BRRI ANNUAL REPORT
2015-2016

Bangladesh Rice Research Institute

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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 2015 to June 2016. 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, technology transfer, farm mechanization and regional stations represent the broader conceptual frameworks of BRRI activities.

With a target to make Bangladesh sustainable as a rice surplus country BRRI scientists have been engaged in developing different location specific, climate smart, stress tolerant rice varieties and some premium quality ones that can compete in the international market.

They dedicated their time and energy to develop and disseminate cost and resource-saving profitable technologies along with some management tools such as urea super granule (USG) applicator, rice transplanter, integrated crop management practices, alternate wetting and drying techniques, rice based farming systems and popularization of BRRI machinery.

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

Above all, the present volume includes various research results out of activities that attempted to minimize yield gap between research level and farmer's fields.

Due to unavoidable reasons, we have had to limit our reports mainly on major findings and the details of different subjects including the extension works could not be accommodated here in this volume. However, readers interested to look into the further details of the summarized version may check out the 'Proceedings of the BRRI Annual Research Review for 2015-16' which is available in another format.

We acknowledge all the efforts that helped bring out the publication and special thanks for those who contributed with different capacities. We expect that the report will be useful for the scientists, extension agents, related policy makers and other partners 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
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++ Resigned from BRRI

Weather information

Manual weather station (July 2015-June 2016)
Weather is an instantaneous state of atmosphere. It influences growth and development as well as pest and diseases. We present here the available weather parameters *viz.* maximum and minimum temperature (°C), rainfall (mm), sunshine hours (hours/day), solar radiation (Cal/cm^2/day), relative humidity (%) during the experimental year (July 2015-June 16) as recorded from BRRI headquarters and five regional stations Rangpur, Barisal, Habiganj, Bhanga and Comilla by Plant Physiology Division.

Temperature. During the reporting period, mean monthly maximum temperature ranged from 24.87°C (January) to 36.52°C (April) in Gazipur. More or less similar trend was observed in other stations. The ranges of maximum temperature was 22.6°C (January) to 32.6°C (June), 24.28°C (January) to 34.42°C (April), 23.2°C (January) to 31.9°C (June), 25.0°C (January) to 34.3°C (June), 24.2°C (January) to 36.2°C (April) at Rangpur, Barisal, Habiganj, Comilla and Bhanga station respectively. The highest maximum temperature was recorded in Gazipur in the month April and it was 36.52°C. Mean monthly minimum temperature ranged from 29.85°C to 12.85°C in Gazipur. More or less similar trend was observed in other stations. The lowest minimum temperature was observed in Bhanga station and it was 11.6°C (Fig. 1).

Rainfall. During the reporting period monthly total rainfall ranges from 0 to 826.6 mm (Fig. 2). The highest amount of monthly total rainfall was recorded in July in all stations (except Rangpur) and it ranges from (318.0 to 826.6 mm). There was no rainfall in the month of November in all station. Highest rainfall (826.6 mm) was recorded at Barisal station.

Monthly total evaporation. The evaporation data was recorded in four (4) stations viz, Gazipurpur, Rangpur, Barisal and Comilla. Among the stations, the highest evaporation 195.0 mm (July) was recorded at Rangpur and lowest 38.0 mm at Barisal. Evaporation at Gazipur was the highest in April (159 mm) and lowest in January (52.9 mm). (Fig. 3).

Relative humidity (RH). In Gazipur, mean relative humidity (RH) was the highest (87.8%) in December at 9.0 am and lowest (52.0%) in March at 2 pm. In other stations, RH was more or less stable and it was near about 90% at 6 am (Fig. 4).

Bright sunshine hours and solar radiation. The longest period of bright sunshine hours was recorded in July (8.34 hrs/day) but shortest in December (4.36 hrs.) at Gazipur. Among the other stations longest sunshine hour was recorded at Rangpur in December (8.2 hrs) and shortest (1.61 hrs/day) at Barisal. The highest solar radiation 405.0 Cal/cm^2/day was recorded in Gazipur in April. Among the other station highest solar radiation was recorded at Habiganj in April (420.7 Cal/cm^2/day) but lowest (197.9 Cal/cm^2/day) at Bhanga in December (Fig. 5).

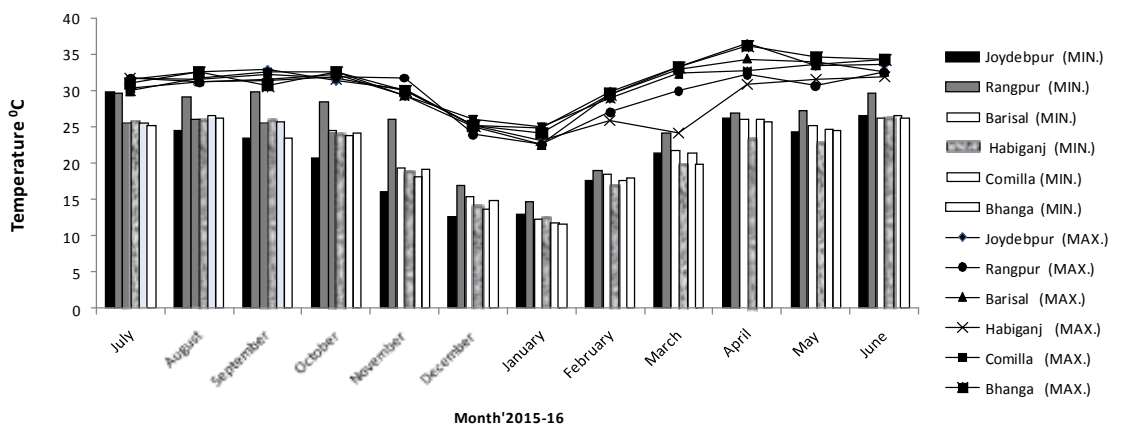

Fig. 1**.** Monthly mean maximum and minimum temperatures (°C) of Gazipur and five Regional Stations, BRRI during 2015-16.

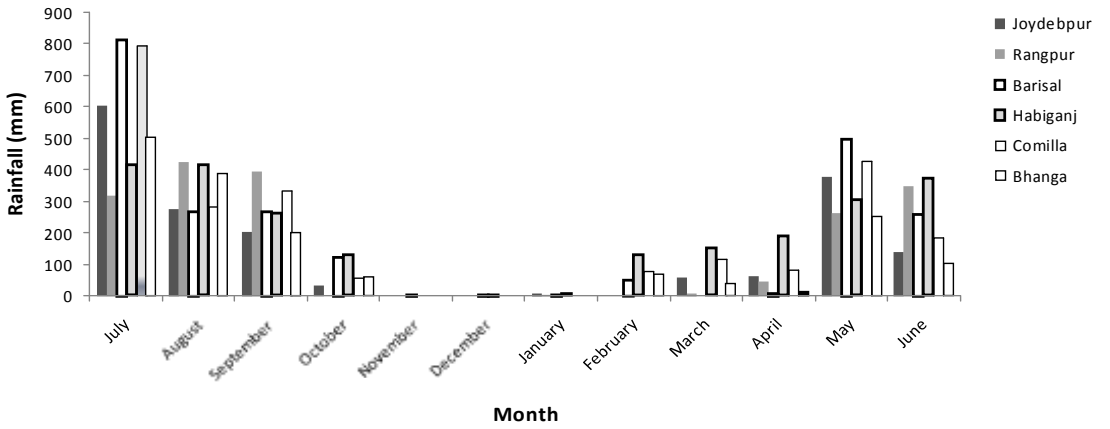

Fig. 2. Monthly total rainfall (mm) of Gazipur and five Regional Stations, BRRI during 2015-16.

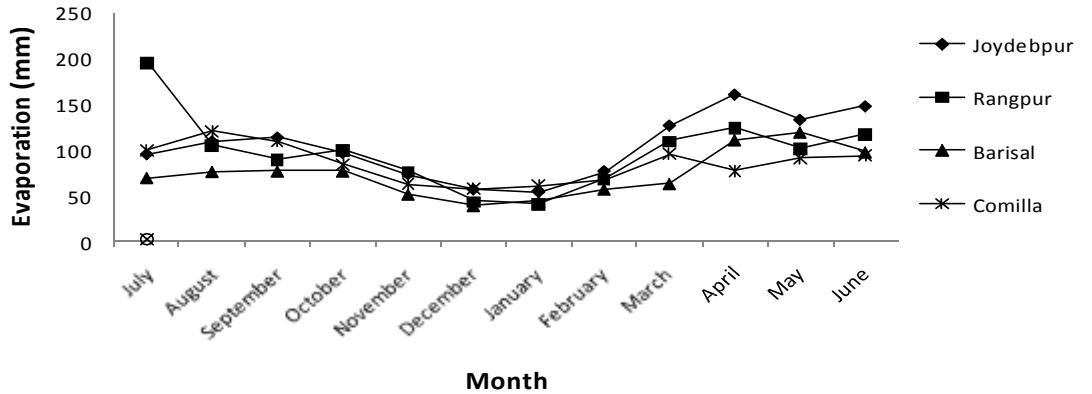

Fig. 3. Monthly total evaporation in Gazipur and five regional stations of BRRI, 2015-16.

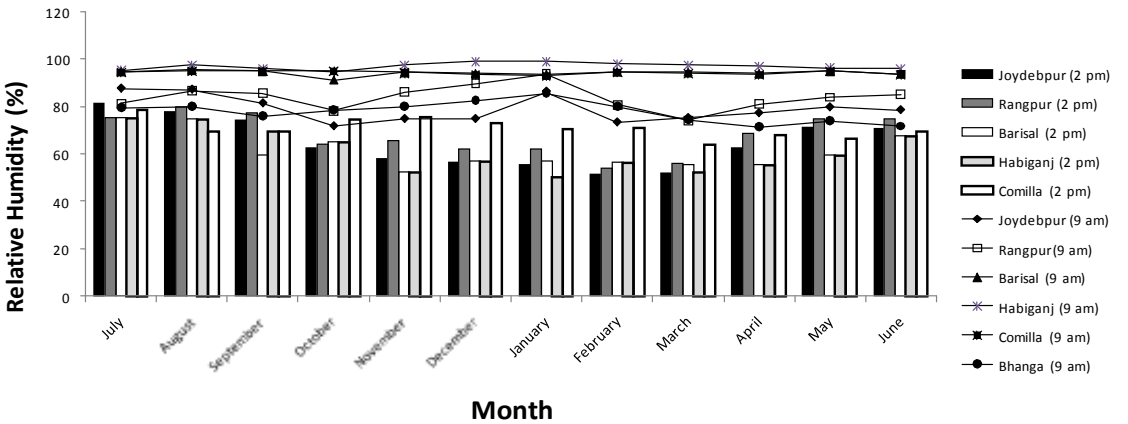

Fig. 4. Monthly mean relative humidity (RH) at 9.00am and 2 pm in Gazipur and five Regional Stations, BRRI during 2015-16.

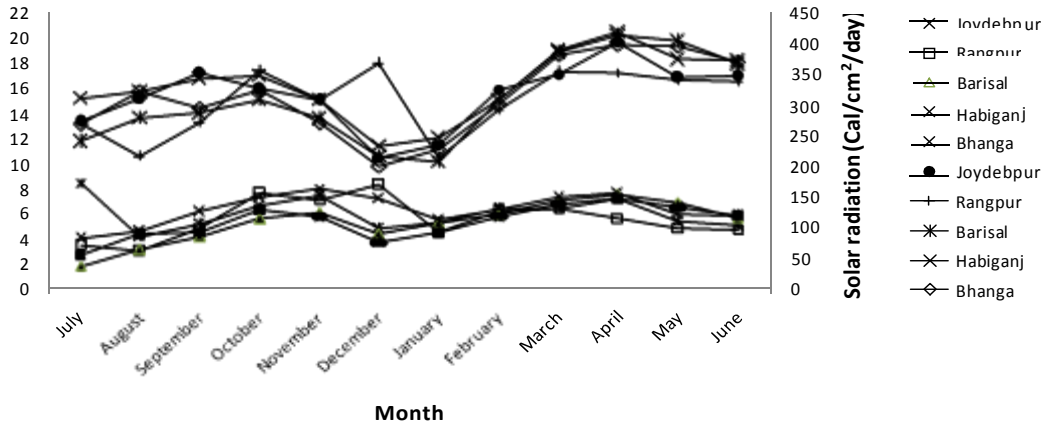

Fig. 5. Monthly mean solar radiations (above lines) and mean bright sunshine hour (lower lines) in Gazipur and five regional stations, BRRI during 2015-16.

