}) and TP24493 (5.46 t ha^{-1}) produced higher yield than BRRI dhan67, respectively during Boro 2018-19.

PYT-3. In T. Aman 2018, IR108158-B-2-AJY1-1 produced higher yield (6.01 t ha^{-1}) among the 18 lines against BRRI dhan54, BRRI dhan73, BR11 and BR23 at Debhata. Similarly, IR15T1376 produced better yield than those of check varieties except BRRI dhan73 at Assasuni and at BRRI RS farm where IR15T1464 produced higher yield at Koyra site.

Higher grain yield was observed in IR15T1375 (6.64 t ha^{-1}) among 27 entries over BRRI dhan67 and Bina dhan-10 tested at Koyra during Boro 2018-19. No entries performed better than BRRI dhan67 and Bina dhan-10 at Debhata site. Tested entries of IR15T1375, IR15T1469 and IR15T1448 yielded higher than the check varieties at BRRI RS farm.

PYT-4. Tested entry of TP30649 produced significantly higher yield against BRRI dhan54 though it showed similar yield with BRRI dhan73 at Debhata site during T. Aman 2018. However, TP30651 produced higher yield (6.36 t ha^{-1}) at significant level compared to check varieties at BRRI RS farm.

In Boro 2018-19, TP10275 and TP30717 yielded more than all the check varieties at BRRI RS farm, while at Debhata, no entries performed better than BRRI dhan67 and Bina dhan-10.

Regional yield trial (RYT) in T. Aman 2018

Thirteen RYTs including three high yielding rice (HYR), two rainfed lowland (RLR) rice, three premium quality rice (PQR), three zinc enriched rice (ZER), one disease resistant (DR) and one insect resistant (IR) rice were conducted at BRRI farm, Satkhira during T. Aman 2018 (Table 1).

None of the entries produced statistically higher yield compared to the check varieties in HYR. In RLR, BR8841-38-1-2-2 and BR8521-30-3-1 entries yielded higher compared to BRRI dhan39 and BRRI dhan49. In RYT-1 for PQR, BR8887-26-8-2-3 and BR8528-2-2-3-HR2 showed better yield over the check varieties, while in RYT-2, most of the tested entries produced higher yield than the check varieties. In RYT-3 for PQR, BR8526-38-2-1-HR2 and BR8526-2-1-4-HR3-HR2(Com) entries showed higher yield than check varieties. In ZER, most of the tested entries showed higher yield over BRRI dhan39 and BRRI dhan62. In DR, BR9140-8-25-6-3, BR8545-5-5-2-7-2 and BR9140-15-20-6-4 produced higher yield over BRRI dhan49.

Regional yield trial (RYT) in Boro 2018-19

Nine RYTs comprises of two for high yielding favourable Boro rice (FBR), one for cold tolerant rice (CTR), one for premium quality Rice (PQR), one for zinc enriched rice (ZER), one for bacterial blight resistant (BB resistant-Bio), two for disease resistant (DR) and one for *haor* short duration rice were conducted in BRRI RS farm, Satkhira and at Dumuria, Khulna during Boro 2018-19. Some replication(s) could not be harvested due to severe salinity damage in all of the experiment. Table 2 presents only the mean data.

None of the entries showed better yield performance in FBR, *haor* short duration rice, ZER, DR, FBR-Bio and BB-Bio compared to the check varieties. However, in PQR, BR8862-8-3-4-4-1 and BR8995-2-5-5-2-1 yielded better than both the check varieties. In case of CTR, BR(Bio)9777-124-1-1-2 yielded similar to BRRI dhan28 but higher than BRRI dhan36. In case of blast resistant rice, five lines yielded higher than BRRI dhan58 among the tested ten lines.

Advanced yield trial (AYT)

In Boro 2018-19, no entries yielded higher than BRRI dhan67 and Binadhan-10 at Debhata site,

Table 1. Performance of different entries under RYT during T. Aman 2018, BRRI RS, Satkhira.

Entry/Variety	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
RYT-1 for HYR (Bio)			
BR(Bio)9777-116-12-2-2	120	107	4.50
BR(Bio)9777-123-4-6-1	121	118	4.93
BRRI dhan49 (ck)	133	109	5.20
BRRI dhan39 (ck)	119	116	4.61
$LSD_{0.05}$	1.15	3.14	0.59
RYT-2 for HYR (Bio)			
BR(Bio)9786-BC2-80-1-1	119	119	5.74
BR(Bio)9786-BC2-65-1-1	115	119	5.95
BR(Bio)9786-BC2-161-1-2	118	111	5.88
BRRI dhan71 (ck)	116	118	5.53
$LSD_{0.05}$	1.37	5.79	0.63
RYT-3 for HYR			
BR9396-2-6-2B	130	136	4.46
BR9892-6-2-2B	126	119	4.47
BR9892-4-5-7-2	121	120	4.35
BR9392-3-5-8-2	129	116	5.32
BRH11-4-3-2-7	113	103	4.16
BR10247-14-18-4	123	121	4.73
BRRI dhan49 (ck)	130	102	5.02
$LSD_{0.05}$	0.98	5.54	0.43
RYT-1 for RLR			
BR8521-30-3-1	127	126	6.08
BR8841-38-1-2-2	128	122	6.22
IR11L433	118	116	4.26
IR13F352	126	117	5.97
IR13F402	127	115	4.93
BRRI dhan39 (ck)	118	114	4.73
BRRI dhan49 (ck)	132	108	5.53
$LSD_{0.05}$	1.24	6.25	0.36
RYT-2 for RLR			
BR8526-25-4-2-2-1-HR1	131	99	5.67
BR8526-38-3-2-1-HR2	132	109	5.28
Habudhan	120	103	4.27
Latabalam	122	122	4.95
BR8526-L8	130	113	5.34
HPB(PQR-TLA3) Red Rice	129	115	4.98
BRRI dhan49 (ck)	130	105	5.42
$LSD_{0.05}$	0.94	3.57	0.45
RYT-1 for PQR			
BR9126-15-3-4-1	*	*	*
BR9126-15-3-4-2	*	*	*
BR9130-78-1-1-4	134	122	3.89
BR8887-26-8-2-3	125	133	4.96
BR9178-7-2-4-4	134	140	3.28
BR9580-30-2-1-1	135	143	3.21
BR8493-3-5-1(com)	124	125	4.06
BR8528-2-2-3-HR1	122	128	4.09
BR8528-2-2-3-HR2	117	123	4.27
Binadhan-13 (ck)	137	142	2.54

Table 1. Continued.

Entry/Variety	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
Kalizira (ck)	132	154	3.23
BRRI dhan34 (ck)	129	134	3.58
Kataribhog (ck)	134	151	3.27
Radhunipagol (ck)	136	143	2.89
$LSD_{0.05}$	0.93	4.39	0.26
	RYT-2 for PQR		
BR9051-1-1-2-3	131	139	4.95
BR9054-6-1-2-3	128	115	4.85
BR8882-30-2-5-2	133	130	4.59
BR8536-4-1-1-3	125	116	4.22
Chinagura (ck)	131	155	3.16
Krishnabhog (ck)	133	154	1.98
BRRI dhan34 (ck)	130	134	3.64
BRRI dhan37 (ck)	133	136	3.28
Kalizira (ck)	133	142	2.13
$LSD_{0.05}$	1.18	5.94	0.28
	RYT-3 for PQR		
BR8526-2-1-4-HR3-HR2 (Com)	129	120	4.15
BR8526-2-1-4-HR3-HR3 (Com)	131	114	4.01
BR8526-38-2-1-HR1	130	113	3.76
BR8526-38-2-1-HR2	129	110	4.44
BR8850-10-12-4-5	134	121	4.03
BR8850-10-12-4-2	133	125	3.62
BR8850-10-12-4-4	129	123	3.95
BR8850-10-12-4-1	129	121	3.47
Kalizira (ck)	131	171	2.87
BRRI dhan37 (ck)	133	165	3.76
$LSD_{0.05}$	1.62	4.04	0.32
	RYT-1 for ZER		
BR8427-2-3-2-P1-2	112	127	4.95
BR8436-21-3-3-3-1	112	120	5.12
BR8436-7-4-2-3-1	113	110	5.09
BR8444-37-2-3-1-1-B3	114	132	4.90
IR99269-33-1-3	113	118	5.08
IR99269-33-4-1	112	120	5.25
BR8143-4-3-3-6-2-4	117	99	5.37
BR8442-9-5-8-1-1	130	118	5.11
IR84725-191-2-6-2-1-P2	124	103	5.15
IR99641-115-2-3	117	119	5.29
BRRI dhan62 (ck)	105	100	4.47
BRRI dhan39 (ck)	120	114	4.44
$LSD_{0.05}$	0.88	6.09	0.45
	RYT-2 for ZER		
BR8442-12-1-3-1-B1	124	132	5.74
BR8436-21-3-1-1-1	*	*	*
IR90210-100-2-3-1-P4	117	123	5.50
BR8444-47-1-1-1	123	124	5.39
IR101760-48-1	120	107	4.18
BR7528-2R-HR16-9-1-P1-2	114	125	4.26
BR8442-12-1-3-1-B7	128	118	6.06
BR7528-2R-19-16-RIL-20	134	141	5.43

Table 1. Continued.

Entry/Variety	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR7528-2R-19-16-RIL-21	135	140	5.51
BR7528-2R-19-16-RIL-22	136	143	5.65
BR7528-2R-19-16-RIL-23	123	108	4.89
BR7528-2R-19-16-RIL-24	128	103	5.50
BRRI dhan72 (ck)	124	118	5.88
BRRI dhan39 (ck)	119	107	4.85
$LSD_{0.05}$	1.22	4.00	0.73
	RYT-3 for ZER		
BR9673-B-20-1-2	123	134	5.91
BR7528-2R-19-HR16-9-3-P7-2-2	*	*	*
IR97641-35-2-2-8-P2	122	131	5.75
BRRI dhan49 (ck)	132	101	5.25
BRRI dhan72 (ck)	126	120	5.73
$LSD_{0.05}$	1.59	6.79	0.31
	RYT for IRR		
BR9143-9-3-3-1	129	109	5.03
BR9141-8-2-2-1	131	127	4.85
BR9142-32-2-2-3	105	98	4.80
BR9143-55-3-2-1	130	132	4.88
BRRI dhan33 (ck)	116	115	4.25
BRRI dhan49 (ck)	130	100	5.14
$LSD_{0.05}$	0.63	5.64	0.85
	RYT for DR		
BR9140-5-22-5-1	120	128	5.50
BR9140-8-25-6-3	121	117	5.85
BR10390-35-7-1	122	112	4.39
BR9140-8-1	121	97	4.47
BR9140-15-20-6-4	120	117	5.61
BR8548-8-22-5-15	118	118	5.02
BR9138-8-10-5-3	124	122	5.08
BR8545-5-5-2-7-2	122	138	5.75
BR10392-B-B-12	129	113	5.51
BR9636-8-6-10-2	123	121	5.47
BR10390-16-2-1	121	101	4.47
BRRI dhan39 (ck)	118	119	4.64
BRRI dhan49 (ck)	128	110	4.99
IRBB60 (ck)	116	84	3.84
$LSD_{0.05}$	1.12	6.27	0.54

***** = Germination failed.

while at Koyra site, BR9620-2-4-1-5 produced higher yield than all the check varieties (Table 3). However, IR 100638-6-CMU3-CMU1, BR9620-2-7-1-1 and IR 96184-24-1-1-AJY2 yielded more than all the check varieties at the BRRI RS farm.

Participatory variety selection (PVS)

A total of 12 entries were evaluated in PVS trial comparing with four checks at five sites during T. Aman 2018 (Table 4). BRRI dhan54 (ck) ranked 1^{st} positive at BRRI RS farm and at Kaliganj site. Similarly BRRI dhan73 (ck) ranked 1^{st} positive at Assasuni site. BR8727-B-2-1-1 and BR8729-B-7-3-2 ranked 1^{st} positive at Koyra and Debhata site respectively.

A PVS trial was conducted with 12 entries comparing with three checks during Boro 2018-19. IR103499-B-2-AJY1 has chosen as 1^{st} and 2^{nd} positive at two and at one site, respectively. BR9625-B-1-4-6 ranked 1^{st} and 2^{nd} positive at two tested sites where IR104002-CMU 28-CMU1-CMU3 has chosen as 2^{nd} positive at one site (Table 5).

Table 2. Performance of different entries under RYT in Boro 2018-19, BRRI RS, Satkhira.

Entry/Variety	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
	RYT for FBR		
BR8904-28-1-2-2-2	90	144	3.60
KARJAT-5	99	150	4.32
BR9675-68-5-1	101	145	4.79
BR9208-8-1-1-1	100	143	4.41
Bikalpa28-DF(Early)	97	140	5.57
BRRI dhan58 (ck)	97	147	5.72
	RYT for SDR		
BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR1(Gaz)-P4(Hbj)	88	131	5.07
BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR1(Gaz)-P8(Hbj)	88	131	5.03
BRRI dhan29-SC3-28-16-10-6-HR6(Com)-HR2(Gaz)-P11(Hbj)	83	131	5.61
BRRI dhan28 (ck)	96	137	5.63
	RYT for ZER		
IR99285-1-1-1-P1	102	147	5.89
IR99285-1-1-1-P2	100	148	6.06
BRRI dhan29 (ck)	97	148	6.33
BRRI dhan74 (ck)	97	141	5.74
BRRI dhan84 (ck)	99	138	5.30
	RYT for PQR		
BR8862-29-1-5-1-3	99	148	5.45
BR8862-8-3-4-4-1	114	148	6.40
BR8995-2-5-5-2-1	112	150	6.14
BR9205-10-1-5-3	104	150	4.55
BRRI dhan50 (ck)	86	145	5.40
BRRI dhan63 (ck)	86	140	6.19
	RYT for DR		
BR9650-99-3-2	95	147	4.85
BR9651-15-2-1-3	81	145	5.31
BR9943-40-3-2	89	150	5.19
BR9651-15-2-1-4	87	145	5.41
BR9651-15-2-1-5	84	142	4.61
BR9651-15-4-3-2	96	145	5.93
BRRI dhan29 (ck)	98	149	6.69
BRRI dhan58 (ck)	100	145	6.02
IRBB60 (Res. ck)	90	145	3.93
	RYT for CTR (Bio)		
BR(Bio)9777-124-1-1-2	96.	139	5.58
BRRI dhan28 (ck)	92	137	5.79
BRRI dhan36 (ck)	87	137	4.09
	RYT for FBR (Bio)		
BR(Bio)9777-116-12-2-4	101	145	5.41
BR(Bio)9777-116-12-2-5	110	144	5.28
BR(Bio)9787-BC2-35-4-2	96	146	5.44

Table 2. Continued.

Entry/Variety	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRRI dhan58 (ck)	99	148	5.39
	RYT for BB (Bio)		
BR(Bio)11447-1-28-4-6	86	142	4.47
BR(Bio)11447-1-28-12-3	84	140	4.55
BR(Bio)11447-1-28-14-1	*	*	*
BR(Bio)11447-1-28-14-3	*	*	*
BR(Bio)11447-3-10-7-1	83	143	3.26
BRRI dhan28 (Std. ck)	87	138	5.75
IRBB60 (Res. ck)	82	143	4.36
	RYT for blast resistance		
HR (path)-2	86	154	5.08
HR (path)-10	82	150	5.07
HR (path)-11	146	152	5.06
Path2440	107	149	5.21
Path2441	105	150	4.97
Path2442	108	152	4.53
Path2443	99	152	4.68
Path2444	86	144	3.11
BR(Path)12452-BC3-16-19	99	143	5.11
BR(Path)12452-BC3-8-13	99	146	1.71
BRRI dhan28 (Sus. ck)	94	141	5.16
BRRI dhan29 (Sus. ck)	92	153	5.28
BRRI dhan58 (Sus. ck)	86	145	4.27

***** = Damaged by salinity.

Table 3. Grain yield of AYT entries at Koyra, Debhata and BRRI RS farm in Boro 2018-19.

Entry/Variety	Yield (t ha^{-1})		
	Koyra	Debhata	BRRI farm
BR9620-2-7-1-1	5.74	5.63	7.45
BR9620-2-4-1-5	6.88	5.32	5.68
BR9621-B-1-2-11	3.99	5.29	4.00
BR9621-4-3-2-30	*	*	*
BR9625-4-1-2-8	6.19	5.56	6.97
BR9625-B-2-4-9	5.68	3.81	6.87
BR9625-3-1-12	4.40	4.50	5.94
BR9626-1-2-12	5.62	5.20	6.58
IR 100638-6-CMU 3-CMU 1	5.65	4.02	7.54
IR 96184-24-1-1-AJY2	5.02	4.83	7.29
IR 106466-30-CMU 3	5.14	4.12	6.69
IR 103499-B-87-AJY 3	4.11	3.80	6.56
BRRI dhan28 (ck)	4.42	5.20	5.85
BRRI dhan67 (Res. ck)	5.98	6.04	6.34
Binadhan-10 (Res. ck)	6.53	6.13	6.75
CV (%)	5.78	3.46	4.51
$LSD_{0.05}$	0.31	0.17	0.29

* = Germination failed.

Table 4. Grain yield of PVS tested at Assasuni, Debhata, Kaliganj, Koyra and BRRI RS farm in T. Aman 2018.

Entry/Variety	Grain yield (t ha^{-1})				
	Assasuni	Dabhata	Kaliganj	Koyra	BRRI farm
BR8729-B-7-3-2	4.3 (2$^{nd +}$)	4.70 (1$^{st +}$)	3.22 (2$^{nd +}$)	4.52	5.56
BR9538-3-1-2	4.51	4.24	3.60 (1$^{st -}$)	4.39	5.14
BR9072-B-4-1-1	5.67	3.32	3.65	4.37	6.81
BR9072-B-4-1-3	5.83	4.40	3.58	4.23	7.00
BR8727-B-2-1-1	3.77	4.38	1.91	4.61 (1$^{st +}$)	5.53
BR9536-B-10-1-26	4.46	3.80	3.46	4.25 (1$^{st -}$)	4.43 (1$^{st -}$)
IR84095-AJY-301-SDO4-B	5.11(1$^{st -}$)	3.98	**	4.39	5.43
IR78761-B-SATB1-52-1	3.60	4.45	2.30 (2$^{nd -}$)	3.80	5.13 (2$^{nd +}$)
IR10T116	3.80	3.35	2.15	4.45 (2$^{nd -}$)	4.45
IR83484-3-B-7-1-1-1	2.16	4.36		3.20	5.74
BR8727-B-2-1-1	*	*	*	*	*
BR8743-B-1-2-2	3.55	4.24	**	4.25	5.23
BRRI dhan73 (ck)	5.69 (1$^{st +}$)	4.03	4.48	5.25	5.92
BRRI dhan54 (ck)	4.36	4.56 (2$^{nd +}$)	4.45 (1$^{st +}$)	4.28	5.72 (1$^{st +}$)
BR11 (Sus. ck)	5.34	4.76 (2$^{nd -}$)	**	4.61	5.60
BR23 (ck)	5.18	4.18 (1$^{st -}$)	**	4.05 (2$^{nd +}$)	5.41 (2$^{nd -}$)
CV (%)	8.86	10.56	9.54	8.98	5.39
$LSD_{0.05}$	0.86	0.94	0.70	0.83	0.64

* = Germination failed, **= Damaged due to high salinity, Level of choice represent in parenthesis.

Table 5. Yield performance of PVS tested at Koyra, Debhata and BRRI RS farm, Satkhira during Boro 2018-19.

Designation	Yield (t ha^{-1})		
	Koyra	Debhata	BRRI farm
BR9154-2-7-1-2	4.48 (1$^{st -}$)	4.59	3.81 (1$^{st -}$)
BR9156-4-1-7-9	5.55	5.08	5.12
IR92860-33-CMU1-1-CMU2-AJYB	4.70	4.24 (2$^{nd -}$)	6.44
BR9620-4-3-2-2	4.76	4.55	6.46
BR9621-B-2-3-22	6.52	4.93	6.65
BR9625-B-1-4-6	4.44	3.97 (2$^{nd +}$)	7.16 (1$^{st +}$)
BR9626-B-2-3-15	4.93	4.37	5.64
BR9627-1-3-1-10	5.37	4.34	7.1
IR 103512-B-AJY 2-2	4.60 (2$^{nd -}$)	3.46 (1$^{st -}$)	5.38
IR 104002-CMU 28-CMU 1-CMU 3	3.65 (2$^{nd +}$)	3.62	5.59 (2$^{nd -}$)
IR 103854-8-3-AJY 1	3.47	3.96	7.14 (2$^{nd +}$)
IR 103499-B-2-AJY 1	4.64 (1$^{st +}$)	4.15 (1$^{st +}$)	6.94
BRRI dhan28 (ck)	4.76	4.11	5.09
BRRI dhan67 (ck)	6.02	4.96	5.97
Binadhan-10 (ck)	5.94	5.19	6.47
CV (%)	10.99	3.49	3.48
$LSD_{0.05}$	0.54	0.15	0.21

Level of choice represents in parenthesis.

Proposed variety trial (PVT) in T. Aman 2018

Five PVTs were conducted at farmer's field for variety selection (Table 6). BR-RS(Raj)-PL4-B (6.29 t ha^{-1}) and BR-SF(Rang)-PL1-B (6.23 t ha^{-1}) yielded higher than BRRI dhan49 (5.85 t ha^{-1}) in RLR-PVT at Jamjami, Monirampur, Jashore. Similarly, BR8535-2-1-2 yielded higher (5.56 t ha^{-1}) than BRRI dhan34 (3.86 t ha^{-1}) with 15 days growth duration advantage in PQR-PVT.