Abbreviation and acronyms

AEZ	=	agroecological zone
ALART	=	advanced line adaptive research trial
ARIMA	=	autoregressive 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 BC	=	Blast
BCR	=	backcross
BI	=	benefit-cost-ratio
BLB	=	blast
BLB	=	bacterial leaf blight
BINA	=	bacterial leaf blight
BMDA	=	Bangladesh Institute of Nuclear Agriculture
BPH	=	Barind Multi Purpose Development Authority
BR	=	brown planthopper
BS	=	Bangladesh rice
BRRI	=	breeder seed
BWDB	=	Bangladesh Rice Research Institute
BShB	=	Bangladesh Water Development Board
	=	bacterial sheath blight
CAB	=	Commonwealth Agriculture Bureau
ck	=	check
cm	=	centimetre Carabid
CDB	=	beetle cytoplasmic male
CMS	=	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 green
GLH	=	leafhopper Government of
GoB	=	Bangladesh Genetic
GRS	=	Resources and Seed green
GSR	=	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
MAS	=	marker assisted selection
ML	=	monogenic line
MLT	=	mulitlocation trial
MMT	=	million metric tons
MR	=	moderately resistant
MT	=	maximum tillering
MV rice	=	modern variety rice
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
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
TSP	=	triple superphosphate
USG	=	urea super granule
WBPH	=	white-backed planthopper
WS	=	wet season

WSR	=	wet-seeded rice
WTR	=	weed tolerant rice
wt	=	weight
YSB	=	yellow stem borer

Plant Breeding Division

SUMMARY

For developing improved rice varieties under different ecosystems, 516 crosses were made and 437 crosses were confirmed as true F_1. From segregating generations' (F_2-F_7), in total 31,597 superior genotypes were selected. Also, 1,100 fixed lines were isolated from advanced segregating generations. A total of 434 genotypes from observational trial and 451 advanced breeding lines were selected from yield trials. A total of 105 germplasms from different biotic and abiotic screening nurseries were selected to use in the breeding programme.

Three promising genotypes viz HUA565 for favourable RLR ecosystem, BR7941-41-2-2-2-4 and BR7941-116-1-2-1 for tidal non-saline wetland were evaluated during T. Aman 2015-16 by National Seed Board of Bangladesh (NSB) field evaluation team and have been released as BRRI dhan75, BRRI dhan76 and BRRI dhan77 respectively. BRRI dhan75 produced about 1.0 t/ha higher yield than BRRI dhan33 with similar growth duration while BRRI dhan76 and BRRI dhan77 had yield potential up to 5.0 t/ha under tidal non-saline wetland condition. Another promising genotype IR77092-B-2R-B-10 having dual tolerance (salinity + submergence) ability, was also evaluated by NSB field evaluation team in T. Aman 2015-16 and it has been recommended as BRRI dhan78 for T. Aman season by the National Technical Committee (NTC) of NSB. This variety showed 6-8 dS/m water salinity tolerance in whole life cycle and 14 days complete submergence at different coastal regions of Bangladesh in the proposed variety trial (PVT). It produced 4.4 t/ha grain yield with 135 days growth duration. Another proposed variety (BR7697-15-4-4-2-2) with premium quality grain yielded 0.96 t/ha higher with 13 days earlier in maturity than the check variety BRRI dhan37 in a PVT during T. Aman 2015-16. This proposed variety is slightly aromatic and it has been recommended by the NSB field evaluation team to release as a variety.

VARIETY DEVELOPMENT

Upland rice (Aus). Major thrust was given to develop varieties in combination of multiple traits viz 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. In total, 28 crosses were made using 22 parents and 18 crosses were confirmed as true hybrid. Eight hundred thirty-three progenies and 67 fixed lines were selected from pedigree nurseries. Sixteen genotypes were selected from observational trial (OT). Thirteen advanced lines were selected from PYT. Five lines from RYT were considered for further evaluation. Thirty-five Chinese genotypes were evaluated and five entries (2015 SA 4, 2015 SA 5, 2015 SA 8, 2015 SA 15 and 2015 SA 16) were selected for further evaluation.

Transplant Aus rice. The project aimed to develop short duration (105-110 days), high yield potential genotypes having tolerance to lodging and heat (high temperature) at reproductive phase, pre-harvest sprouting and good grain quality. In total, 29 crosses were made using 19 parents and 899 F_1 seeds were obtained; seven crosses were confirmed as true hybrid; 387 progenies and 61 fixed lines were selected from pedigree nurseries. Forty-one entries were selected from observational trial (OT) and fifteen advanced lines were selected from PYT on the basis of homogeneity with respect to plant height, phenotypic acceptability at vegetative and maturity stages. NERICA10 pure line (Nerica10-7-PL2-B) was recommended by advanced line adaptive research trial (ALART) and will be conducted proposed variety trial (PVT) in T Aus 2007 to release as a new variety.

Improvement of rice for shallow flooded environment. The major objectives were to develop improved genotypes with slow elongation for shallow flooding condition (1.0 m flood depth). Fifteen crosses were made involving 22 parents and 1807 F_1 seeds were obtained. Six crosses were confirmed as true hybrid. Totally 27 segregating populations were bulked. In observational yield trial conducted under rainfed condition, four entries were selected having grain yield ranging from 3.90 to 4.38 t/ha. In advanced yield trial under rainfed condition, BR8159-20-8-5-8-2 gave the highest grain yield (5.61 t/ha) with 142 days growth duration. Snorkel genes conferring elongation ability were found in 14 genotypes out of 24 such as PCR89350-B-R-3-1-2-1, Bajail 65, Horinga Digha, Hijol Digha, Laxmi Digha, Lal Digha, HbjAVIII,

HbjAIV, HbjAII, RD 19, Jole Kumari, Gour Kajol, Fulkari and Lal Khama. Seeds of the 24 local cultivars were increased and genetic purity was maintained.

Rainfed lowland rice (RLR). Efforts were made for the development of genotypes superior to standard varieties and adaptable to rainfed low land environment in T. Aman season. In the reporting year, 49 crosses were made, 19 crosses were confirmed and 1213 plants were selected from 11 F_2 populations. From pedigree nursery 729 segregating progenies and 114 fixed lines were isolated. Seventy-nine genotypes from OT, 14 genotypes from IRLON, 54 genotypes from PYT, 21 genotypes from SYT, five genotypes from AYT and two lines from RYT were selected.

Tidal submergence tolerant rice (T. Aman). The aim of the project was to develop high yielding varieties adaptable to tidal non-saline condition in the southern districts. A proposed variety trial conducted during T. Aman 2015-16 showed that BR7941-41-2-2-2-4 and BR7941-116-1-2-1 could give yield up 5.0 t/ha (Table 1) in tidal non-saline wetland condition. Table 2 presents the grain characteristics of these breeding lines. NSB approved these lines to release as BRRI dhan76 and BRRI dhan77 respectively.

Salt tolerant rice (T. Aman and Boro). This programme emphasized on the development of salt tolerant rice variety suitable for the saline prone areas of coastal districts in T. Aman and Boro seasons. Twenty-six and 39 crosses were made for T. Aman and Boro season respectively. A total of 29 F_1s for Aman and 51 F_1s for Boro season were confirmed and selected. Nineteen F_2 populations were grown and 250 progenies were selected and bulked crosswise. Eight hundred forty progenies and 30 fixed lines were selected from pedigree nurseries (F_3-F_6) in T. Aman season. Bulk progenies were selected from 25 F_2 populations. Also, 720 progenies and 40 fixed lines were selected from pedigree nurseries (F_3-F_6) of Boro season. Fifteen advanced lines were selected from 69 genotypes in observational trial (OT). From a preliminary yield trial conducted with 30 genotypes along with two tolerant checks BRRI dhan61 and BRRI dhan67 and one sensitive check BRRI dhan28, nine entries viz BR9154-2-7-1-2, BR9154-3-2-4-7, BR8980-B-1-1-1, BR8980-B-1-3-5, BR8992-B-18-2-26, BR8980-3-4-1-3, IR 87870-6-1-1-1-1-B, IR 87872-7-1-1-2-1-B and IR12T133 were selected based on salt tolerance, earliness and high yield for further evaluation to confirm yield potential under stress condition. In T. Aman 2015-16, eight entries (out of 22 genotypes) were selected from PYTs.

Table 1. Yield and agronomic performance of BRRI dhan76 and BRRI dhan77 in the proposed variety trial (PVT), T. Aman 2015-16.

Designation	Seedling height (cm)	Plant height (cm)	Growth duration (days)	Grain yield (t/ha)									
				L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean
BRRI dhan76 (BR7941-41-2-2-2-4)	54	134	163	6.14	6.40	3.64	5.70	4.52	3.75	5.12	5.13	4.93	5.04
BRRI dhan77 (BR7941-116-1-2-1)	56	133	154	6.14	6.11	4.02	5.57	4.07	4.65	4.76	4.76	5.00	5.01
BRRI dhan44 (ck)	38	112	160	5.74	5.38	3.07	3.75	3.27	3.56	4.79	4.68	4.66	4.32
Sadamota	66	145	173	4.44	4.12	2.64	3.92	2.80	2.80	2.95	4.81	4.11	3.62
Dudkolom	66	140	155	4.75	5.35	3.07	2.38	3.10	3.68	4.02	2.60	3.50	3.61
Planting date				22/8	22/8	19/8	22/8	16/8	20/8	20/8	21/8	4/9	

Seeding date: 4 July 2015. L1: Nolchiti (Jhalakathi), L2: Dumki (Patuakhali), L3: Sadar (Pirozpur), L4: Kawkhali (Pirozpur), L5: Zianagar (Pirozpur), L6: Rajopara (Patuakhali), L7: Sikanderkhali (Patuakhali), L8: Patharghata (Barguna), L9: Bakerganj (Barisal).

Table 2. Grain characteristics of the proposed variety.

Designation	Milling yield (%)	Head rice yield (%)	Decorticated grain				ER*	1000 grain wt (g)	Protein (%)	Amylose (%)
			Length (mm)	Breadth (mm)	L-B ratio	Size and shape				
BR7941-41-2-2-2-4 (BRRI dhan76)	73.0	67.5	5.3	2.3	2.3	MB	1.6	25.6	8.2	26.1
BR7941-116-1-2-1 (BRRI dhan77)	71.5	61.4	5.4	2.5	2.1	MB	1.5	29.3	8.5	26.3
BRRI dhan44 (ck)	71.0	62.6	5.8	2.6	2.2	MB	1.5	26.6	8.8	27.2

*ER: Elongation ratio.

Saltol and *Sub1* QTLs were pyramided into BRRI dhan49 through marker assisted selection. Recovery of parental genome in the BRRI dhan49-*Saltol* (BR10050-32-181-32-263) was 98.2% (Fig. 2). Two breeding lines IR77092-B-2R-B-10 and BR9377-9-21-3B showed 6-8 dS/m water salinity tolerance in its whole life and 14 days complete submergence with BRRI dhan41 and BR23 as standard checks at different coastal regions of Bangladesh. This variety showed tolerance to 6-8 dS/m water salinity from panicle initiation (PI) to booting stage at different coastal regions of Bangladesh in the PVT. These lines have dual tolerance (salinity+submergence) ability. In a PVT conducted under salt stress condition during T. Aman 2015-16, these breeding lines yielded 4.4-4.5 t/ha with 135 days and 142 days growth duration, respectively. IR77092-B-2R-B-10 has been recommended by the NTC of NSB to release as BRRI dhan78. Table 3 shows the agronomic performance of the two proposed varieties and Figure 1 shows the levels of salinity. Table 4 presents grain characteristics of the materials.

A PVS preference analysis conducted during Boro 2015-16 at three different upazilas in Satkhira identified PVS-7 (IR86385-117-1-1-B), PVS-9 (IR58443-6B-10-3) and PVS-8 (BR8371-18-20-52-124) as the best materials. PVS-7 (IR86385-117-1-1-B) was the most preferred genotype by both male and female farmers because of more number of grains in the panicle, higher yield and more number of tillers, compact panicle under salt stress condition. This line performed consistently better than the other in all three locations.