BR8210-10-3-1-2 (4.70 t ha^{-1}) and BR-SF (Rang)-PL1-B (4.89 t ha^{-1}) yielded higher than the check BRRI dhan49 (4.39 t ha^{-1}) in RLR-PVT at Gudderdangi, Satkhira sadar. BR8492-9-5-3-2 (5.80 t ha^{-1}) yielded higher than BRRI dhan39 (5.03 t ha^{-1}) in RLR and ZER-PVT. The tested entry BR8535-2-1-2 (4.59 t ha^{-1}) yielded higher than BRRI dhan34 (3.12 t ha^{-1}) with 14 days growth duration advantage. And BR8535-2-1-2 line has already released as new variety BRRI dhan90.

Proposed variety trial (PVT) in Boro 2018-19

Table 7 and Figure 2 presents the results of seven tested PVTs and field salinity level respectively. Tested three entries of HHZ5-DT20-DT2-DT1, HHZ12-SAL2-Y3-Y2 and IR83484-3-B-7-1-1-1 performed better in all test locations even under high salinity level where check varieties were completely damaged.

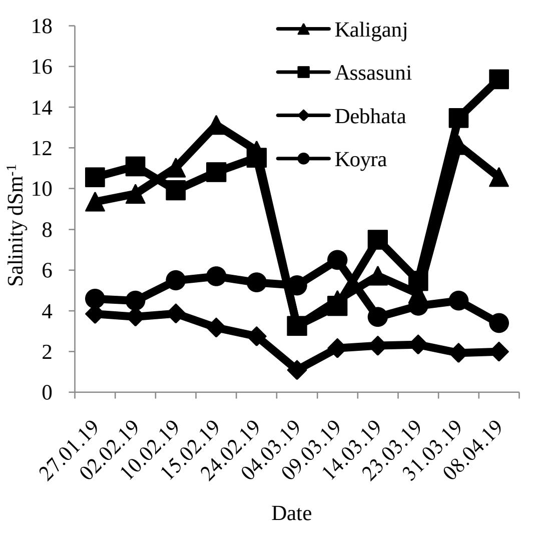

Fig. 2. Water salinity of different experimental plots at Assasuni, Kaliganj and Debhata (Satkhira) and Koyra (Khulna) in Boro 2018-19.

Development and validation of beta-carotene enriched rice (Golden rice)

A confined field trial (CFT) was conducted at BRRI RS farm for development of golden rice. The yield of golden rice was 6.6 t ha^{-1}, lower than BRRI dhan29 (7.3 t ha^{-1}) with similar growth duration (144-145 days).

Green super rice (GSR) during Boro 2018-19

Tested three lines of 7FBR-404, 7FBR-340 and 7FBR-102 produced significantly higher yield among 64 lines and the four check varieties along with nine landraces in an observational yield trial. Tested genotype of 7FBR-222 performed better than BRRI dhan28, BRRI dhan67 and BRRI dhan69 under preliminary yield trial.

Advanced yield trial (AYT) during Boro 2018-19 under breeding zone trial

Among 432 breeding lines, fifteen genotypes were selected comparing their yield performance (6.39-7.58 t ha^{-1}) for the advancement of breeding materials.

CROP-SOIL-WATER MANAGEMENT

Missing element trial

Application of NPKS and Zn significantly increased rice yield compared to N omitted plot only. Omission of NPKS and Zn (control plot) significantly reduced rice yield over the missing of PK S and Zn plot. However, insignificant variation in rice yield was observed between the missing of N solely and control treatment.

SOCIO-ECONOMIC AND POLICY

Stability analysis of BRRI varieties during 2018-19

In Aus 2018, BRRI dhan27 yielded (4.66 t ha^{-1}) significantly higher than the other varieties except BRRI dhan83 and BR24 (both yielded 4.15 t ha^{-1}). Among the T. Aman varieties, BRRI dhan49, BRRI dhan87, BR10, BRRI dhan33, BRRI hybrid dhan6, BRRI dhan71, BRRI dhan75 and BRRI dhan52 performed better and yield level was higher than 6.50 t ha^{-1}. In Boro 208-19, BRRI hybrid dhan2, 3 5 produced higher yield compared to inbred rice varieties.

Table 6. Grain yield of PVT at different sites of Jashore and Satkhira in T. Aman 2018.

Entry/Variety	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
	RLR for Monirampur, Jashore		
BR-RS(Raj)-PL4-B	125	139	6.29
BR-SF(Rang)-PL1-B	127	137	6.23
BR8210-10-3-1-2	117	126	5.88
BRRI dhan49 (ck)	109	136	5.85
	PQR for Monirampur, Jashore		
BR8535-2-1-2	119	120	5.56
BRRI dhan34 (ck)	146	135	3.86
	RLR for Gudderdangi, Satkhira sadar		
BR-RS(Raj)-PL4-B	134	135	4.36
BR-SF(Rang)-PL1-B	133	135	4.89
BR8210-10-3-1-2	127	126	4.70
BRRI dhan49 (ck)	116	136	4.39
	RLR and ZER for Gudderdangi, Satkhira sadar		
BR7528-2R-HR16-2-24-1	126	119	4.71
BR8492-9-5-3-2	124	125	5.80
BRRI dhan39 (ck)	124	123	5.03
PQR for Gudderdangi, Satkhira sadar			
BR8535-2-1-2	118	122	4.59
BRRI dhan34 (ck)	145	136	3.12

Table 7. Grain yield of PVT at different sites of Khulna, Bagerhat and Satkhira in Boro 2018-19.

Entry/Variety	Yield (t ha^{-1})						
	Dumuria	Paikgacha	Batiaghata	Rampal	Tala	Debhata	Kaliganj
IR83484-3-B-7-1-1-1	4.49	1.01	5.45	4.71	3.93	1.09	2.38
HHZ12-SAL2-Y3-Y2	6.01	0.44	5.64	4.56	3.56	0.98	0.82
HHZ5-DT20-DT2-DT1	6.44	0.21	6.58	4.14	4.44	1.04	0.83
BRRI dhan28 (ck)	1.74	0.00	4.86	0.95	2.54	0.04	0.00
BRRI dhan67 (Res. ck)	4.23	0.00	5.14	3.17	4.01	0.73	0.00
CV (%)	18.03		1.02	11.64	26.03		
$LSD_{0.05}$	0.82		0.05	0.39	0.96		

Performance of hybrid rice under saline field condition

Nine hybrid rice varieties were evaluated against three inbred varieties of BRRI dhan28, BRRI dhan67 and Bina dhan-1. Hybrid rice variety of IT produced higher yield (5.1 t ha^{-1}) than the other varieties. Notably, BRRI dhan67 and Bina dhan-10 yielded slightly higher (4.0 t ha^{-1}) than the other hybrid rice varieties under salinity affected farmer's field at Faridpur, Kaliganj, Satkhira.

TECHNOLOGY TRANSFER

Validation of BRRI developed rice varieties

In integrated rice-fish culture, BRRI dhan49, BRRI dhan79 and BRRI dhan52 yielded better (5.17-5.39 t ha^{-1}) while BR10 and BRRI dhan52 performed better (5.49-5.79 t ha^{-1}) in stagnant water environment.

Head to head trial

The experiment was conducted at Assasuni, Shyamnagar, Kaliganj, Keshobpur and Koyra upazilas during T. Aman 2018. BRRI dhan73 yielded higher (5.24-6.47 t ha^{-1}) under high salinity affected area with shorter growth duration (117-129 days).

Seed production

A sum of 28.397 tons of breeder seeds of different Aman and Boro rice varieties were produced and sent to GRS Division BRRI HQ. In addition, 24.039 tons of truthfully labelled seed of different Aus, Aman and Boro rice varieties were produced, stored as well as sold and distributed to the farmers, NGOs and DAE.

Training, field day and fair

A total of 101 demonstrations of BRRI newly released rice varieties (Aus: 28, Aman: 42, Boro: 31) were conducted during 2018-19 under seed production and dissemination programme. Twelve farmer's training on rice production technology, quality seed production and preservation was conducted to train up 390 farmers of Satkhira, Khulna and Jashore districts. A total of fourteen field days were arranged during the reporting period. BRRI RS, Satkhira took part in two different agricultural and development fairs as well as participated workshop, seminar, regional and district agricultural coordination committee meeting, district coordination committee meeting, discussion meeting, farmers' field visit with advisory activities in field level and on line basis.

Climate resilient farming systems research and development for the coastal ecosystem

Farming systems research and development activities were initiated under the BARC coordinated sub-project of PBRG, NATP-2 starting from 2018 at south western coastal ecosystem of Bishnupur union, Kaliganj, Satkhira. A total of 26 studies were done for maximizing the total farm productivity using the existing resources.

Mustard-BRRI dhan81-BRRI dhan75 and Mustard-BRRI dhan86-BRRI dhan75 were successfully proven to increase the total productivity as much as of 40% higher rice equivalent yield over existing Fallow-BRRI dhan28-BRRI dhan49 cropping pattern (10.42 t ha^{-1}). BRRI dhan73 and BRRI dhan67 performed better especially in saline affected area in T. Aman and Boro season respectively.

Homestead areas become more productive with adopting vegetable production round the year while bottle gourd, cabbage, cucumber, potato, papaya, indian spinach, red amaranth showed better performance to increase farm income and improve the nutrition consumption of the farm family as well.

Improvement of the productivity of *gher* system proved highly profitable with inclusion of vegetable production on *gher* bund by average gross margin of 328140 Tk ha^{-1}. In the fish poly-culture in saline *gher* system, the highest total production for a *gher* was 909 kg/180 decimal, while the lowest production was 321 kg/130 decimal. Average gross margin from the *gher* was 147,588 Tk ha^{-1}.

In poultry system, Sonali chicken, Khaki Campbell duck and Turkey rearing under scavenging system seems to be a good option to increase farmers' income and consequently increased family consumption of egg and meat also. Cooperative farmer's success to Turkey production encouraged other farmers in the locality for adopting Turkey rearing.

BRRI RS, Sonagazi

SUMMARY

Regional yield trials (RYT) were conducted at experimental field of BRRI RS, Sonagazi to test the yield performance of superior breeding lines. A total of 85 breeding lines were tested under this trial during the reporting period from which 23 were found better than the checks regarding grain yield and yield contributing characters. The breeding lines were supplied from Plant Breeding and Biotechnology Divisions. Twenty-four lines along with standard checks BR26, BRRI dhan28, BRRI dhan43, BRRI dhan48, BRRI dhan65, BRRI dhan82 and BRRI dhan83 were tested during Aus season from which the advanced lines BR9029-51-3-5, BR9011-25-4-1-1, BR9011-25-4-1-3, BR9011-62-2-1-2, BR9039-20-2-2-1, BR9039-202-2-2, BR9039-12-2-1, BR9011-12-2-1, BR9039-30-1-1, BR9640-2B-9-1, BR9640-2B-14-2 and BR8235-2B-12-4 were recommended for advanced trial. In T. Aman season two rainfed lowland rice (RLR), three zinc enriched rice (ZER), one high yielding rice (HYV) were evaluated under on-station condition, which were supplied from Plant Breeding Division. Two RYT materials from Biotechnology Division were also evaluated. The RLR lines BR8521-30-3-1, IR13F352 were selected for advancing. On the basis of growth duration, yield and yield contributing characters the ZER advanced lines BR8427-2-3-2-P1-2, BR8436-21-3-3-3-1, BR8436-7-4-2-3-1, BR8444-37-2-3-1-1-B3, IR99269-33-1-3, IR99269-33-4-1, BR8143-4-3-3-6-2-4, BR8442-9-5-8-1-1, IR84725-191-2-6-2-1-P2, IR99641-115-2-3, and BR8436-21-3-1-1-1 were found better than the check variety. During Boro season 2018-19 no advanced lines were found performing better than the checks.

On-farm demonstrations were conducted under SPDP during Aus, Aman and Boro seasons. Number of total demonstrations was 40 and direct beneficiary farmers were 170 from which 132 tons quality seed was produced and the amount of the farmers' retained seed was 85 tons. The proposed lines BR8492-9-5-3-2 (RLR) and BR7528-2R-HR16-2-24-1 (ZER) along with standard check BRRI dhan39 were evaluated under on-farm condition during T. Aman 2018. The grain yield of the tested lines BR8492-9-5-3-2 (RLR) and BR7528-2R-HR16-2-24-1 (ZER) were 3.73 t ha^{-1} and 3.61 t ha^{-1} respectively whereas the check produced 3.56 t ha^{-1} with no significant yield increase. The standard check was nearly 13 days earlier than BR8492-9-5-3-2 (RLR).

In the reporting period, BRRI RS, Sonagazi produced 20.30 tons of breeder seed during Aman and Boro seasons. All the Breeder seeds of different varieties were sent to Genetic Resource and Seed Division, BRRI HQ, Gazipur. A total of 850 kg truthfully labelled seeds (TLS) of BRRI dhan27, BRRI dhan42, BRRI dhan48 and BRRI dhan65 were produced during T. Aus and 8,524 kg seeds of nine varieties during T. Aman seasons. A total of 20 farmers' training programmes were arranged with the participation of 700 farmers. Fifteen field days were arranged in selected demonstration sites at crop maturity stage where nearly 3,000 people participated and shared knowledge about modern rice production technology.

EVALUATION OF BREEDING MATERIALS

Regional yield trial (RYT-1) in T. Aus 2018

Fifteen advanced lines BR9029-51-3-1, BR9029-51-3-5, BR9011-25-4-1-1, BR9011-25-4-1-3, BR9011-62-2-1-2, BR9039-20-2-2-1, BR9039-202-2-2, BR9039-21-1-1-1, HHZ5-DT20-DT20-DT1, BR9039-12-2-1, BR9011-12-2-1, BR8773-9-1-3, SP21-1-4, BR9029-51-3-12 and BR9039-30-1-1 along with three checks BR26, BRRI dhan28 and BRRI dhan48 were tested at BRRI RS, Sonagazi experimental farm during Aus 2018 with three replications.

The advanced lines BR9029-51-3-5, BR9011-25-4-1-1, BR9011-25-4-1-3, BR9011-62-2-1-2, BR9039-20-2-2-1, BR9039-202-2-2 , BR9039-12-2-1, BR9011-12-2-1 and BR9039-30-1-1 produced 4.32, 4.33, 4.83, 4.45, 5.01, 4.53, 4.48, 4.77 and 4.81 t ha^{-1} respectively that were higher than standard checks (Table 1). Based on the yield performance the following lines may be recommended for advanced trial.

RYT-2 in upland Aus 2018

Nine advanced lines BR9640-2B-9-1, BR9640-2B-14-2, BR9643-2B-19-1, BR9101-2B-1-2-1, BR9101-2B-5-3-1, BR8235-2B-4-4, BR8235-2B-12-4, BR8235-2B-13-3 and BR8236-2B-4-1 along with four checks BRRI dhan43, BRRI dhan65, BRRI dhan82 and BRRI dhan83 were tested at

BRRI RS, Sonagazi farm during Aus 2018 with three replications.

The advanced lines BR9640-2B-9-1, BR9640-2B-14-2 and BR8235-2B-12-4 produced grain yield 3.24, 3.33 and 3.14 t ha^{-1} respectively that were higher than standard checks (Table 2). Based on the yield performance BR9640-2B-9-1, BR9640-2B-14-2 and BR8235-2B-12-4 may be recommended for advanced trial.

RYT-1 (Bio) in T. Aman 2018

Two advanced lines BR (Bio) 9777-116-12-2-2 and BR (Bio) 9777-123-4-6-1 along with check BRRI dhan49 and BRRI dhan39 were tested at BRRI RS, Sonagazi farm during Aus 2018 with three replications. The advanced lines BR (Bio) 9777-116-12-2-2 and BR (Bio) 9777-123-4-6-1 produced 6.05 and 5.88 t ha^{-1} respectively that was higher than the standard check BRRI dhan49 and BRRI dhan39 (Table 3). Based on the yield performance BR (Bio) 9777-116-12-2-2 and BR (Bio) 9777-123-4-6-1 may be recommended for advanced trial.

Regional yield trial, RYT-2 (Bio) during T. Aman 2018

Three advanced lines BR (Bio) 9786-BC2-80-1-1, BR (Bio) 9786-BC2-65-1-1 and BR (Bio) 9786-BC2-161-1-2 along with check BRRI dhan71 were tested at BRRI RS, Sonagazi farm during T. Aman 2018 with three replications. The advanced lines BR (Bio)9786-BC2-80-1-1 produced 5.61 t ha^{-1} yield that were higher than the standard checks (Table 4). Based on yield performance BR (Bio) 9786-BC2-80-1-1 may be recommended for advanced trial.

RYT-1 (RLR) in T. Aman 2018

Five advanced lines BR8521-30-3-1, BR8841-38-1-2-2, IR11L433, IR13F352 and IR13F402 along with two checks BRRI dhan39 and BRRI dhan49 were tested at BRRI RS, Sonagazi farm during T. Aman 2018 with three replications.

The advanced lines BR8521-30-3-1 and IR13F352 produced yield of 4.79 and 4.95 t ha^{-1} respectively that were higher than the standard checks (Table 5). So, these two lines may be recommended for further trial.

Table 1. Performance of some breeding lines in RYT-1 in T. Aus 2018 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR9029-51-3-1	95	117	3.94
BR9029-51-3-5	91	116	4.32
BR9011-25-4-1-1	89	123	4.33
BR9011-25-4-1-3	87	123	4.83
BR9011-62-2-1-2	97	121	4.45
BR9039-20-2-2-1	85	124	5.01
BR9039-202-2-2	75	124	4.53
BR9039-21-1-1-1	83	121	3.73
HHZ5-DT20-DT20-DT1	92	129	3.87
BR9039-12-2-1	84	124	4.48
BR9011-12-2-1	94	122	4.77
BR8773-9-1-3	96	120	4.35
SP21-1-4	93	114	3.11
BR9029-51-3-12	87	120	3.94
BR9039-30-1-1	86	127	4.81
BR26 (ck)	108	116	3.64
BRRI dhan48 (ck)	104	114	4.41
BRRI dhan28 (ck)	91	117	2.83
$LSD_{0.05}$	3.90	0.16	0.41
CV(%)	2.60	3.10	6.00

Table 2. Performance of some breeding lines under RYT-2 during upland Aus 2018 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR9640-2B-9-1	83	107	3.24
BR9640-2B-14-2	90	107	3.33
BR9643-2B-19-1	95	102	2.20
BR9101-2B-1-2-1	94	103	2.04
BR9101-2B-5-3-1	79	105	2.40
BR8235-2B-4-4	94	106	2.36
BR8235-2B-12-4	94	112	3.14
BR8235-2B-13-3	93	112	2.63
BR8236-2B-4-1	104	105	2.58
BRRI dhan82 (ck)	106	101	2.27
BRRI dhan43 (ck)	101	102	3.09
BRRI dhan65 (ck)	88	101	2.67
BRRI dhan83 (ck)	104	106	3.12
$LSD_{0.05}$	3.09	0.21	0.29
CV(%)	1.84	2.90	6.50

Table 3. Performance of some breeding lines under RYT-1 (Bio) in T. Aman 2018 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR(Bio)9777-116-12-2-2	108	125	6.05
BR(Bio)9777-123-4-6-1	108	125	5.88
BRRI dhan49 (ck)	100	136	5.15
BRRI dhan39 (ck)	105	124	4.19
$LSD_{0.05}$	4.00	0.52	0.23
CV(%)	1.90	3.50	2.20

Table 4. Performance of some breeding lines under RYT-2 (Bio) in T. Aman 2018 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR(Bio)9786-BC2-80-1-1	107	119	5.61
BR(Bio)9786-BC2-65-1-1	106	121	4.76
BR(Bio) 9786-BC2-161-1-2	102	110	4.58
BRRI dhan71 (ck.)	111	118	5.29
$LSD_{0.05}$	1.96	0.74	0.62
CV(%)	1.9	2.7	6.2

Table 5. Performance of some breeding lines under RYT-1 (RLR) in T. Aman 2018 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR8521-30-3-1	119	134	4.79
BR8841-38-1-2-2	116	132	4.34
IR11L433	122	120	4.41
IR13F352	104	133	4.95
IR13F402	107	136	3.54
BRRI dhan39 (ck)	106	121	3.77
BRRI dhan49 (ck)	100	136	4.78
$LSD_{0.05}$	4.45	0.12	0.24
CV(%)	2.3	3.5	3.1

RYT-2 (RLR) in T. Aman 2018

Five advanced lines BR8526-25-4-2-2-1-HR1, BR8526-38-3-2-1HR2, Habudhan, Lata Balam and BR8526-L8 along with the checks HPB (PQR-TLA3) Red Rice and BRRI dhan49 were tested at BRRI RS, Sonagazi farm during T. Aman 2018 with three replications.

None of the tested lines performed better than the standard checks (Table 6).

RYT-1 (ZER) in T. Aman 2018

Ten advanced lines BR8427-2-3-2-P1-2 , BR8436-21-3-3-3-1, BR8436-7-4-2-3-1, BR8444-37-2-3-1-1-B3, IR99269-33-1-3, IR99269-33-4-1, BR8143-4-3-3-6-2-4, BR8442-9-5-8-1-1, IR84725-191-2-6-2-1-P2 and IR99641-115-2-3 along with two checks BRRI dhan39 and BRRI dhan62 (C was tested at BRRI RS, Sonagazi farm during T. Aman 2018 with three replications.

The advanced lines BR8444-37-2-3-1-1-B3, IR99269-33-4-1, BR8143-4-3-3-6-2-4, IR84725-191-2-6-2-1-P2 and IR99641-115-2-3 produced grain yield 4.56, 4.59, 5.11, 4.77 and 5.51 t ha^{-1} respectively that were higher than the standard check (Table 7). So, those five lines may be recommended for further trial (Table 7).

RYT-2 (ZER) in T. Aman 2018

Eleven advanced lines BR8442-12-1-3-1-B1, BR8436-21-3-1-1-1, IR90210-100-2-3-1-P4, BR8444-47-1-1-1, IR101760-48-1, BR7528-2R-HR-16-9-1-P1-2, BR8442-12-1-3-1-B7, BR7528-2R-19-16-RIL-28, BR7528-2R-19-16-RIL-28, BR7528-2R-19-16-RIL-14 and BR7528-2R-HR-16-3-147-P4 along with three checks BRRI dhan39, BRRI dhan49 and BRRI dhan72 (ck) were tested at BRRI RS, Sonagazi farm, in T. Aman 2018 with three replications.