Premium quality rice (PQR). Efforts were made to develop aromatic and non-aromatic fine quality rice with national (Kalizira/Chinigura/BRRI dhan34 type) and international (Basmati/Banglamati/Balam type) standards for domestic use and export. Experiments were conducted in T. Aman and Boro seasons. In T. Aman, 23 crosses were made, 21 crosses were confirmed and 353 plants were selected from 13 F_2 populations. From pedigree nursery 597 segregating progenies and 60 fixed lines were isolated. Twenty-four genotypes from OT, 22 genotypes from PYT, 16 materials from SYT and two genotypes from RYT were selected for further evaluation in the RYT. BR7697-15-4-4-2-2 yielded 0.96 t/ha higher yield than the standard check BRRI dhan37 with 13 days shorter growth duration in PVT (Table 5). This proposed variety is slightly aromatic and the NSB field evaluation team has recommended to release it as a variety. In Boro, 24 crosses were made while 27 crosses were confirmed and 1,312 plants were selected from 15 F_2 populations. From pedigree nursery 2,743 segregating progenies and 39 fixed lines were isolated. Twenty-five genotypes were selected from OT, three genotypes were selected from PYT, eight materials were selected from SYT and three genotypes were selected from RYT for promoting in ALART.

Table 3. Yield and agronomic performance of the proposed lines in the PVT, T. Aman (Salinity) 2015-16.

Location	Proposed varieties with check					
	IR77092-B-2R-B-10		BR9377-9-21-3B		BRRI dhan41 (ck)	
	Grain yield (t/ha)	Growth duration (day)	Grain yield (t/ha)	Growth duration (day)	Grain yield (t/ha)	Growth duration (day)
Assasuni, Satkhira	4.42	130	4.31	130	3.90	142
Tarali, Kaliganj, Satkhira	4.61	131	4.68	131	4.99	136
Dumuria, Khulna	4.59	130	4.60	130	4.71	138
Rampal, Bagerhat	4.13	153	3.33	159	3.34	156
Paikghacha, Khulna	4.05	144	3.46	153	3.69	148
Debhata, Satkhira	5.36	139	3.63	150	4.16	143
Chokhoria,Cox's Bazar	2.51	148	5.95	158	5.20	157
Subarnachar, Noakhali	4.42	146	4.50	153	4.01	154
Ghotkhali, Barguna	3.75	133	4.06	143	3.91	144
Patharghata, Barguna	3.86	137	4.37	139	3.86	139
Kalapara, Patuakhali	6.89	133	6.40	133	5.31	135
Sarankhola, Bagerhat	4.46	128	4.91	130	5.43	128
Mean	4.42	135	4.51	142	4.38	143

Table 4. Grain characteristics of the proposed variety.

Designation	Milling yield (%)	Head rice yield (%)	Decorticated grain Length (mm)	Breadth (mm)	L-B ratio	Size and shape	Chalkiness	ER*	IR*	Protein (%)	Amylose (%)
IR77092-B-2R-B-10 (BRRI dhan78)	69.4	63.3	5.4	2.2	2.4	MB	Tr/Wb_5	1.4	2.9	8.0	25.2
BR9377-9-21-3B	71.6	67.0	5.7	2.5	2.3	MB	Tr/Wc_5	1.5	3.1	6.1	27.5

*ER: Elongation ratio, IR: Imbibition ratio, Tr-Translucent, Wb-White belly, Wc-White center.

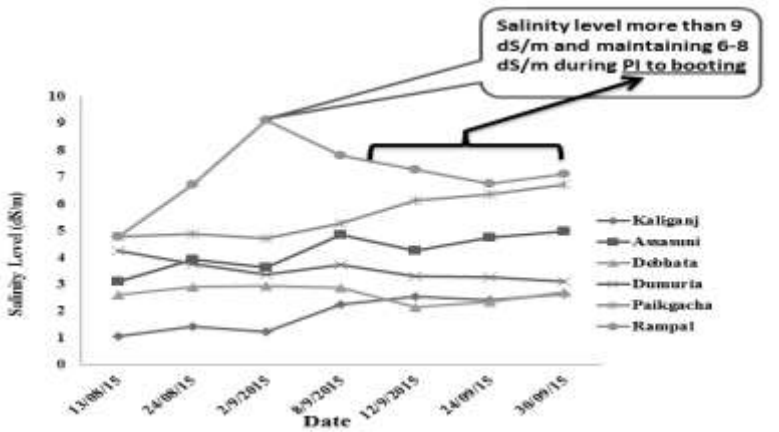

Fig. 1. Water salinity levels of different experimental locations in proposed variety trials, T. Aman 2015-16.

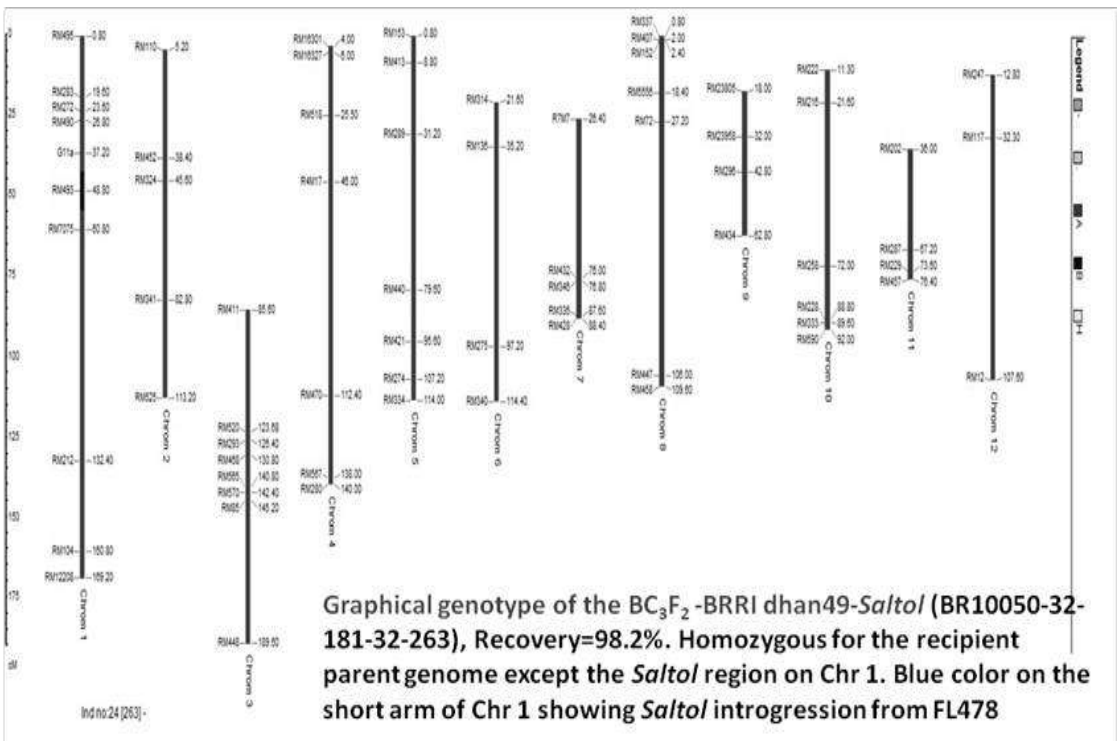

Fig. 2. Marker assisted introgression of *Saltol* QTL into BRRI dhan49.

Table 5. Performance of the proposed variety for premium quality rice, T. Aman 2015-15.

Designation	Plant height (cm)	Growth duration (days)**	Grain yield (t/ha)*	Grain characteristics						
				Head rice yield (%)	L-B ratio	Size and shape	Elongation ratio (ER)	Imbibition ratio (IR)	Protein (%)	Amylose (%)
BR7697-15-4-4-2-2	121	136	4.46	65.1	3.2	LS	1.3	3.1	8.5	23.6
BRRI dhan37 (ck.)	130	149	3.50	67.4	3.3	MS	1.2	3.7	10.3	23.8

*Mean of 10 locations (Gazipur, Mymensingh, Satkhira, Sonagazi, Comilla, Rajshahi, Kushtia, Rangpur, Barisal and Habiganj). **Mean of nine locations. Sonagazi is excluded in calculating mean because two times flooding occurred there.

Favourable Boro rice. The major objective of the project was to develop improved genotypes with high yield potential (≥8.0 t/ha), earliness (130-135 days) and acceptable grain quality for favourable irrigated ecosystems in Bangladesh. Thirty-six crosses were made and 15 crosses were confirmed as true F_1. In total, 214 superior individual plants were selected from F_2 populations. From pedigree nurseries 1,229 individual progenies and 66 fixed lines were isolated. Eleven genotypes were selected from OT based on growth duration, yield, and homogeneity in other morpho-agronomic traits. Six breeding lines were selected from PYT. In RYT, BRRI dhan29-SC3-28-28-16-15-HR2 (Com) and BRRI dhan29-SC3-8-HR1 (Com) yielded 0.6 and 0.4 t/ha higher than BRRI dhan58 with similar growth duration**.** Also, BR8643-6-4-3 yielded significantly higher than BRRI dhan28 with no significant difference in growth duration. In an advanced yield trial of 100 IR lines under multi-environment variety testing programme of IRRI, 12 breeding lines showing 0.6 t/ha to 1.2 t/ha higher yield than BRRI dhan28 with contemporary growth duration were selected for further evaluation.

Cold tolerant rice. The major objective of the project was to develop high yielding rice varieties tolerant to cold injury. Twenty-five crosses were made and 40 crosses were confirmed as true F_1. In total, 409 individual plants were selected from F_2 population based on superior phenotype. From Pedigree nursery, 521 superior individual plants and eight fixed lines were isolated from three crosses of F_3 - F_7 generations. Three genotypes were selected from OT based on growth duration, yield, and homogeneity in other morpho-agronomic traits and superiority in one or more traits over the check variety. From PYT, BR8562-11-2-6-1-1-1, BR8562-11-2-6-1-1-2, BR8562-11-2-6-2-5-2, BR8562-18-1-2-3-4-2 and BR8564-32-1-1-6-1-1 showing 0.2-0.9 t/ha higher yield than BRRI dhan28 with similar growth duration were selected. In RYT BR7812-19-1-6-1-P2 and BR7812-19-1-6-1-P4 yielded 6.4 t/ha and 6.2 t/ha respectively, while the check varieties BRRI dhan28 and BRRI dhan29 yielded 5.8 t/ha and 6.6 t/ha with growth duration of 142 days and 156 days, respectively. In total 8,583 individual progenies were harvested from rapid generation advanced of segregating populations of different generations. Also, 350 progenies tolerant to cold at seedling stage were selected from CS2 pedigree nurseries. In a validation trial, with four genotypes conducted at 10 IAPP sites in Rangpur and Nilphamari districts BR7812-19-1-6-1-P4 showed comparatively higher yield (0.6 t/ha) over check variety of BRRI dhan28 with almost similar growth duration. Three main effective QTLs (qCTS1.1, qCTS3, and qCTS12) significant at the 5% level of threshold LOD and two minor effect QTLs (qCTS11.4 and qCTS11.2) that were declared at 2.5 LOD were detected from a QTLs analysis study of a $F_{2:3}$ mapping population derived from a cross between cold susceptible BR1 and cold tolerant BR18 (Table 6). In a marker assisted backcross programme to introgress seedling stage cold tolerance from HbjBVI into BRRI dhan28, two plants with RPG value of 89% at BC_2F_1 generation were selected for further backcrossing to produce BC_3F_1 seeds. Figure 3 shows the graphical genotype of one BC_2F_1 plant 132A-3. A total of 200 backcross seeds were produced from these two plants. The seeds will be used for further evaluation to isolate cold tolerant version of BRRI dhan28.

Micronutrient enriched rice. The project aims to develop high yielding rice varieties with improved nutritional quality in terms of higher zinc content in polished grain. The experiments were conducted in T. Aman and Boro seasons. Sixteen single crosses in T. Aman and 42 single crosses in Boro season were made using high zinc elite lines

Table 6. Putative QTLs identified for seedling stage cold tolerance from a $F_{2:3}$ mapping population of BR1×BR18.