The advanced lines BR8436-21-3-1-1-1 produced grain yield 4.96 t ha^{-1} that was higher than the standard check (Table 8). So, this lines may be recommended for further trial (Table 8).

Table 6. Performance of some breeding lines under RYT-2 (RLR) in T. Aman 2018 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR8526-25-4-2-2-1-HR1	98	134	4.44
BR8526-38-3-2-1HR2	99	128	3.57
Habudhan	94	119	3.03
Lata Balam	110	124	4.49
BR8526-L8	106	132	4.50
HPB (PQR-TLA3) Red Rice	106	125	3.39
BRRI dhan49 (ck)	101	135	4.47
$LSD_{0.05}$	3.03	0.19	0.24
CV(%)	1.70	2.90	3.52

Table 7. Performance of some breeding lines under RYT-1 (ZER) in T. Aman 2018 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR8427-2-3-2-P1-2	105	125	4.01
BR8436-21-3-3-3-1	103	124	4.16
BR8436-7-4-2-3-1	113	124	4.28
BR8444-37-2-3-1-1-B3	128	124	4.56
IR99269-33-1-3	117	123	3.90
IR99269-33-4-1	117	124	4.59
BR8143-4-3-3-6-2-4	129	136	5.11
BR8442-9-5-8-1-1	124	136	3.89
IR84725-191-2-6-2-1-P2	100	128	4.77
IR99641-115-2-3	98	128	5.51
BRRI dhan62 (ck)	102	105	3.35
BRRI dhan39 (ck)	108	124	4.26
$LSD_{0.05}$	3.51	0.68	0.31
CV(%)	1.90	2.60	4.20

Table 8. Performance of some breeding lines under RYT-2 (ZER) in T. Aman 2018 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR8442-12-1-3-1-B1	130	132	4.07
BR8436-21-3-1-1-1	115	128	4.96
IR90210-100-2-3-1-P4	112	127	4.64
BR8444-47-1-1-1	117	130	4.44
IR101760-48-1	101	131	3.57
BR7528-2R-HR-16-9-1-P1-2	118	125	4.11
BR8442-12-1-3-1-B7	112	133	4.71
BR7528-2R-19-16 -RIL-28	128	134	3.52
BR7528-2R-19-16 -RIL-28	133	136	3.94
BR7528-2R-19-16 -RIL-14	133	141	3.90
BR7528-2R-HR-16-3-147-P4	100	136	3.88
BRRI dhan49 (ck)	101	135	4.63
BRRI dhan72 (ck)	117	128	4.62
BRRI dhan39 (ck)	108	122	4.35
$LSD_{0.05}$	5.22	0.60	0.41
CV(%)	2.70	3.40	5.90

RYT-3 (ZER) in T. Aman 2018

Three advanced lines along with two checks BRRI dhan49 (ck) and BRRI dhan72 (ck) were tested at BRRI RS, Sonagazi farm during T. Aman 2018 with three replications.

No advanced breeding lines performed better than the standard checks in respect of grain yield and growth duration (Table 9).

RYT (HY) in T. Aman 2018

Six advanced breeding lines BR9396-2-6-2B, BR9892-6-2-2B, BR9892-4-5-7-2, BR9392-3-5-8-2, BRH11-4-3-2-7 and BR10247-14-18-4 along with the check BRRI dhan49 were tested at BRRI RS, Sonagazi farm Aman 2018 with three replications.

None of the tested lines performed better than the standard checks (Table 10).

RYT-1 (PB) in Boro 2018-19

Four advanced lines BR8862-29-1-5-1-3, BR8862-8-3-4-4-1, BR8995-2-5-5-2-1 and BR9205-10-1-5-3 along with two checks BRRI dhan50 and BRRI dhan63 were tested at BRRI RS, Sonagazi farm in Boro 2018-19 with three replications.

None of the tested lines performed better than the standard checks (Table 11).

Table 9. Performance of some breeding lines under RYT-3 (ZER) in T. Aman, 2018 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR9673-B-20-1-2	117	137	4.01
BR7528-2R-19-HR16-9-3-P7-2-2	122	136	5.06
IR9764-35-2-2-8-P2	105	135	3.98
BRRI dhan49 (ck)	98	136	5.12
BRRI dhan72 (ck)	111	128	5.13
$LSD_{0.05}$	4.16	0.79	0.21
CV(%)	2.00	3.50	2.40

Table 10. Performance of some breeding lines under RYT (HY) in T. Aman 2018 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR9396-2-6-2B	123	123	4.87
BR9892-6-2-2B	111	132	4.53
BR9892-4-5-7-2	105	124	3.74
BR9392-3-5-8-2	98	135	4.80
BRH11-4-3-2-7	91	113	3.17
BR10247-14-18-4	106	136	4.65
BRRI dhan49 (ck)	99	134	4.73
$LSD_{0.05}$	4.21	1.5	0.17
CV (%)	2.3	3.6	2.9

Table 11. Performance of some breeding lines (RYT-1, PB) in Boro 2018-19 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR8862-29-1-5-1-3	97	158	6.70
BR8862-8-3-4-4-1	103	153	5.99
BR8995-2-5-5-2-1	100	149	6.21
BR9205-10-1-5-3	115	157	5.80
BRRI dhan50 (ck)	83	150	6.53
BRRI dhan63(ck)	84	155	6.50
LSD $_{(0.05)}$	2.14	NS	0.40
CV (%)	1.21	NS	3.51

RYT-2 (PB) during Boro 2018-19

Two advanced lines IR99285-1-1-1-P1 and IR99285-1-1-1-P2 along with the checks BRRI dhan29, BRRI dhan74 and BRRI dhan84 were tested at BRRI RS, Sonagazi farm in Boro 2018-19 with three replications.

None of the tested lines performed better than standard checks (Table 12).

RYT, BB (PB), Boro 2018-19

Six advanced lines BR9650-99-3-2, BR9651-15-2-1-3, BR9943-40-3-2, BR9651-15-2-1-4, BR9651-15-2-1-5 and BR9651-15-4-3-2 along with checks BRRI dhan29 (Sus ck), BRRI dhan58 (Sus ck) and IRBB60 (Res ck) were tested at BRRI RS, Sonagazi farm in Boro 2018-19 with three replications.

None of the tested lines performed better than the standard checks (Table 13).

Table 12. Performance of some breeding lines in RYT-2, (PB) during Boro 2018-19 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
IR99285-1-1-1-P1	103	157	5.58
IR99285-1-1-1-P2	101	155	6.49
BRRI dhan29 (ck)	98	159	7.06
BRRI dhan74 (ck)	90	149	7.31
BRRI dhan84 (ck)	99	146	6.64
LSD $_{(0.05)}$	2.25	NS	0.489
CV (%)	1.21	NS	3.920

RYT for favourable Boro rice (FBR) in Boro 2018-19

Six advanced lines BR8904-28-1-2-2-2, KARJAT-5, BR9675-68-5-1 and BR9208-8-1-1-1 along with checks Bikalpa28-DF (Early), BRRI dhan58 (ck) and IRBB60 (Res. ck) were tested at BRRI RS, Sonagazi farm during Boro 2018-19 with three replications. None of the tested lines performed better than the standard checks (Table 14).

Table 13. Performance of some breeding lines in (RYT, BB (PB), Boro 2018-19 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR9650-99-3-2	103	150	5.21
BR9651-15-2-1-3	90	148	4.98
BR9943-40-3-2	102	156	5.19
BR9651-15-2-1-4	87	147	4.81
BR9651-15-2-1-5	82	148	4.81
BR9651-15-4-3-2	94	149	4.39
BRRI dhan29 (ck)	98	158	6.57
BRRI dhan58 (ck)	93	151	6.36
IRBB60 (Res. ck)	77	149	4.42
LSD $_{(0.05)}$	2.49	NS	0.50
CV (%)	1.56	NS	5.66

Table 14. Performance of some breeding lines in RYT (FBR) during Boro, 2018-19 at BRRI RS, Sonagazi.

Entry	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR8904-28-1-2-2-2	92	159	6.52
KARJAT-5	103	161	6.31
BR9675-68-5-1	108	157	6.31
BR9208-8-1-1-1	81	147	6.29
Bikalpa28-DF (Early)	101	149	7.61
BRRI dhan58 (ck)	97	150	7.10
LSD $_{(0.05)}$	2.47	NS	0.52
CV (%)	1.39	NS	4.31

On-farm evaluation of breeding lines through advanced lines adaptive research trial (ALART)

ALARTs were conducted during T. Aus 2018 in two locations of Feni and Chattogram districts which had four lines BR9011-48-4-3, BR9011-64-1-2, BR9011-67-4-1 and BR(Bio)9787-BC2-63-2-4 with two checks BR26 and BRRI dhan48.

Four categories of ALARTs were conducted during T. Aman 2018 such as RLR, ZER , IRR and RLR-Bio. The trials were conducted at two locations such as Sonagazi, Feni and Mirsorai, Chattogram. The ALARTs were also conducted during Boro 2018-19 season such as BBR-Bio, FBR, FBR-Bio, IRR, PQR and ZER at Sonagazi, Feni and Hathazari, Chattogram. All recommended and suggested agronomic management practices were provided in the trials. 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 Adaptive Research Division of BRRI, HQ which were analyzed and reported.

On-farm evaluation of breeding lines through proposed variety trial (PVT)

PVTs were conducted at farmers' fields by the participation of researchers, extension people, BADC workers and employees of Seed Certification Agency (SCA) just prior to variety release. The proposed lines BR8492-9-5-3-2 (RLR) and BR7528-2R-HR16-2-24-1 (ZER) along with standard check BRRI dhan39 were evaluated under on-farm condition during T. Aman season 2018. The grain yield of the tested lines BR8492-9-5-3-2 (RLR) and BR7528-2R-HR16-2-24-1 (ZER) were 3.73 t ha^{-1} and 3.61 t ha^{-1} respectively whereas the check variety produced 3.56 t ha^{-1} with no significant yield increase. The standard check was nearly 13 days earlier than BR8492-9-5-3-2 (RLR)

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 2018 and Boro 2018-19. Sites were selected with the suggestion and collaboration of upazila agricultural officer (UAO) of Department of Agricultural Extension (DAE). Sub assistance agricultural officer (SAAO) of concerned block helped in site selection who were the front line workers and very much familiar to the farmers as well as their fields.

Bacterial leaf streak (BLS), sheath rot, BLB, and sheath blight infestation were observed in different scores during T. Aman season. BRRI dhan28 and BRRI dhan29 were affected severely by neck blast during Boro season. Others were also affected in different degrees such as BRRI dhan58 and BRRI dhan67. The farmers were suggested for taking preventive measures using fungicide.