[a] QTL name	Chromosome	QTL bordering marker	SM			IM			CIM		
			Peak LOD	[b]R^2 (%)	Additive effect	Peak LOD	R^2 (%)	Additive effect	[c]Peak LOD	R^2 (%)	Additive effect
qCTS1.1	1	RM220 - RM10829	-	-	-	-	-	-	6.14*	50.7	-1.15
qCTS3	3	RM546-RM7	7.38	57.2	-1.85	5.23	45.2	-0.216	4.3*	39.0	-0.54
qCTS11.2	11	RM7283-RM3428	-	-	-	3.51	33.3	-1.37	3.64	34.3	-0.84
qCTS11.4	11	RM254-RM144	4.17	38.1	-0.85	3.42	31.3	1.78	2.92	27.4	-0.8
qCTS12	12	RM27877-RM463	9.61	66.9	2.24	11.41	73.1	2.55	6.5*	52.7	1.58

[a]Individual QTL is designated with "q", an abbreviation of the trait name and the chromosome number on the chromosome. QTLs were declared at LOD>2.5. [b]Portion of phenotypic variation explained by the individual QTL. [C]Significant loci after 1000 permutation analysis at P<0.05 with LOD (Logarithm of Odds) = 4.327. [ns]Null significant showed after permutation analysis.

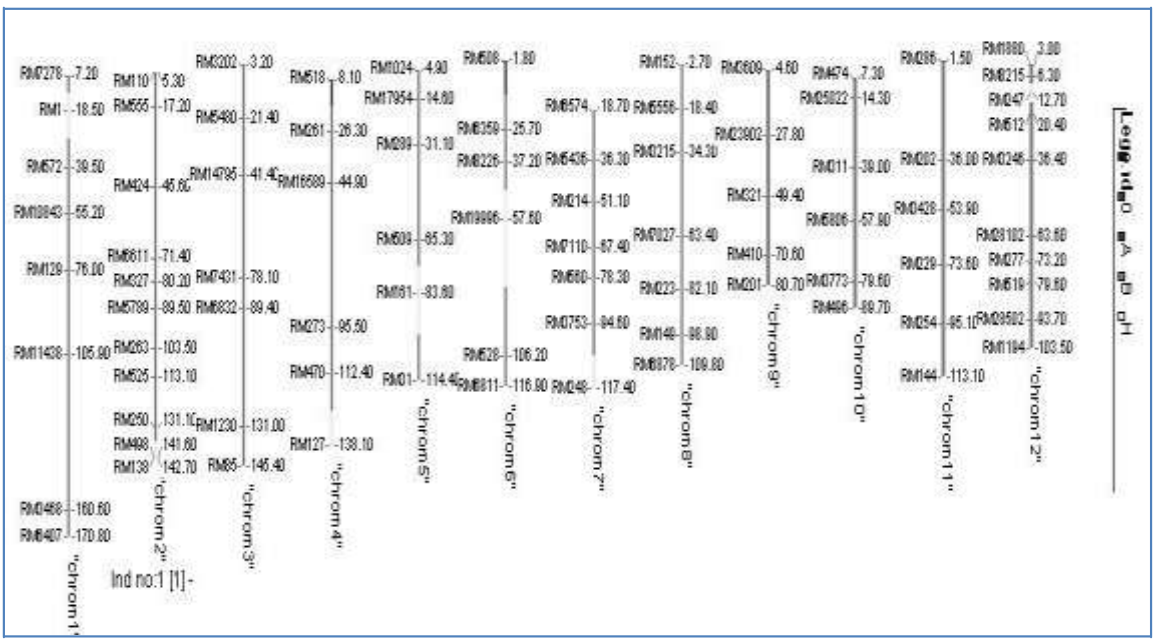

Fig. 3. Graphical genotype of plant no. 132A-3 of BC_2F_1 generation showing homozygous loci for BRRI dhan28 (green), heterozygous loci (yellow) and homozygous HbjBVI loci (red).

as parents. Six and 11 single crosses involving high zinc germplasm were made in T. Aman and Boro seasons, respectively. Fourteen backcrosses, double crosses or three way crosses for T. Aman and 11 for Boro season were also made. Forty-one crosses in each of T. Aman and Boro seasons were confirmed as true F_1s. A total of 2029 individual progenies and 103 fixed lines in T. Aman season and 820 individual plants and 192 fixed lines in Boro season were isolated from pedigree nurseries. From OT, 10 uniform genotypes with yield potential 4.6 to 6.7 t/ha were selected considering yield advantage over the check varieties during T. Aman season, whereas in Boro season, 28 uniform entries having yield potential of at least 0.5 t/ha higher with growth duration similar or less than the check varieties were selected. In T. Aman season three breeding lines (BR7528-2R-19-16-RIL-14, BR7528-2R-19-HR16-20-6, and BR7528-2R-19-16-RIL-1) from PYT, one breeding line from SYT and two breeding lines (BR7528-2R-HR16-12-23-P1 and BR7528-2R-HR16-12-3-P1) from RYT showing significantly higher grain yield than the check varieties were selected. In Boro season, 26 breeding lines showing at least 0.5 t/ha yield advantage with similar or shorter growth duration than the check varieties were selected from PYT. The selected genotypes yielded from 5.3 to 8.8 t/ha

with a growth duration of 141-150 days. Also, two breeding lines (BR8631-12-3-5-P2 and BR 8631-12-3-6-P3) having significant higher yield with no significant difference in growth duration than BRRI dhan28 and one breeding line (BR7831-59-1-1-4-5-1-9-P1) with red pericarp and no significant difference in yield, growth duration and, grain size and shape from the check variety (BRRI dhan28) were selected from SYT and RYT, respectively in Boro season.

Provitamin A enriched rice (Golden rice). The main objective of the project is to develop high yielding rice varieties with enhanced provitamin A content in polished rice grain. Experiments were conducted in T. Aman and Boro seasons. In T. Aus season, 170 transgenic BC_5F_3 GR2-E BRRI dhan29 Golden rice introgression lines were tested in a contained trial in the transgenic screenhouse. At maturity, 13 entries were found very similar to BRRI dhan29 in phenotypes. Although, the average yield/plant of 170 entries was 11.5 g with a range between 6.4 to 27.7 g, which was bit lower than that of BRRI dhan29 (15.6 g), there were still many individual plants in the test entries that yielded significantly higher than BRRI dhan29. In Boro season, a set 23 BC_5F_4 introgression lines selected from contained trial were tested under confined field trial with one null segregant and non-transgenic BRRI dhan29 in the CFT site of BARI farm, Gazipur (Fig. 4). The overall crop of the GR2-E BRRI dhan29 Golden rice was found uniform in phenotype and looked very similar to BRRI dhan29. PCR analysis with event specific primers also showed that all the entries were homozygous for GR2-E locus (Fig. 5). The transgenic lines matured at 147 days on average with the range from 143 -152 days, while the non-transgenic BRRI dhan29 and null segregants matured at 148 days and 146 days respectively. On the other hand, the transgenic lines yielded 6.2 to 7.7 t/ha with an average of 7.0 ± 0.38 t/ha, while the non-transgenic BRRI dhan29 yielded 7.0 t/ha. The total carotenoid content in milled rice after two months of storage at ambient temperature ranged from 8.4-14.4 μg/g with an average value of 11.2 ± 1.12 μg/g.

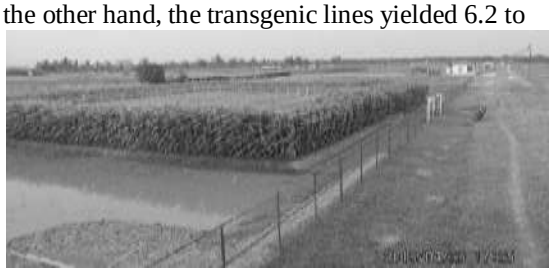

Fig. 4. A wide view of pro-vitamin A enriched GR2-E BRRI dhan29 golden rice crop in the confined field trial showing net installed over the crop to keep away the stray birds.

Insect resistant rice. The main thrust of the project was to develop varieties resistant to brown plant hopper (BPH), white backed plant hopper (WBPH) and gall midge (GM). Twenty-three crosses for T. Aman and 29 crosses for Boro season were made. Nine and 37 crosses were confirmed in T. Aman and Boro seasons. From F_2 populations, 534 progenies in T. Aman, from pedigree nurseries 2100 progenies (1568 for BPH and GM in T. Aman season and 609 for BPH and GM in Boro season) and 30 fixed lines for BPH and GM in T. Aman season were selected from pedigree nursery. Nine genotypes selected from OT, seven lines from PYT-1 and six lines from PYT-2 showing resistance to BPH were selected in T. Aman season. Four genotypes from SYT and two entries from RYT were selected based on yield and agronomic traits in Boro season 2015-16.

Disease resistant rice. Efforts were made for developing varieties resistant to bacterial blight (BB), rice tungro virus (RTV) and blast diseases. Seventeen crosses for BB and six for blast in T. Aman and 23 crosses for BB and five for blast were made in Boro season. Six crosses for BB and six for blast during T. Aman and thirteen crosses for BB and six for blast in Boro were confirmed as true F_1. One hundred fifty-nine resistant progenies from F_2 for BB in T. Aman season and 571 progenies from F_2 for BB in Boro season were selected. Three hundred seventy-three superior progenies for BB, 128 for blast and 35 for RTV were selected in T. Aman whereas, 139 superior progenies from F_3, F_5 and F_6 generations were selected for BB during Boro season. Nine fixed lines for BB, 20 for blast and three fixed lines for RTV were isolated during T. Aman season, while 21 fixed lines were isolated from F_5 and F_6 generation for BB during Boro season. From OT, 15 homogeneous lines for BB and 10 lines for blast in T. Aman, while 20 entries for BB during Boro season showed better yield potential and agronomic performance over the check varieties. From PYT, 11 genotypes were selected for BB and two breeding lines for RTV were selected from

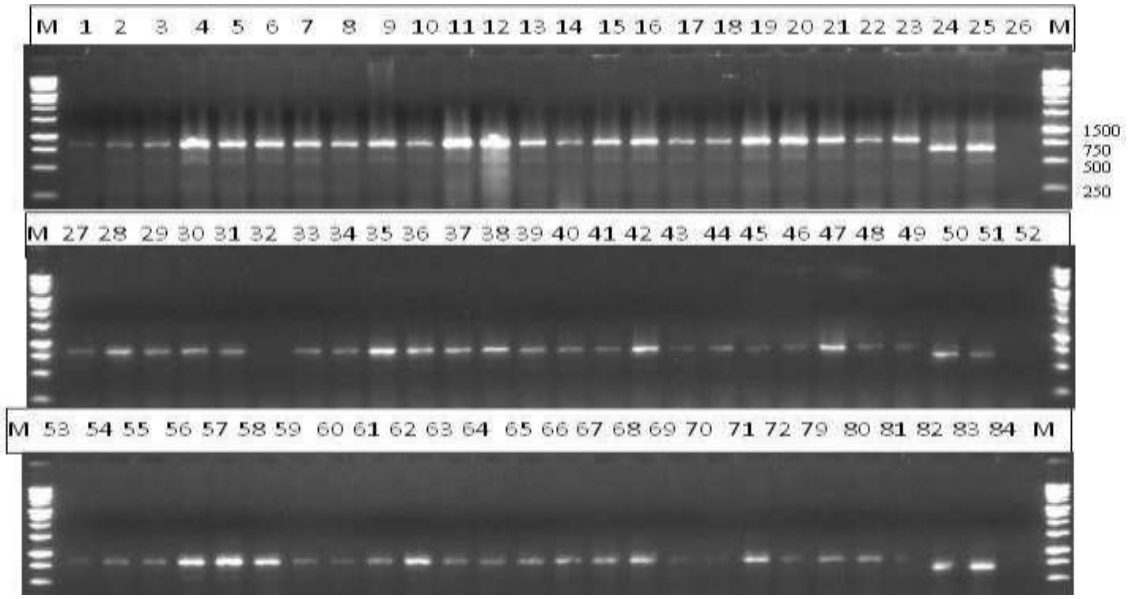

Fig. 5. Gel image of GR2E specific STS marker analysis of the entries tested in CFT, Boro 2016. Lane 1-23, 27-49 and 53-81 represent GR2E BRRI dhan29 introgression lines, lane 24, 50, 82 for null segregant, lane 25, 51, 81 for wild type BRRI dhan29 and lane 26, 51 and 83 for no DNA control.

SYT. Two genotypes for BB and one for blast and three for RTV were selected from RYT during T. Aman season. Two genotypes for BB resistance were selected from each of the trial (PYT, SYT and AYT) during Boro season.

Submergence and water stagnation tolerant rice varieties. The project aims at the development of high yielding rice varieties tolerant to submergence (flash flooding) and medium stagnant water (MSW) stresses in collaboration with IRRI as flash flooding and water stagnation are the major constraints in the rainfed lowland rice ecosystem in Bangladesh. Totally 10 single crosses, three backcrosses and three three-way crosses were made involving 12 parents and 1,463 F_1 seeds were produced. Fifteen crosses were selected and confirmed as true F_1s. Pedigree generations were grown under controlled submergence and medium stagnant water condition of BRRI, Rangpur. A total of 400 tolerant progenies from F_3-F_7 generations and 25 homogygous tolerant lines were isolated from pedigee nurseries. In marker assisted selection, introgression of SUB1 QTL into the genetic background of BR22 was advanced up to BC_5F_1 generation and 95.2% recipient genome was recovered from the best plant BR10190-3-1-20-3 (Fig. 6).

From three OYTs, two PYTs and three SYTs conducted under rainfed conditions, 51 genotypes were selected based on grain yield and growth duration. In PVS trial conducted under both flooded and non-flooded condition, the highest preference score was obtained by BR9158-19-9-6-7-50 for better submergence and water stagnation tolerance, more effective tiller, acceptable grain quality, tall plant type, lodging resistance, long panicle, less disease attack, less sterility and prediction of high yield. The entry BR9158-19-9-6-7-50 also produced highest grain yield (5.0-6.0 t/ha) under multiple flash flooding and water stagnant situation in the farmers field as well as under controlled submerged condition of 18 days. However under non-flooded conditions of four locations, BR9158-19-9-6-7-50 produced 5.34 t/ha grain yield. In 'Head to Head' trial, Sub1-varieties were tested under non-flooded conditions of 3 locations and the highest average grain yield was obtained from BRRI dhan52 being 4.98 t/ha with 144 days growth duration whereas the lowest average growth duration was exhibited by BINA dhan11 (124 days) that yielded 4.06 t/ha.

Drought tolerant rice. The project emphasizes for developing high yielding rice varieties tolerant to drought stresses in the rainfed lowland rice ecosystems in Bangladesh.

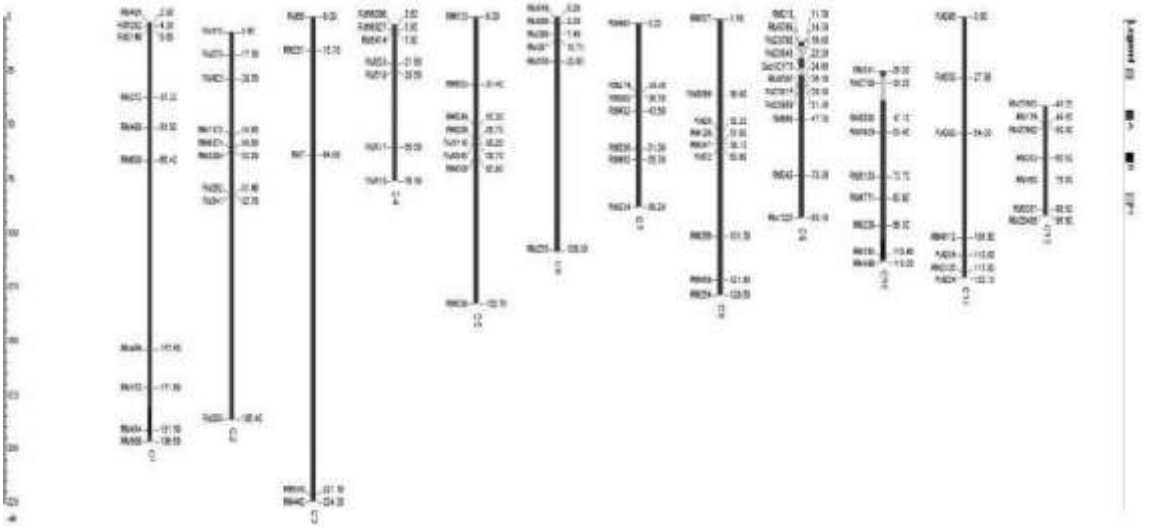

Fig. 6. Graphical genotype of the selected best plant no. BR10190-3-1-20-3 of BC_4F_1 generation which possessed 95.26% recipient parent genetic background.

Experiments were conducted in T. Aman season. In total, 26 crosses were made, 14 crosses were confirmed and 809 plants were selected from 20 F_2 populations. From pedigree nursery 1044 segregating progenies and 62 fixed lines were isolated. In OYT, 25 genotypes performed better than the local and international check varieties in respect to yield under reproductive stage drought condition. From AYT, 11 genotypes were selected based on yield with 100-120 days growth duration.

Water saving and aerobic rice varieties for low water environment. The objective of the project was to develop high yielding rice varieties suitable for limiting water environment. In T. Aman 2015, five single crosses were made involving seven parents and 147 F_1 seeds were produced. Seven crosses were selected and confirmed as true F_1s. Pedigree populations were grown under AWD condition of BRRI, Gazipur. A total of 143 tolerant progenies from F_2 and F_4 generations were selected and preserved. From four OYTs conducted under AWD conditions, 57 genotypes were selected based on grain yield and growth duration. Five nematode resistant breeding lines were selected based on grain yield and growth duration. In Boro 2015-16, nine crosses were selected and confirmed as true F_1s. Pedigree generations were grown under AWD condition of BRRI, Gazipur. A total of 36 progenies from F_3 and F_5 generations were selected and preserved. From three OYTs, one SYT and two AYTs conducted under AWD condition, 56 genotypes were selected based on grain yield and growth duration. Based on average data over five locations in late Boro trials, the highest grain yield was produced by BRRI dhan58 (5.67 t/ha) followed by BRRI dhan45 (5.55 t/ha) and BRRI dhan48 (5.42 t/ha). In these trials, the average growth duration exhibited by these three varieties viz. BRRI dhan58, BRRI dhan45, BRRI dhan48 were 115, 102, 107 days respectively.

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, twelve genotypes were selected on basis of yield, plant type, grain quality, homogeneity and other agronomic traits from OT. Five genotypes from PYT#1 and two genotypes from PYT# 2 were selected. Four genotypes from SYT, eight genotypes from RYT#1 and three genotypes from RYT#2 were selected. A candidate variety, HUA565 was evaluated by NSB and released as variety BRRI dhan75 for T. Aman season. It can produce about 1.0 t/ha higher yield than BRRI dhan33 with similar growth duration (Table 7). In Boro season, 18 fixed lines were selected from OT as compared with the check variety. Seven genotypes from PYT#1 and five from PYT#2 were selected. Five from SYT#1 and four from SYT#2 were also selected.

Table 7. Performance of BRRI dhan75 on the proposed variety trial, development of Green Super rice, T. Aman, 2015-16.

Designation	Plant height (cm)*	Growth duration (day)*	Grain yield (t/ha)*	Grain characteristics					
				Head rice yield (%)	L-B ratio	Size and shape	Elongation ratio	Protein (%)	Amylose (%)
BRRI dhan75 (HUA 565)	104	117	5.37	65.6	2.7	LB	1.2	9.2	23
BRRI dhan33 (ck)	100	118	4.48	65.9	2.0	SB	1.5	8.5	25

*Mean of nine locations (Godagai of Rajshahi, Rangpur, Satkhira, Kushtia, Sonagazi, Habiganj, Mymensingh, Comilla and Gazipur).

International Network for Genetic Evaluation of Rice (INGER). This project focused on sharing and use of germplasm and breeding lines through international platform for the acceleration of genetic improvement of rice varieties. Totally, 100 germplasms from 12 INGER nursery sets were selected to use in different breeding programmes either as parents or for direct use in the breeding pipeline.

Biotechnology Division

SUMMARY

Twenty experiments were conducted under eight projects during the reporting period. One hundred and sixteen doubled haploid green plants were regenerated from anther culture. For future anther culture programme, 61 crosses were made and 6,354 F_1 seeds were harvested. During Aus 2015 and Boro 2015-16, 41 homozygous pedigree lines were selected from 119 pedigree lines. During T. Aman 2015, 41 homozygous lines were bulked from 183 pedigree lines. During T. Aman 2015 and Boro 2015-16, 35 double haploids were evaluated in OT and among them 17 lines were selected. In 2015-16, thirty-two advanced lines were evaluated in four PYTs and 15 lines were selected from them. In T. Aman 2015, fifteen advanced lines were evaluated in two SYTs and nine lines were selected from them. In transgenic study, eight putative transformants (T_3 generation) of BRRI dhan29 were confirmed by *GlyI* and *GlyII* gene specific primer. During the reported year, 41 materials developed under yield enhancing QTL project were evaluated as PYT, SYT and RYT. Among them seven, three and nine lines were selected for SYT, RYT and ALART respectively. In total, 112 polymorphic SSR markers were identified from salt tolerant QTL study. Genotyping were completed with 37 polymorphic SSR markers of a mapping population derived from BRRI dhan29/ IR4630-22-2-5-1-3 cross. QTL mapping population for taller seedling height was developed by crossing between BR11/Shadamota and 677 F_1 seeds were harvested from this cross. A total of 99 SSR markers were identified as polymorphic from parental survey. Nine BB pyramided BRRI dhan29 lines having two resistant genes (*Xa4* and *Xa21*) were evaluated as PYT during Boro 2015-16 and five lines were selected depending on the phenotypic acceptability, yield performance and BB scoring. For the gene cloning study, *Porteresia coarctata* plants were treated with 100 mM NaCl salt for seven days and then RNA was extracted from the salt treated plants.

DEVELOPMENT OF DOUBLE HAPLOID RICE THROUGH ANTHER CULTURE

Low glycemic index (GI) rice variety. A total of 55,843 hybrid anthers from 21 crosses were plated in N6 media (Table 1). In total, 822 calli were obtained. The highest number of calli (290) was obtained from hybrid anthers of MR219/Kanaklata. In total, 60 green plants were regenerated from four crosses. Besides, 1,058 F_1 seeds were harvested from 22 crosses for future anther culture programme.

Salt tolerant rice variety. A total of 51,543 hybrid anthers from seven crosses were plated in N_6 media and 217 calli were obtained from them (Table 1). The highest number of calli (88) was obtained from hybrid anthers of BRRI dhan28/BRRI dhan61 cross. Five and eight green plants were regenerated from BRRI dhan28/BRRI dhan61and BRRI dhan29/BRRI dhan61 cross respectively (Fig. 1). A total of 1,636 F_1 seeds were harvested from eight crosses for future anther culture programme.

Premium quality rice variety. A total of 34,184 hybrid anthers were plated in N_6 media and 512 calli were obtained. The highest number of calli (232) was obtained from hybrid anthers of BRRI dhan29/Kalizira cross (Table 1). One, 27 and 10 green plants were regenerated from BRRI dhan50/Tepi boro (acc. no. 930), BRRI dhan29/Kalizeera and BRRI dhan50/Bashful crosses, respectively. Besides, 826 F_1 seeds were harvested from eight crosses for future anther culture programme.

Aus rice variety. A total of 17,584 hybrid anthers were plated in N_6 media and 440 calli were obtained. The highest number of calli (128) was obtained from hybrid anthers of BRRI dhan28/NERICA 7 cross (Table 1). Five green plants were regenerated from four crosses BRRI dhan28/NERICA7, BRRI dhan29/ NERICA7, MR219/NERICA7 and BR(Bio)8072-AC5-4-2-1-2-1/NERICA7 respectively. Besides, 760 F_1 seeds were harvested from eight crosses for future anther culture programme.

Swarna type rice variety. Different Swarna rice varieties were collected from BRRI RS, Rangpur during T. Aman 2015. Sixteeen crosses were made using three Swarna genotypes and three BRRI varieties. A total of 2,074 F_1 seeds were harvested for future anther culture programme.