Monitoring of insect pests and natural enemies by using light trap

Rice insect pests and their natural enemies were monitored throughout the reporting period by Pennsylvanian light traps from July 2018 to June 2019 at the experimental field of BRRI RS, Sonagazi. The abundance of leaf roller (LR), stem borer (SB), rice bug (RB), green leafhopper (GLH), grasshopper (GH), mole cricket (MC), field cricket (FC), and stink bug (SB) were found in the light trap during the reporting period. Leaf roller (LR) populations were the highest among all the insect pests.

TECHNOLOGY TRANSFER

Seed production and dissemination programme (SPDP) in T. Aus 2018

The demonstrations were conducted in six upazilas of five districts (Noakhali, Feni, Chattogram, Laxmipur Cox's bazaar and Khagrachori) during T. Aus 2018. BRRI dhan48 and BRRI dhan27 were 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 UAO 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 (4.25 t ha^{-1}) was found in Mirsorai upazila of Chattogram district followed by Companiganj upazila of Noakhali district. A total of 8,922 kg seeds produced in demonstrated areas from which farmers retained 2,452 kg seeds for next year cultivation. The knowledge gained farmers were 1612 and motivated farmers were 1876 who decided for next year cultivation.

Seed production and dissemination programme (SPDP) during T. Aman 2018

The demonstrations on SPDP were conducted in 17 upazilas of seven 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 45 demonstrations were conducted in 55 farmers' fields having two *bighas* of each variety.

The total seed production of BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan49, BRRI dhan76 and BRRI dhan77 were 4,217 kg, 4,236 kg, 4,125 kg, 4,587 kg, 2,547 kg and 1,247 kg whereas retained seeds were 1,478 kg, 1,270 kg, 2,145 kg, 2,587 kg, 225 kg and 325 kg of those varieties respectively.

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 dhan71 and BRRI dhan87 were used as cultivar in those upazilas considering land suitability, agro-ecology and seed availability.

The total seed production of BRRI dhan71 and BRRI dhan87 were 5,478 kg and 7,854 kg whereas retained seeds were 3,287 kg and 4,256 kg of those varieties respectively.

SPDP in Boro 2018-19

The demonstrations on SPDP were conducted in 12 upazilas of five districts of jurrisdicted areas of BRRI RS, Sonagazi during Boro season under core programme. BRRI dhan29, BRRI dhan58 and BRRI dhan67 were used as cultivars in different upazilas. A total of 40 demonstrations were conducted in farmers' fields having two bighas of each variety.

The total seed production of different varieties were 45,236 kg and farmers retained 21,257 kg seeds for next year cultivation and distribution to other interested farmers. The knowledge gained farmers were 14,256 and motivated farmers were 8,569 for different varieties demonstrated in farmers' fields. Demonstrations on SPDP were conducted in four upazilas of three districts such as Feni, Laxmipur and Noakhali. BRRI dhan67 and BRRI dhan69 were used as cultivar in those upazilas. The total seed production of BRRI dhan67 and BRRI dhan69 were 20,136 kg and motivated farmers were 2,337 for those varieties demonstrated in 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 training programmes 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 staffs participated in which they were trained up with rice production technologies 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 to create interests among the farmers and concerned extension agents about the modern rice production technologies. These activities generated wide publicity and familiarity of the institute, our technologies and BRRI's contribution towards national economy. About 150-200 people (farmers, researchers, extension service providers, local leaders, public representatives and administrative personnel etc.) were invited in a field day. A total of 15 field days were arranged during Aus, T. Aman and Boro season. Nearly 3,000 progressive farmers, local leaders, DAE field staff, public representatives and NGO workers participated in those occasions.

ENRICHMENT OF SEED STOCK

Production of truthfully labelled seed

Truthfully labelled seed (TLS) production activities were undertaken at BRRI RS research field during Aus 2018, Aman 2018 and Boro 2018-19. 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. Different organizations also purchased seeds. Total production of TLS during Aus, Aman and Boro were 870 kg, 8,563 kg and 421 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. BR11, BRRI dhan34, BRRI dhan41 and BRRI dhan80 were cultivated during Aman season whereas BRRI dhan28 and BRRI dhan29 were cultivated during Boro season. A total of 10.60 tons and 9.67 tons breeder seeds were produced during Aman and Boro season respectively All the produced seeds were sent to GRS Division of BRRI HQ, Gazipur.

BRRI RS, Kushtia

SUMMARY

A total of 29 experiments were conducted during Aus 2018 to Boro 2018-19 under varietal development, rice farming systems, socio-economics and policy and technology transfer programme areas. Under varietal development programme area 21 regional yield trials (RYT) were conducted, of which one was in Aus, 13 in T. Aman and seven were in Boro season. In addition, four proposed variety trials (PVT) were conducted of which three were in T. Aman and one in Boro season.

In the RYT in B. Aus, none of the tested lines performed better than all the checks in both set of trials. However, BR8235-2B-4-4 yielded (3.92 t ha^{-1}) higher than the check BRRI dhan43 (3.62 t ha^{-1}) only.

Thirteen RYTs and three PVTs were carried out in T. Aman 2018. In RYT for high yielding rice (HYR-1), Biotech., both the tested lines failed to express better yield potentiality than the checks. In another RYT for high yielding rice (HYR-2), Biotech., all tested lines out yielded the check BRRI dhan71. Two RYTs were conducted for rainfed lowland rice (RLR) development. In RLR-1, tested genotypes failed to cross the yield limit of the checks in this trial. However, IR11L433 yielded 5.71 t ha^{-1} with 10 days short duration than BRRI dhan49 (ck). In another trial (RLR-2), BR8526-L8 was the highest yielder (5.87 t ha^{-1}) with same growth duration compared to check variety. In RYT for the development of high yielding rice (HYR) (Breeding), overall performance of BR9892-4-5-7-2 line was best for its short duration (116 days) with higher yield (5.50 t ha^{-1}) than check BRRI dhan49. Three RYTs were conducted for zinc enriched rice (ZER). In ZER-1 trial, highest yielder was BR84725-191-2-6-2-1-P2 (5.19 t ha^{-1}), but with much longer growth duration than check. In ZER-2, against two long duration checks (BRRI dhan49 and BRRI dhan72) overall performance of line BR8436-21-3-1-1-1 was better (6.06 t ha^{-1}) with short duration (119 days). In ZER-3, all the three tested lines failed to perform better than the checks. For developing premium quality rice (PQR) three RYTs were conducted in T. Aman 2018. In PQR-1, among the tested lines BR8528-2-2-3-HR2 and BR8887-26-8-2-3 outyielded all the checks with short growth duration. In PQR-2, genotype BR9051-1-1-2-3 was the highest yielder. In PQR-3 only BR8526-2-1-4-HR3-HR2 and BR8526-2-1-4-HR3-HR3 yielded higher than the standard checks. Another RYT for insect resistant rice (IRR) was conducted on-station condition. The IRR's results showed that all the lines yielded lower than the standard check BRRI dhan49 but only the line BR9143-55-3-2-1 performed better than another check BRRI dhan33. In RYT for disease resistant rice (DRR) BR9140-5-22-2-1 yielded the highest.

In proposed variety trial (PVT) for RLR+ZER, RLR line BR8492L-9-5-3-2 yielded higher than the check. However, ZER line (BR7528-2R-HR16-2-24-1) growth duration was much shorter than the check. In another PVT for PQR, proposed material (BR8535-2-1-2) performed excellent (5.51 t ha^{-1}) with 18 days shorter growth duration and already released as new variety BRRI dhan90. In the last one PVT of the season for RLR, BR-RS (Raj)PL4-B yielded higher (6.64 t ha^{-1}) than the check BRRI dhan49 (6.19 t ha^{-1}).

A total of seven RYTs and one PVT were carried out in Boro, 2018-19. In RYT for PQR, BR8862-8-3-4-4-1 was the highest yielder (7.17 t ha^{-1}) but maximum 1000 grain weight (26.53 g). In RYT for disease resistance of BB, BR9943-40-3-2 yielded the highest. In RYT for favourable Boro rice (FBR), the highest yielder was BR8964-28-1-2-2-2 (7.59 t ha^{-1}). In another RYT for ZER, both the tested lines failed to perform better than BRRI dhan29. But two lines performed better than another check BRRI dhan84. Among seven RYT three were from Biotechnology Division. In RYT for FBR, none of the tested lines yielded higher than the check. In RYT for cold tolerant rice (CTR) the highest yield recorded from the genotype BR (Bio) 9777-124-1-1-2. Another RYT for disease resistant of BB, BR(Bio) 11447-1-28-14-3 yielded higher than BRRI dhan28 (ck).

In proposed variety trial (PVT) for FBR (short duration), tested material BR (Bio)9787-BC2-63-2-2 yielded higher (7.15 t ha^{-1}) than the check BRRI dhan28 with similar growth duration.

Under rice farming systems programme area a validation trial of high intensity cropping pattern was done. Here, the highest rice equivalent yield (REY) was achieved from Maize+Potato - T. Aus - T. Aman cropping pattern.

Stability analysis of BRRI varieties were conducted to observe their performance under

Genotype × Environment interaction. In T. Aus season, the highest yielder was BRRI dhan65 and the lowest was BRRI dhan24. In T. Aman season, the highest yield was scored by BRRI dhan87 and the lowest by BRRI dhan62. Several varieties lodged during T. Aman. In Boro season, the highest yielder was BRRI hybrid dhan3 and the lowest was BR12.

Thirteen batches of farmers' training programmes 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 as well agriculture technology fair held in Kushtia.

VARIETY DEVELOPMENT

Aus 2018

Regional yield trial, B. Aus 2018. Nine genotypes and four standard checks BRRI dhan43, BRRI dhan65, BRRI dhan82 and BRRI dhan83 were tested under this experiment. From the Set-1 trial it was found that none of the tested lines performed better than newly released BRRI dhan83 (ck) (3.90 t ha^{-1}) (Table 1.1). The same scenario was also found from the Set-2 trial. However, BR8235-2B-4-4 yielded (3.92 t ha^{-1}) higher than the check BRRI dhan43 (3.62 t ha^{-1}) only (Table 1.2). After compiling both the trial it can be concluded that no promising line was found in consideration of yield potentiality.

Table 1.1. Performance of some B. Aus advanced lines in RYT, set-1, B. Aus 2018.

Variety/Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR9640-2B-9-1	112	98.20	256	19.26	2.52
BR9640-2B-14-2	112	89.67	255	20.37	2.47
BR9643-2B-19-1	107	96.93	173	23.97	2.27
BR9101-2B-1-2-1	109	76.80	288	21.33	2.87
BR9101-2B-5-3-1	108	80.07	267	20.48	2.43
BR8235-2B-4-4	113	96.80	293	21.23	2.97
BR8235-2B-12-4	114	96.67	267	23.18	2.41
BR8235-2B-13-3	109	98.93	262	22.64	2.81
BR8236-2B-4-1	110	120.20	203	25.79	3.02
BRRI dhan82 (ck)	106	97.07	239	21.44	2.32
BRRI dhan43 (ck)	106	99.73	328	19.35	3.22
BRRI dhan65 (ck)	107	80.47	255	21.48	2.66
BRRI dhan83 (ck)	110	112.07	252	23.11	3.90
HSD(0.05)	6.12	14.47	116.58	3.74	1.13
CV(%)	1.87	5.06	15.18	5.74	13.65

DS: 23 Apr 2018, TGW= 1000 grain weight.