DEVELOPMENT OF RICE VARIETY THROUGH SOMACLONAL VARIATION

Somaclone using EMS treated rice seed. Three hundred seeds of BR11, BRRI dhan29, BRRI dhan48, BR8072AC5 and Tilbazal were used in

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

Cross combination	No. of anthers plated	No. of calli obtained	No. of green plants regenerated
	For low GI experiment		
MR219/BR16	4539	7	7
MR 219/Kanaklata	7668	290	19
BRRI dhan29/Kanaklata	3197	196	31
MR219*^{3}/BR16	2551	21	3
	For salinity experiment		
BRRI dhan28/BRRI dhan61	17438	88	5
BRRI dhan29 /BRRI dhan61	4487	83	8
	l or premium quality experiment		
BRRI dhan50/Tepiboro	3805	99	1
BRRI dhan29/Kalizeera	6799	232	27
BRRI dhan50 /Bashful	11012	52	10
	For Aus experiment		
BR28\NERICA7	5129	128	1
BR29\NERICA7	980	1	1
MR219\NERICA7	4106	103	1
BR8072-AC5-4-2-1-2-1\NERICA7	3440	84	2
Total			116 green plants

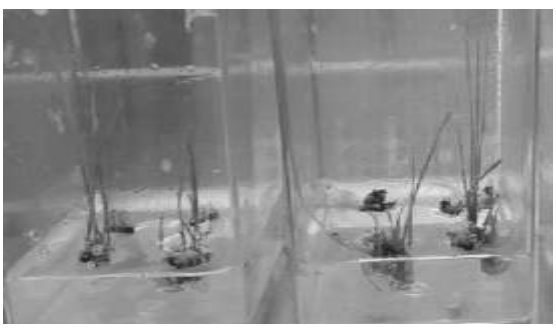

Fig. 1. Anther culture derived plantlets from BRRI dhan29/BRRI dhan61 cross.

this study. The highest number of calli were obtained from BRRI dhan48 (168) followed by BRRI dhan28 (102) and BRRI dhan29 (86) respectively. Whereas the highest regeneration was observed in BRRI dhan29 (24) followed by BRRI dhan48 (18) and BRRI dhan28 (17) respectively. However, the highest numbers of green plants were obtained from BRRI dhan48 (57).

FIELD PERFORMANCE OF TISSUE CULTURE DERIVED LINES

Progeny selection. In Aus 2015, 21 homozygous pedigree lines were selected from 69 pedigree lines. During T. Aman 2015, 41 homozygous lines were bulked from 183 pedigree lines for further evaluation. In Boro 2015-16, 20 lines were selected from 50 pedigree lines for further evaluation.

Observational trial (OT). In T. Aman 2015, a total of 11 doubled haploids were grown in an observational trial with standard checks to select agronomically desirable and high yield potential materials. Among them six double haploid lines were selected depending on the growth duration and comparable yield with checks. In Boro 2015-16, twenty-four materials were evaluated with standard checks. Eleven materials were selected depending on the duration and comparable yield with checks.

Preliminary yield trial (PYT). In T. Aman 2015, twenty-one doubled haploids were evaluated with standard checks in three PYTs and among them 10 lines were selected for further evaluation (Tables 2, 3 and 4). On the other hand, during Boro 2015-16 season 11 advanced breeding lines were evaluated with standard check and four lines were selected depending on the duration and comparable yield with checks (Table 5).

Secondary yield trial (SYT). In T. Aman 2015, fifteen doubled haploids were evaluated with standard checks in two SYTs and among them nine lines were selected for further evaluation as RYT (Tables 6 and 7).

Regional yield trial (RYT). Three doubled haploid lines were evaluated in T. Aus 2015 with standard check. None of them was selected.

Advanced line adaptive research trial (ALART). In Boro 2015-16, two ALART trials

Table 2. Agronomic characteristics of doubled haploids during T. Aman 2015 (PYT-1).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)8018-AC3-2-2-1	126	115	4.35
BR(Bio)8018-AC6-2-2-2	121	117	4.03
BR(Bio)8018-AC12-4-1-5	109	125	5.50*
BR(Bio)8018-AC14-4-3-6	134	125	5.51*
BR(Bio)8019-AC2-1-2-13	114	125	3.93
BR(Bio)8019-AC3-1-3-14	107	126	4.38
BR(Bio)8019-AC13-1-2-17	105	124	4.50
BR(Bio)8019-AC16-1-3-20	125	126	3.97
BRRI dhan33 (ck)	102	119	4.14

Eight lines were evaluated and two lines were selected. *=selected.

Table 3. Agronomic characteristics of doubled haploids during T. Aman 2015 (PYT-2).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)8009-AC13	104	123	4.00
BR(Bio)8009-AC15	119	128	5.19*
BR(Bio)8009-AC16	117	124	5.12*
BR(Bio)8009-AC20	113	128	5.25*
BR(Bio)8009-AC23	113	128	5.16
BR(Bio)8009-AC25	124	124	5.17*
BR(Bio)8009-AC26	123	127	5.20
BRRI dhan49 (ck)	101	134	5.34
BRRI dhan39 (ck)	105	123	4.33

Seven lines were evaluated and four lines were selected. *=selected.

Table 4. Agronomic characteristics of doubled haploids during T. Aman 2015 (PYT-3).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)8011-AC3-4-1-2	130	125	5.23
BR(Bio)8011-AC3-4-1-4	128	125	5.05
BR(Bio)9777-26-4-3	104	127	5.33*
BR(Bio)9777-26-4-1	105	126	5.42*
BR(Bio)9777-113-12-5	102	127	5.26*
BR(Bio)9777-106-7-4	112	124	4.59*
BRRI dhan33 (ck)	108	120	4.69
BRRI dhan39 (ck)	107	123	4.79

Six lines were evaluated and four lines were selected. *=selected.

Table 5. Agronomic characteristics of advanced breeding materials during Boro 2015-16 (PYT).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)9777-26-4-3	100	155	7.77
BR(Bio)9777-26-4-1	103	154	5.66
BR(Bio)9777-41-6-1	104	159	8.17
BR(Bio)9777-72-12-2	98	156	6.99

Table 5. Continued.

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)9777-79-3-4	101	152	6.08
BR(Bio)9777-79-3-5	101	155	5.98
BR(Bio)9777-106-7-11	97	158	7.36
BR(Bio)9777-106-7-4	104	152	7.30*
BR(Bio)9777-113-12-5	111	155	7.61*
BR(Bio)9777-118-6-4	97	155	8.11*
BR(Bio)9777-120-8-3	98	155	7.49*
BRRI dhan47 (ck)	107	149	6.77
BRRI dhan29 (ck)	104	160	7.89
BRRI dhan58 (ck)	95	155	7.29
CV	2.84	0.53	8.53
LSD	6.24	1.78	1.32

Eleven lines were evaluated and four lines were selected. *=selected.

Table 6. Agronomic characteristics of doubled haploids during T. Aman 2015 (SYT-1).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)8018-AC2-2-2-1	125	120	4.4
BR(Bio)8019-AC4-1-1-3	104	126	5.0*
BR(Bio)8019-AC5-1-2-1	111	127	5.2*
BR(Bio)8019-AC8-1-2-2	106	125	5.3*
BR(Bio)8019-AC9-3-3-1	104	125	5.2*
BR(Bio)8032-AC3-4-1-3	104	126	5.3*
BR(Bio)8032-AC4-1-2-2	107	126	5.1*
BRRI dhan33 (ck)	103	120	4.0
BRRI dhan39 (ck)	107	125	4.8

Seven lines were evaluated and six lines were selected. *= selected.

Table 7. Agronomic characteristics of doubled haploids during T. Aman 2015 (SYT-2).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)7783-AC6-3-2-2-1	107	129	4.55
BR(Bio)7783-AC12-3	104	129	4.99*
BR(Bio)7783-AC13-5	105	129	5.27*
BR(Bio)7783-AC14-5	106	129	5.32*
BR(Bio)9783-AC3-1-3-2	104	127	4.60
BR(Bio)9783-AC5-1-5-2	103	129	4.75
BR(Bio)9783-AC6-2-2-2	106	129	4.51
BR(Bio)9783-AC8-1-4-1	105	129	4.50
BRRI dhan39 (ck)	106	124	4.89
BRRI dhan49 (ck)	100	135	5.20

Eight lines were evaluated and three lines were selected.*=selected.

were conducted by Adaptive Research Division, at 10 locations with three advanced breeding lines (BR(Bio)8072-AC5-4-2-1-2-1, BR(Bio)8072-AC8-1-1-3-1-1 and BR (BE)6158RWBC2-1-2-1-1) which were developed by Biotechnology Division using different biotechnological method.

DEVELOPMENT OF RICE VARIETY THROUGH DIFFERENT METHODS

Wide hybridization followed by embryo rescue. Crossing was carried out using six wild rice and three BRRI varieties. Hybrid embryos were excised from spikelet, 8-12 days after pollination. Embryos were cut from de-husked, sterilized premature seeds and cultured on the media. The cultures were maintained in dark at 25°C until germination. Seedling were kept in growth room until the development of shoot and roots and after that transferred to soil. Among them 17 plants were rescued from four crosses.

Wide hybridization followed by anther culture. BR11, BRRI dhan48 and BR8072-AC8-4-2-1-2-1 were used as recipient and different wild rice were used as donor parent. Thirteen crosses were made and 296 F_1 seeds were harvested for future anther culture programme.

RICE GENETIC ENGINEERING

Salt tolerant transgenic rice. Salt tolerant genes *Gly1* and *GlyII* were introduced into BRRI dhan29 to make it salt tolerant. In 2015-16, eight putative transformants (T_3 generation) of BRRI dhan29 were confirmed by *GlyI and GlyII* gene specific primer (Figs. 2 and 3). Transformation of BRRI dhan29 with *AeMDHAR* salt tolerant gene was done and 100 putative transformed calli of BRRI dhan29 are now in different selection stage.

Drought and salt tolerant transgenic rice. Co-culture and selection of putative transformants were done. In 2015-16, 20 putative transformed calli of BRRI dhan28 are now in regeneration stage. Fifty putative transformed calli of BRRI dhan30 are now in different selection stages.

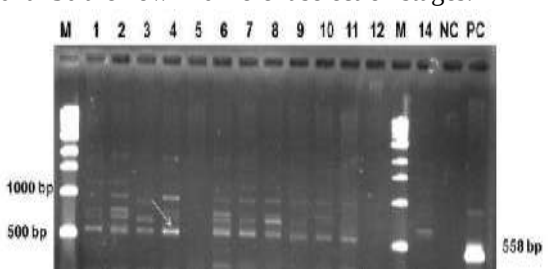

Fig. 2. Putative transformants (T_3 generation) confirmed by *GlyI* gene specific primer. Lane M: 1 kb ladder, lane1-12: Transformed plants, lane14: Untransformed BRRI dhan29, NC: Negative control and PC: Plasmid.

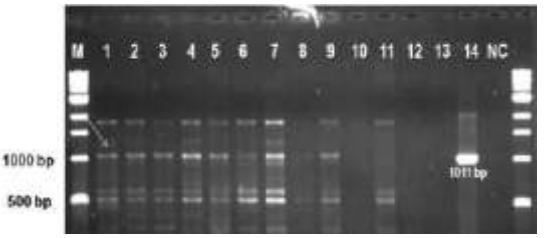

Fig. 3. Putative transformants (T_3 generation) confirmed by *GlyII gene* specific Primer. Lane M: 1 kb ladder, lane1-12: Transformed plants, lane13: Untransformed BRRI dhan29, lane14: plasmid and NC: Negative control.

ALLELE MINING

Identification of yield enhancement QTLs. Three backcrossed populations (BC_2F_2) were developed through backcross breeding method, where BRRI dhan28 and BRRI dhan29 were used as recurrent parent and *Oryza rufipogon* (acc. no. 103404) and *Oryza rufipogon* (acc. no. 105890*)* were used as donor parents. In the reporting year, 41 materials developed under yield enhancing QTL project were evaluated as PYT (Tables 8 and 9), SYT (Table 10) and RYT (Figs. 4, 5 and 6). Among them seven, three and nine lines were selected for SYT, RYT and ALART respectively.

Identification of QTLs for salinity tolerance both at seedling and reproductive stage. A total of 112 polymorphic SSR markers were identified. Genotyping were completed with 37 markers for 121 individuals of BRRI dhan29/ IR4630-22-2-5-1-3 cross.