Table 1.2. Performance of some B. Aus advanced lines in RYT, set-2, B. Aus 2018.

Variety/Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR9640-2B-9-1	112	98.93	215	20.05	2.48
BR9640-2B-14-2	113	98.73	196	19.92	3.16
BR9643-2B-19-1	107	103.73	223	25.54	2.26
BR9101-2B-1-2-1	111	80.93	321	21.07	2.77
BR9101-2B-5-3-1	113	86.73	287	20.09	3.43
BR8235-2B-4-4	112	123.40	277	21.46	3.92
BR8235-2B-12-4	111	77.80	245	22.38	3.24
BR8235-2B-13-3	115	109.60	288	22.60	2.74
BR8236-2B-4-1	111	129.13	170	24.62	2.92
BRRI dhan82 (ck)	108	110.13	263	23.02	3.98
BRRI dhan43 (ck)	111	105.93	193	22.21	3.62
BRRI dhan65 (ck)	105	93.73	366	25.76	4.99
BRRI dhan83 (ck)	112	122.00	199	23.62	4.20
HSD (0.05)	9.14	48.81	133.55	4.05	1.71
CV(%)	2.76	15.83	18.18	6.03	17.03

DS: 22 Apr 2018, TGW= 1000 grain weight.

T. Aman 2018

Biotechnology Division

RYT, high yielding rice (HYR-1). Two genotypes and two standard checks BRRI dhan39 and BRRI dhan49 were evaluated under this trial. None of the tested lines performed better than the checks (Table 2). But both the genotypes BR (Bio) 9777-116-12-2-2 and BR (Bio) 9777-123-4-6-1 are 12-13 days shorter than mega variety BRRI dhan49 (ck).

RYT, high yielding rice (HYR-2). Three genotypes and one standard checks BRRI dhan71 were evaluated under this trial. The tested lines yielded higher than the check BRRI dhan71 (5.32 t ha^{-1}) (Table 3). But the growth duration of BRRI dhan71 (ck) was shorter than all the tested lines. However, all the lines can be considered for further evaluation.

Breeding Division

RYT, rainfed lowland rice (RLR-1). Five 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 (Table 4). However, IR11L433 yielded 5.71 t ha^{-1} with 119 days growth duration and can be considered for further evaluation.

RYT, RLR-2. Six genotypes and one standard checks BRRI dhan49 were evaluated under this experiment. All the tested lines except BR8526-25-4-2-2-1-HR1 (4.58 t ha^{-1}) and Habu dhan (4.97 t ha^{-1}) exhibited better yield performance than the check BRRI dhan49 (5.01 t ha^{-1}) (Table 5). BR8526-L8 was the highest yielder (5.87 t ha^{-1}) with same growth duration compared to the check variety.

RYT, development of high yielding rice (HYR). Six genotypes and one standard check BRRI dhan49 was evaluated under this experiment. It was observed from the trial that one of the tested lines BR9892-6-2-2B higher yield (5.57 t ha^{-1}) than the check BRRI dhan49 (4.63 t ha^{-1}) (Table 6). But among the lines BR9892-4-5-7-2 yielded 5.50 t ha^{-1} within 116 days growth duration, which was nine days shorter than the check BRRI dhan49.

RYT, zinc enriched rice (ZER-1). Ten genotypes and two standard checks BRRI dhan39 and BRRI dhan62 were evaluated under this experiment. Among the tested lines, only BR84725-191-2-6-2-1-P2 yielded higher (5.19 t ha^{-1}) than the check BRRI dhan39 (5.09 t ha^{-1}). In addition, its growth duration (127 days) was 10 days longer than the check BRRI dhan39 (Table 7). All the tested lines performed better than another check BRRI dhan62 (2.95 t ha^{-1}).

Table 2. Performance of some high yielding rice (HYR-1) lines in RYT, T. Aman 2018.

Variety/Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR (Bio) 9777-116-12-2-2	115	104	103.6	22.84	4.47
BR (Bio) 9777-123-4-6-1	116	109	108.8	23.85	4.37
BRRI dhan49 (ck)	127	105	104.8	18.22	5.13
BRRI dhan39 (ck)	113	100	100.13	23.27	5.06
LSD (0.05)	1.73	NS	NS	1.57	0.51
CV(%)	0.74	5.72	5.72	3.55	5.39

DS: 10 Jul 2018, DT: 31 Jul 2018.

Table 3. Performance of some high yielding rice (HYR-2) lines in RYT, T. Aman 2018.

Variety/Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR (Bio) 9786-BC2-80-1-1	118	120	221.67	23.14	6.26
BR (Bio) 9786-BC265-1-1	117	124	221.33	23.82	6.23
BR (Bio) 9786-BC2161-1-2	116	114	253.00	22.93	6.44
BRRI dhan71 (ck)	112	124	186.33	23.63	5.32
LSD (0.05)	1.33	5.1	17.96	NS	0.24
CV(%)	0.58	2.4	4.08	3.31	1.96

DS: 10 Jul 2018, DT: 31 Jul 2018.

Table 4. Performance of rainfed lowland rice (RLR-1) lines in RYT, T. Aman 2017.

Variety/Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR8521-30-3-1	125	116.73	252	15.72	5.40
BR8841-38-1-2-2	130	107.47	241	22.96	5.60
IR11L433	119	108.13	228	27.04	5.71
IR13F352	123	104.87	272	21.76	5.31
IR13F402	132	112.53	233	28.07	5.63
BRRI dhan39 (ck)	119	105.93	244	22.91	6.16
BRRI dhan49 (ck)	130	97.13	261	18.33	5.93
HSD (0.05)	1.87	8.23	23.64	3.32	0.57
CV(%)	0.52	2.68	3.35	5.18	3.51

DS: 19 Jul 2018, DT: 14 Aug 2018.

Table 5. Performance of some rainfed lowland rice (RLR-2) lines, T. Aman 2018.

Variety/Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR8526-25-4-2-2-1-HR1	127	100.33	260	17.81	4.58
BR8526-38-3-2-1-HR2	129	101.20	241	17.02	5.47
Habu dhan	122	99.93	193	15.62	4.97
Lata Balam	123	119.53	233	25.37	5.02
BR8526-L8	133	109.67	268	16.97	5.87
HPB(PQR-TLA3)Red Rice	125	110.27	219	20.94	5.06
BRRI dhan49 (ck)	133	103.93	263	17.68	5.01
HSD(0.05)	6.21	10.42	43.71	2.59	0.49
CV(%)	1.7	3.43	6.38	4.84	3.42

DS: 19 Jul 2018, DT: 15 Aug 2018.

Table 6. Performance of some high yielding rice lines in RYT, Breeding, T.Aman 2018.

Variety/Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
V1=BR9396-2-6-2B	127	138	240.33	25.08	5.14
V2= BR9892-6-2-2B	131	126	260.33	23.81	5.57
V3= BR9892-4-5-7-2	116	127	217.33	25.42	5.50
V4= BR9392-3-5-8-2	129	114	214.33	22.92	5.17
V5= BRH11-4-3-2-7	109	96	288.33	16.09	4.04
V6= BR10247-14-18-4	130	124	215.67	23.09	4.65
V7= BRRI dhan49	125	96	253.67	18.64	4.63
HSD(0.05)	0.62	7.37	51.29	1.63	0.56
CV(%)	0.18	2.19	7.16	2.57	3.96

DS: 24 Jul 2018, DT: 19 Aug 2018.

RYT, ZER-2. Eleven genotypes and three standard checks BRRI dhan39, BRRI dhan49 and BRRI dhan72 were evaluated under this experiment. Among the tested lines, BR8436-21-3-1-1-1 and BR8442-12-1-3-1-B7 yielded higher (6.06 t ha^{-1} and 6.07 t ha^{-1} respectively) than the check varieties BRRI dhan39 and BRRI dhan49 (5.12 t ha^{-1} and 5.76 t ha^{-1} respectively) (Table 8). None of the tested lines performed better than another check BRRI dhan72 (6.61 t ha^{-1}). BR8436-21-3-1-1-1, it's growth duration was recorded seven days shorter (119 days) than the checks BRRI dhan49 and BRRI dhan72. Therefore, BR8436-21-3-1-1-1 can be considered for further evaluation.

RYT, ZER-3. Three genotypes and two standard checks BRRI dhan49 and BRRI dhan72 were evaluated under this experiment. All the tested lines failed to perform better (considering yield) than both the checks (Table 9). BRRI dhan49 (5.87 t ha^{-1}) and BRRI dhan72 (6.56 t ha^{-1}).

RYT, premium quality rice (PQR-1). Nine genotypes, two standard checks BRRI dhan34 and BINA dhan13 and three local checks Kalijira, Kataribhog and Radhuni Pagol were evaluated under this experiment. Among the tested lines BR8528-2-2-3-HR2 and BR8887-26-8-2-3 out yielded (5.26 t ha^{-1} and 5.25 t ha^{-1} respectively) all the checks (Table 10). In addition, its growth duration was much shorter than the checks. Therefore, this line can be considered for further trials.

Table 7. Performance of some zinc enriched rice (ZER-1) lines, T. Aman 2018.

Variety/Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR8427-2-3-2-P1-2	116	102.80	202	20.89	4.43
BR8436-21-3-3-3-1	120	104.27	195	22.89	4.82
BR8436-7-4-2-3-1	118	104.40	197	22.23	4.41
BR8436-37-2-3-1-1-B3	118	118.60	204	18.89	5.03
IR99269-33-1-3	114	108.47	203	19.58	4.53
IR99269-33-4-1	117	106.93	247	20.97	4.68
BR8143-4-3-3-6-2-4	125	108.20	197	21.87	5.07
BR8442-9-5-8-1-1	131	111.27	210	22.95	4.66
BR84725-191-2-6-2-1-P2	127	101.53	260	22.31	5.19
IR99641-115-2-3	123	101.60	219	20.42	4.65
BRRI dhan62	110	99.00	251	23.21	2.95
BRRI dhan39	117	102.67	166	22.81	5.09
HSD(0.05)	NS	10.68	57.35	2.09	0.81
CV(%)	16.33	3.40	9.08	3.26	5.88

DS: 15 Jul 2018, DT: 14 Aug 2018.

Table 8. Performance of some zinc enriched rice (ZER-2) lines, T. Aman, 2018.