Identification of QTLs for taller seedling height. QTL mapping population was developed

Table 8. Agronomic characteristics of wide crossed materials during Aus 2015 (PYT-1).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)9785-BC2-9-2-3	114	113	3.66
BR(Bio)9785-BC2-6-2-2	100	110	4.27*
BR(Bio)9785-BC2-120-1-3	102	114	3.68
BR(Bio)9785-BC2-62-2-2	100	111	2.50
BR(Bio)9785-BC2-110-1-2	109	114	3.36
BR(Bio)9785-BC2-110-1-3	108	115	3.35
BR(Bio)9785-BC2-120-2-1	104	113	3.86*
BR(Bio)9785-BC2-147-1-3	113	111	3.59
BR(Bio)9785-BC2-8-4-2	98	108	3.85*
BRRI dhan48 (ck)	100	117	4.40

Nine lines were evaluated and three lines were selected. *selected.

Table 9. Agronomic characteristics of wide crossed materials during Boro 2015-16 (PYT).

Designation	Plant height	Growth duration	Yield (t/ha)
(cm) (day)		BR(Bio)9786-BC2-80-1-1	
103 158 7.90*	BR(Bio)9786-BC2-119-1-2		
108 162 6.38			
BR(Bio)9786-BC2-65-1-1	108	159	8.22*
BR(Bio)9786-BC2-122-1-2	110	159	7.70*
BR(Bio)9786-BC2-142-1-2	111	162	7.56
BR(Bio)9786-BC2-146-2-2	111	162	7.73
BR(Bio)9786-BC2-161-1-2	99	158	7.78*
BRRI dhan29 (ck)	100	162	7.68
CV	0.99	0.00	5.71
LSD	2.51	0.00	1.03

Seven lines were evaluated and four lines were selected. *selected.

Table 10. Agronomic characteristics of wide crossed materials during Boro 2015-16 (SYT).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)9785-BC2-6-2-2	101	141	6.76*
BR(Bio)9785-BC2-19-3-1	101	142	6.30*
BR(Bio)9785-BC2-20-1-3	100	141	6.37
BR(Bio)9785-BC2-27-1-1	115	145	6.30
BR(Bio)9785-BC2-19-3-5	97	141	6.50*
BR(Bio)9785-BC2-62-2-2	87	141	5.95
BRRI dhan28 (ck)	99	141	6.21
CV	8.48	0.00	2.99
LSD	20.73	0.00	0.47

Six lines were evaluated and three lines were selected. *selected.

by crossing between BR11/Shadamota (acc. no. 1576) and 677 F_1 seeds were collected. Parental polymorphism survey was carried out and 99 SSR markers were identified as polymorphic.

Fig. 4. Field view of BR9786-BC2-132-1-3.

Fig. 5. Field view of BR(Bio)9787-BC2-63-2-2 and BR(Bio) 9787-BC2-173-1-3.

Fig. 6. Field view of RYT-1, BR(Bio)9786-BC2-122-1-3, Yield: 7.49 t/ha, GD:153 days.

GENE PYRAMIDING

Gene pyramiding for resistance to bacterial blight. Nine bacterial blight (BB) genes pyramided BRRI dhan29 lines having two BB resistant genes (*Xa4* and *Xa21*) were evaluated as PYT during Boro 2015-16 with standard checks. Among them five lines were selected depending on the phenotypic acceptability, yield performance and BB scoring (Fig. 7).

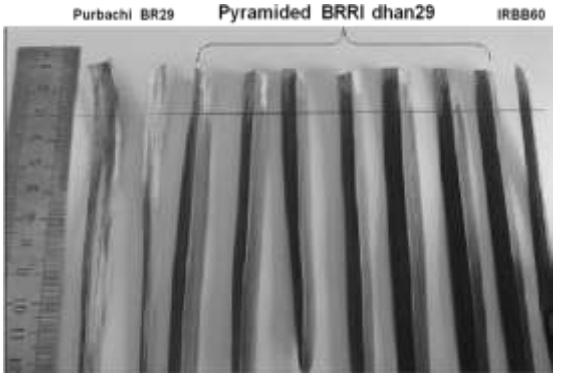

Fig. 7. BB pyramided BRRI dhan29 after 21 days bacterial inoculation with BxO9.

GENE CLONING

Isolation and cloning of stress tolerant gene from *Porteresia coarctata.* During 2015-16, different salt tolerant genes like salt overly sensitive (SOS), potassium transporter (HKT), Na+/H+ antiporters (NHX), vacuolar H+ pyrophosphatases (e.g. AVP1) were selected from literature survey as a target salt tolerant gene for cloning. On the other hand, for drought tolerant DREB1and BREB2 was targeted for cloning. *Porteresia coarctata* plants were treated with 100 mM NaCl salt for seven days then RNA extraction was done.

Genetic Resources and Seed Division

SUMMARY

In total, 252 rice germplasm including 110 Jhum varieties (Hill rice) were collected from different districts of Bangladesh during 2015-16. Thirty one germplasm accessions in T. Aus, 112 in T. Aman and 45 in Boro seasons were characterized against 53 morpho-agronomic traits. Molecular characterization of 31 Aus germplasm was performed using 36 SSR and 11 ILP (intron length polymorphism) markers to safeguard from biopiracy. Rejuvenation and conservation (in short term) of 2,395 accessions were performed of which 367 accessions in T. Aus, 1,464 accessions in T. Aman and 564 accessions in Boro. Again, 202 and 240 accessions in Aus and 1,019 and 1,119 accessions in T. Aman were conserved in medium and long term storages respectively during the reporting year. Apart from this, 37 new germplasm were registered as new accessions (from accession number 8045 to 8081) in BRRI Genebank. Moreover, 2,133 samples of rice germplasm and BRRI developed varieties were supplied to different users. Genetic diversity was pronounced in 50 Aus germplasm on the basis of 15 morpho-agronomic and yield contributing characters and the varieties were grouped into five clusters. Molecular diversity and DNA finger printing of 50 Aus germplasm and 26 BRRI varieties were performed using 50 and 52 SSR markers, respectively. Tepi Boro, Kali Boro, Natel Boro, Shita Boro, Panpiaz, Laldinga, Rata, Sada Boro, Lal Boro and Lara were identified as highly heat tolerant (>80% fertility) Boro germplasm. Besides, 2,133 samples of which 1,523 germplasm were supplied for research purpose and 610 samples of BRRI varieties were supplied for demonstration/other purposes to different users.

Eighty-five BRRI developed and recommended rice varieties were maintained and nucleus seed of 56 varieties were produced for the breeder seed source. In total, 177.71 tons of breeder seed of which 52.96 tons from 36 varieties in T. Aman and 124.75 tons from 19 varieties in Boro seasons were produced during 2015-16. Besides, 149.44 tons of breeder seed of which 113.46 tons from 18 varieties in Boro, 4.80 tons from 12 varieties in Aus and 31.18 tons from 31 varieties in T. Aman were distributed among the 'Rice Seed Network' partners. The number of the network partners (GO, NGO and PS) reached to 906 in 2016. Again, 1,120 kg seeds from 7 varieties of Boro, 73 kg from three varieties of Aus and 351 kg from 16 varieties of T. Aman were also distributed as quality seed (QS). 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. Four collection missions were made during the reporting year and 252 rice germplasm of which 30 in Aus, 110 from Jhum, 98 in T. Aman and 14 in Boro were collected from different districts of Bangladesh.

Germplasm rejuvenation for storage. Rice germplasm were rejuvenated to increase the seed for safe storage in the Genebank. The accessions, which possessed less than 80% germination and stored before 2012, were used in the experiment. The experiment was carried out under transplanted conditions using single row of 5.4 m long per accession with a spacing of 20 × 20 cm between rows and plants respectively. Fertilizers were applied @ 60:20:40 kg NPK/ha in T. Aus and T. Aman and @ 80:20:40 kg NPK/ha in Boro seasons.

A total of 2,395 germplasm of which 367 accessions in T. Aus, 1,464 accessions in T. Aman and 564 accessions in Boro 2015-16 were rejuvenated in field for getting fresh seed and on average 500 g of seeds were produced per accession.

Morphological characterization. Three experiments were conducted to characterize rice germplasm using 53 morpho-agronomic traits. 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 188 accessions of which 31 in T. Aus, 112 in T. Aman (new collection) and 45 in Boro were used for characterization. Fertilizers were applied @ 60:20:40 kg NPK/ha in T. Aus and T. Aman and @ 80:20:40 kg NPK/ha in Boro.

In Aus 2015, 14 varieties had short (<100 days), 16 had medium (100-120) and 25 had long (>120) growth duration (Table 1). Nine germplasm were found with long (>125) plant height. Eleven

Table 1. Some important features of characterized germplasm in T. Aus 2015, T Aman 2015 and Boro 2015-16.

Growth duration (day)		Plant height (cm)		Panicle length (cm)		No. of tiller		No. of effective tiller		Grain LB ratio		1000-grain weight (g)		Yield/hill (g)	
Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries
Aus 2015															
<100	14	<90	10	21-25	20	<10	29	6-10	23	2.1-2.5	21	≤15	15	<5	11
100-120	16	90-125	12	26-30	11	10-15	11	11-15	7	2.6-3.0	8	16-19	16	5-10	21
>120	1	>125	9	>30	0	>15	1	>15	1	>3.0	2	20-23	8	>10	8
Shortest (108)	NC (Porangi)	Shortest (75.6)	NC (Kadidet)	Shortest (21.2)	NC (Digha bawali, Porangi)	Lowest (7)	NC (Soto habji, Parbat jira)	Lowest (6)	NC (Baula, H-171)	Lowest (1.21)	NC (Adab Ali)	Lowest (18.0)	NC (Bagun Bichi)	Lowest (5.6)	NC (Digha Bawali)
Longest (136)	NC (Millika)	Longest (144.8)	NC (Mallika)	Longest (29.4)	NC (Kuchmuch)	Highest (37)	Acc. 7668 (Pabda for)	Highest (18)	NC (Kalo Aus)	Highest (4.36)	NC (Minikit)	Highest (28.6)	NC (Kuchmuch)	Highest (14.04)	NC (Bagunbichi)
Mean	121.52		119.15		24.71		14.44		9.61		2.53		24.10		8.20
Std. Dev.	8.23		20.21		2.24		5.46		2.32		0.42		2.96		1.78
CV	6.77		28.10		9.08		37.79		24.13		16.58		12.27		21.65
LSD	2.72		6.69		0.74		1.59		0.77		0.14		0.98		0.59
T. Aman 2015															
<120	0	<110	98	≤20	71	<10	15	<6	1	<1.5	0	≤15	22	<5	17
120-130	46	110-130	14	21-25	37	10-15	93	6-10	69	1.5-2.0	7	16-19	12	5-10	67
>130	66	>130	0	26-30	4	>15	4	>10	42	2.1-2.5	34	20-23	20	>10	28
				>30	0					2.6-3.0	30	24-27	17		
										>3.0	41	>27	41		
Shortest (120)	ACI-1	Shortest (58.0)	ACI-1	Shortest (13.1)	Moni mala	Lowest (7.0)	Kargil (Indian)	Lowest (5.0)	Kargil (Indian)	Lowest (1.81)	BD-1	Lowest (6.2)	Deshi Katari	Lowest (1.86)	Jhora dhan
Longest (158)	Ranojet	Longest (119.2)	Motha mota	Longest (28.8)	Tulshi mala	Highest (20.0)	Moulata	Highest (17.0)	Kali jira	Highest (4.46)	Vushi aman	Highest (35.8)	Boukhari	Highest (16.84)	Kacha mota
Mean	131.41		93.39		20.12		11.64		10.09		2.86		23.52		7.88
Std. Dev.	5.08		14.12		2.77		2.10		1.86		0.55		7.73		3.00
CV	3.87		15.12		13.76		18.04		18.41		19.07		32.86		38.13
LSD	0.94		2.61		0.51		0.39		0.34		0.10		1.43		0.56

Table 1. (Continued).