Variety/Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain weight (g)	Yield (t ha^{-1})
BR8442-12-1-3-1-B1	126	112.13	238	21.85	5.39
BR8436-21-3-1-1-1	119	113.67	263	20.03	6.06
IR90210-100-2-3-1-P4	120	118.63	227	21.89	5.07
BR8444-47-1-1-1	121	110.13	247	21.97	5.76
IR101760-48-1	119	102.53	267	21.06	5.02
BR7528-2R-HR-16-9-1-P1-2	118	122.47	287	17.73	5.62
BR8442-12-1-3-1-B7	126	109.67	273	22.19	6.07
BR7528-2R-19-16-R12-20	130	126.33	207	21.73	5.23
BR7528-2R-19-16-R12-28	130	128.27	224	21.95	5.58
BR7528-2R-19-16-R12-14	130	132.20	225	21.36	5.21
BR7528-2R-HR-16-3-147-P4	125	96.40	213	18.27	5.27
BRRI dhan49 (ck)	126	99.67	275	17.93	5.76
BRRI dhan72 (ck)	124	114.47	222	27.21	6.61
BRRI dhan39 (ck)	112	106.80	180	23.45	5.12
HSD (0.05)	3.00	6.96	39.00	1.98	0.89
CV(%)	0.81	2.02	5.42	3.09	5.33

DS: 16 Jul 2018, DT: 9 Aug 2018.

Table 9. Performance of some zinc enriched rice (ZER-3) lines, T. Aman 2018.

Variety/Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR9673-B-20-1-2	128	123	182	19.15	5.25
BR7528-2R-19-HR16-9-3-P7-2-2	128	124	216	18.97	5.70
IR97641-35-2-2-8-P2	131	120	251	22.67	5.24
BRRI dhan49 (ck)	129	109	256	17.93	5.87
BRRI dhan72 (ck)	127	128	223	26.44	6.56
LSD(0.05)	0.97	7.4	17.60	1.47	0.52
CV(%)	0.40	3.24	4.14	3.72	4.85

DS: 15 Jul 2018, DT: 9 Aug 2018.

Table 10. Performance of some premium quality rice (PQR-1) lines, T. Aman 2018.

Variety/Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
V1=BR9126-15-3-4-1	127	102.20	294.00	9.22	3.73
V2= BR9126-15-3-4-2	126	105.67	274.33	9.12	3.61
V3= BR9130-78-1-1-4	139	122.27	261.33	14.15	3.27
V4= BR8887-26-8-2-3	116	124.07	238.33	14.91	5.25
V5= BR9178-7-2-4-4	135	133.33	274.67	14.56	3.77
V6= BR9580-30-2-1-1	138	125.27	260.33	12.60	3.92
V7= BR8493-3-5-1 (Com)	126	117.73	235.67	14.31	3.75
V8= BR8528-2-2-3-HR1	121	114.53	226.67	15.97	5.09
V9= BR8528-2-2-3-HR2	121	116.67	241.00	16.47	5.26
V10= BINA dhan13 (ck)	140	158.33	275.00	14.68	3.75
V11= Kalijira (ck)	134	160.53	255.67	10.64	3.55
V12= BRRI dhan34 (ck)	133	145.07	274.00	10.92	4.33
V13= Kataribhog (ck)	131	145.20	272.00	13.76	4.52
V14= Radhuni Pagol (ck)	142	165.20	246.67	12.69	2.63
HSD(0.05)	0.67	18.44	48.55	1.17	0.68
CV(%)	0.17	4.67	6.22	2.95	5.47

DS: 18 Jul 2018, DT: 9 Aug 2018.

RYT, PQR-2. Four genotypes, two standard checks BRRI dhan34 and BRRI dhan37 and three local checks Chinigura, Krishnobhog and Kalijira were evaluated under this experiment. Among the tested lines BR9051-1-1-2-3 out yielded (5.51 t ha^{-1}) all the checks. Among the checks BRRI dhan34 was high yielder (4.58 t ha^{-1}).

RYT, PQR-3. Eight genotypes, one standard checks BRRI dhan37 and one local checks Kalijira were evaluated under this experiment. Except four genotypes (V5, V6, V7 and V8), all other lines performed better than standard check BRRI dhan37 (4.11 t ha^{-1}). Among them BR8526-2-1-4-HR3-HR2 (Com) and BR8526-2-1-4-HR3-HR3 (Com) out yielded (5.75 t ha^{-1} and 5.61 t ha^{-1} respectively) the check variety. Also, all the lines yielded higher compared to local check Kalijira (3.23 t ha^{-1}).

RYT, insect resistant rice (IRR). Four genotypes and two standard checks BRRI dhan33 and BRRI dhan49 were tested under this experiment. It was observed from the trial that none of the tested lines performed better than BRRI dhan49. Only the line BR9143-55-3-2-1 yielded (5.13 t ha^{-1}) higher than the check BRRI dhan33 but growth duration was longer.

RYT, disease resistant rice (DRR). Eleven genotypes against two standard checks BRRI dhan39 and BRRI dhan49 and one resistant check IRBB60 were evaluated under this experiment. Among the tested lines BR9140-5-22-2-1 and BR10390-16-2-1 produced higher yield (6.32 t ha^{-1} and 6.12 t ha^{-1} respectively) than all the check materials with short growth duration except the check BRRI dhan39. Both the lines showed better performance than the resistant check IRBB60.

PVT, (RLR and ZER). Two genotypes and one standard check BRRI dhan39 was evaluated under this trial. The proposed RLR line BR8492L-9-5-3-2 yielded (6.63 t ha^{-1}) higher than the check. But in case of growth duration the best one was

ZER line BR7528-2R-HR16-2-24-1 (104 days) with lowest yield (5.00 t ha^{-1}) in the trial.

PVT, premium quality rice (PQR). One proposed line along with one check BRRI dhan34 was evaluated under this trial. The proposed material BR8535-2-1-2 performed better (5.51 t ha^{-1}) than the check variety BRRI dhan34 with 18 days shorter growth duration. Thus, this promising line has already released as BRRI dhan90.

PVT, (RLR). Three proposed lines along with one check BRRI dhan49 was evaluated under this trial. The proposed material BR-RS (Raj) PL4-B performed better (6.64 t ha^{-1}) than the check, which was followed by BR-SF (Rang) PL1-B (6.28 t ha^{-1}) with same growth duration.

Boro 2018-19

Breeding Division

RYT, Premium quality rice (PQR). Four genotypes along with BRRI dhan50 and BRRI dhan63 were evaluated in this trial. All the tested lines produced higher yield than both the checks except the line BR8862-29-1-5-1-3. Among the genotypes, BR8862-8-3-4-4-1 was the higher yielder (7.17 t ha^{-1}) compared to the check varieties with maximum 1000 grain weight (26.53 g).

RYT, disease resistant rice (BB). Six genotypes were tested against two susceptible checks BRRI dhan29 and BRRI dhan58 and one resistant check IRBB60. Among the tested lines BR9943-40-3-2 out yielded (8.13 t ha^{-1}) all the checks. However, its growth duration (164 days) was longer than the checks.

RYT, favourable Boro rice (FBR). Five genotypes and one standard check BRRI dhan58 were tested under this experiment. Among the tested lines BR8964-28-1-2-2-2 yielded the highest (7.59 t ha^{-1}) with longer growth duration than the check variety. However, the genotype Bikalpa 28DF (early) also performed (7.48 t ha^{-1}) well with short duration (150 days) and lower TGW (21.85 g) than highest yielder and check. Therefore, Bikalpa 28DF (early) can be considered for further evaluation.

RYT, zinc enriched rice (ZER). Two genotypes and three standard checks BRRI dhan29, BRRI dhan74 and BRRI dhan84 were tested under this experiment. Both the tested lines performed better than the check BRRI dhan84 (7.03 t ha^{-1}). But another standard check BRRI dhan29 out yielded (7.82 t ha^{-1}) all the lines. Also, growth duration of both the lines was longer compared to the checks.

Biotechnology Division

RYT, favourable Boro rice (FBR). Three genotypes and one standard check BRRI dhan58 were tested under this experiment. It was observed from the trial that none of the tested lines performed better than BRRI dhan58. Growth duration of tested lines was also longer than check.

RYT, cold tolerant rice (CTR). One genotype and two standard checks BRRI dhan28 and BRRI dhan36 were tested under this experiment. The tested line BR (Bio) 9777-124-1-1-2 was found the highest yielder (6.78 t ha^{-1}) over the check varieties. Growth duration of the line was slightly shorter than the checks.

RYT, disease resistant rice (BB). Five genotypes were tested against one standard check BRRI dhan28 and one resistant check IRBB60. Among the tested lines BR(Bio)11447-1-28-14-3 was found higher yielder (6.74 t ha^{-1}) than both the checks. However, its growth duration (150 days) was same as BRRI dhan28 (ck).

PVT, favourable Boro (short duration). One proposed line along with one check BRRI dhan28 was evaluated under this trial. The proposed material BR(Bio)9787-BC2-63-2-2 performed better (7.15 t ha^{-1}) than the check variety BRRI dhan28 with same growth duration.

RICE FARMING SYSTEMS

Validation of high intensity cropping pattern for Kushtia

A study was undertaken in Kushtia during 2018-19 for validation of high intensity cropping pattern to increase the system productivity and income of the farmers through introduction of highly intensified improved cropping patterns. Maize+Potato-T. Aus-T. Aman and Mustard + Pumpkin-T. Aus-T. Aman pattern were introduced against existing Maize-Fallow-T. Aman cropping pattern. Selected cropping patterns were improved through replacing existing low yielding varieties by modern varieties. High yielding variety BRRI dhan71 (T. Aman), Maize (Kaveri), BARI alu-8, BARI sarisha-14, Pumpkin (Thai hybrid-2) was introduced. Result showed that Maize+Potato-T. Aus-T. Aman pattern produced highest rice equivalent yield (21.58 t ha^{-1}) which was followed by Mustard + Pumpkin-T. Aus-T. Aman pattern (14.17 t ha^{-1}). From the existing patterns Maize-Fallow-T. Aman recorded very low productivity (8.55 t ha^{-1}).

SOCIO-ECONOMICS AND POLICY

Stability analysis of BRRI varieties

The number of varieties tested under this experiment in T. Aus, T. Aman and Boro were 10, 42 and 42 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 20 days, 29 days and 44 days in T. Aus, T. Aman and Boro seasons respectively.

Among the tested varieties in T. Aus, the highest yield was scored by BRRI dhan65 (4.94 t ha^{-1}) and the lowest by BRRI dhan24 (3.15 t ha^{-1}). Lodging tendency was not observed during T. Aus.

In T. Aman, 2018 trial, among 42 varieties, the highest yielder was BRRI dhan87 (6.94 t ha^{-1}) and the lowest yielder was BRRI dhan62 (2.53 t ha^{-1}). Lodging was observed at different magnitudes (20%-35%) in case of six varieties namely BR5, BR25, BRRI dhan34, BRRI dhan37 and BRRI dhan38.

In Boro 2018-19, among 42 tested varieties the highest yield was obtained by BRRI hybrid dhan3 (8.63 t ha^{-1}) and the lowest by BR12 (5.6 t ha^{-1}). 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 participated. 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, Entomology and TRB projects in the farmers field in Kushtia, Chuadanga, Meherpur and Jhenaidah districts. The varieties include BRRI dhan70, BRRI dhan71, BRRI dhan75, BRRI dhan87 and BRRI hybrid dhan6 in T. Aman and BRRI dhan58, BRRI dhan63, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan86, BRRI dhan89 and BRRI hybrid dhan5 in Boro season. Also BRRI developed technologies were demonstrated in development fair and agriculture technology fair held in Kushtia.