Growth duration (day)		Plant height		Panicle length		No. of tiller		No. of effective tiller		Grain LB ratio		1000-grain weight		Yield/hill	
Range	No. of Entries	Range (cm)	No. of entries	Range (cm)	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range (g)	No. of entries	Range (g)	No. of entries
							Boro 2015-16								
<135	0	<100	7	≤20	1	<10	6	<6	0	<1.5	0	≤15	2	<5	0
135-150	7	100-120	19	21-25	24	10-15	23	6-10	14	1.5-2.0	2	16-19	6	5-10	3
>150	38	>120	19	26-30	16	>15	16	>10	31	2.1-2.5	14	20-23	8	>10	42
				>30	4					2.6-3.0	20	24-27	9		
										>3.0	9	>27	20		
Shortest (147)	NC (Jagliboro, Boro,Sotohabj, Jagli,Bhawai, Kaliboro, Rushianjira) Acc. 7677	Shortest (72.8)	Acc.7660 (Sadavojon)	Shortest (18)	Acc. 7668 (Pabda for)	Lowest (7)	NC (Soto habji, Parbat jira)	Lowest (6.00)	NC (Soto habji)	Lowest (1.88)	Acc. 7664 (Begun bichi)	Lowest (12.8)	NC (Parbat jira)	Lowest (9.05)	Acc.7661 (Khannidhan)
Longest (176 days)	(Kakhaiberuin), Acc.7656 (Khatovojon)	Longest (144.2)	Acc.7670 (Lakhain), Acc.7662 (Abdul hai)	Longest (30.6)	Acc.7662 (Abdul hai)	Highest (37)	Acc. 7668 (Pabdafor)	Highest (36.00)	Acc. 7668 (Pabdafor)	Highest (4.52)	NC (Rushianjira)	Highest (34.7)	Acc. 7667 (Asamiboro)	Highest (32.01)	Acc. 7667 (Asamiboro)
Mean	157.22		116.91		25.63		14.44		13.67		2.76		25.26		16.67
Std. Dev.	7.65		16.73		2.85		5.46		5.36		0.52		5.59		4.82
CV	4.87		14.31		11.13		37.79		39.22		18.66		22.14		28.90
LSD	2.24		4.89		0.83		1.59		1.57		0.15		1.63		1.41

germplasm were found with long (26-30 cm) panicle length. One variety had many (>15) effective tillers. Two genotypes possessed slender (>3.0) type grain. Besides, Bagun Bichi (New Collection, NC) had the lowest (18 g) and Kuchmuch (NC) had the highest (28.6 g) 1000-grain weight (TGW). The highest yield per hill (14.04 g) was observed in Bagun Bichi (NC) during Aus. In T. Aman 2015, four entries were found with long (26-30 cm) panicle length. Forty-two varieties possessed many (>10) effective tillers. Again, the shortest growth duration (120 days) was observed in ACI-1. Tulshi mala possessed the longest panicle (28.8 cm). Kali jira was found with the highest effective tillers (17). The highest grain length breadth ratio (4.46) was observed in Vushi aman. The highest yield per hill (16.84 g) was observed in Kacha mota during T. Aman. In Boro 2015-16, seven germplasm had medium (135-150 days) growth duration. Four genotypes had very long (>30) panicle length. Thirty-one varieties possessed high (>10) effective tillers. Moreover, the shortest growth duration (147 days) was observed in Tupa Boro (Acc. 62). The shortest plant height (64.2 cm) was observed in Dud saita (Acc. 1795). The highest effective tillers (25) was observed in Boro deshi (Acc. 938). The highest yield per hill (6.29 g) was observed in Kumri boro (Acc. 257) during Boro. Finally, the varieties having higher yield would be utilized in crossing programme, if other characters satisfy the breeder's objectives.

Molecular characterization. Thirty-one Aus rice landraces were characterized using SSR/ILP (intron length polymorphism) markers for varietal identification and establishment of property right. DNA was extracted from young leaf of three weeks old plants following a simple and modified protocol of Zheng *et al.* (1995). PCR was performed in 12.5 µl reaction containing 5-25 ng of DNA template, 1.25 µl of $MgCl_2$ free 10X PCR buffer (100 mMTris-HCl pH 9.0 at 25°C, 500 mMKCl, 0.1% Triton® X-100 and H_2O), 1.5 µl of 25 mM $MgCl_2$, 0.25 µl of 10mM dNTP, 0.25 µl of 5 U/µl Taq polymerase enzyme, 0.625 µl each of 10 µM forward and reverse primers using a MJ Research single 96 well thermal cycler. The mixture was overlaid with one drop of mineral oil to prevent evaporation. The temperature profile was an initial denaturation step for 5 minute at 94 °C, followed by 35 cycles of 1 minute denaturation at 94 °C, 1 minute annealing at 55 °C, and 2 minute extension at 72 °C with a final 7 minute extension at 72 °C. The PCR products were 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). The amplification products of 2.5 µl were resolved by running gel in 1xTBE buffer for 2-2.5 hrs depending upon the allele size at around 75 volts and 180 mA current. The gels were stained in 0.5 mg/ml ethidium bromide and were documented using UVPRO (Uvipro Platinum, EU) gel documentation unit. After serving 100 SSR markers, most polymorphic 36 SSR and 11 ILP with known amplification were used. The data were analyzed in computer using AlphaEase FC version 5.0, Power Marker version 3.25 (Liu and Muse, 2005) and NTSYS-pc version 2.2 (Rohlf, 2002) softwares. Again after surveying one hundred markers, most polymorphic 36 SSR and 11 ILP markers were selected to use.

A total of 141 alleles were detected across the 36 SSR markers. The number of alleles per locus ranged from 2 to 10, with an average of 3.92. The PIC values ranged from 0.06 to 0.78, with an average of 0.48. As RM 304 had the highest PIC value (0.78) and the highest number of alleles (10), therefore it was the best marker. Again, 28 alleles with an average of 2.55 alleles per locus were identified by 11 ILP markers. The PIC values ranged from 0.06 to 0.57 with an average of 0.33. It was revealed that RI05559 was the best marker with the highest PIC value for the studied genotypes. Besides, the UPGMA cluster analysis grouped the genotypes into five major clusters (Fig. 1).

Germplasm processing. In total 2,395 germplasm were processed to conserve with respective accession number in different storages of Genebank. The germplasm were cleaned and dried with a seed moisture content of less than 9%.

Three hundred accessions in Aus, 340 in T. Aman and 250 in Boro seasons were checked randomly for viability (germination %) test in short term storage during 2015-16. Five varieties namely Dharial (Acc. 649), Hashikalmi (3575), Purbachi

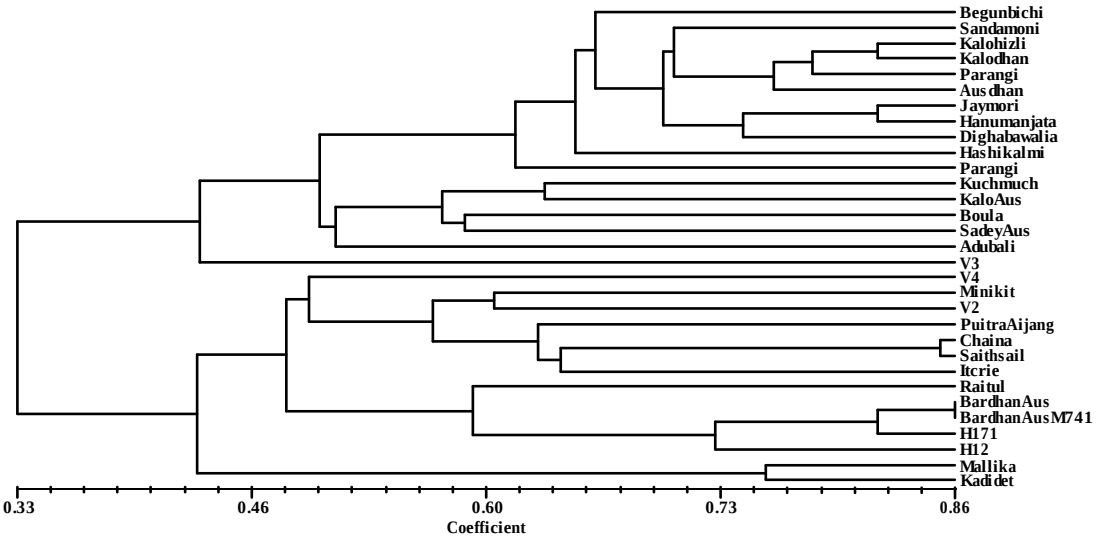

Fig. 1. A UPGMA cluster dendrogram showing the genetic relationships among 31 Aus rice genotypes based on allele detected by 36 microsatellite markers.

(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. Before storage of rice germplasm in the Genebank, viability of the seed was also monitored.

Among the randomly selected 375 stored germplasm, 262 had viability between 80-90% and 35 had viability above 90%. The germplasm accessions stored during 2015-16 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 2015 and March 2016 were 76-96% and 72-97% respectively, which indicate the viability condition of stored germplasm in medium and long term storages.

Germplasm distribution/exchange. A total of 2,133 samples of rice germplasm as well as BRRI developed rice varieties were supplied to different users in the reporting year. Among the samples, 1,523 germplasm accessions were supplied for research purpose and 610 samples of BRRI varieties were supplied to researchers, DAE personnel and university students for research, demonstration as well as other purposes.

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

SEED PRODUCTION AND VARIETY MAINTENANCE

Variety maintenance. Eighty-five BRRI developed and recommended rice varieties including 14 local improved varieties (LIV) were maintained using panicle to row method and thorough rouging (Table 2).

Nucleus seed production. A total of 55 BRRI varieties (MV's) of which 36 in T. Aman and 19 in Boro were grown in panicle to row method to produce nucleus stock. The objective for nucleus seed production was to maintain genetic purity and homogeneity of morphological characteristics of a variety and subsequently breeder seed production. These nucleus seeds would be used for production of breeder seed in the following seasons.

Breeder seed production and distribution. GRS Division, Farm Management Division and

Table 2. List of BRRI developed and recommended rice varieties maintained as nucleus stock.

Season	Number		Variety name
	MV	38	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
	LIV	8	Nizersail, Latisail, Rajasail, Kalijira, Kataribhog, Basmati-D, Patnai23, Tilockkachari
	MV	33	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
	LIV	6	Hbj Boro II, Hbj Boro IV, Hbj Boro VI, Hbj Boro VIII, Purbachi, IR8

eight regional stations of BRRI were engaged in breeder seed (BS) production as per national demand during 2015-16. 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 lot for getting 'tag' from Seed Certification Agency (SCA) for distribution.

A total of 177.71 tons of breeder seed, of which 52.96 tons from 36 varieties in T. Aman and 124.75 tons from 19 varieties in Boro seasons were produced during 2015-16 (Table 3 and 4). On the other hand, 149.44 tons of breeder seed of which 113.46 tons from 18 varieties in Boro, 4.80 tons from 12 varieties in Aus and 31.18 tons from 31 varieties in T. Aman were distributed among the 'Rice Seed Network' partners (Tables 5, 6 and 7). Besides, 1,120 kg seeds from seven varieties of Boro, 73 kg from three varieties of Aus and 351 kg from 16 varieties of T. Aman were distributed as quality seed (QS). Apart from this, 620 kg seeds from 39 varieties of QS were also distributed as free of cost for research and demonstration purposes.

Monitoring seed production plots/farms. Breeder seed production plots of BRRI RSs Rangpur, Rajshahi, Habiganj, Comilla, Bhanga, Sonagazi, Barisal and Satkhira and foundation seed production farms of Ali Seed Farm (Jessore), Atik Seed (Tangail), Global Agro Farming (Dinajpur), Green Global Seeds (Nilphamari), Haychem (Bangladesh) Ltd (Dinajpur), Ispahani Seed (Rangpur), J C Seed Company (Chuadanga), Konika Seed Co Pvt Ltd (Chuadanga), Padma Seed Farm (Jessore), Renesa Agro (Dinajpur), BRAC (Bhaluka) and BADC (Madhupur) were visited to observe the varietal purity and performances of breeder and foundation seed. During the visit, no major insect-pest damage was noticed in the plots. Varietal purity (%) was observed as average of more than 99% in all the varieties. The crops were found almost free from weeds. In maximum cases, isolation distance was properly maintained. Foundation seed (FS) producers were advised to discard three meters boarder lines, where isolation distance was not maintained. Overall crop conditions and management was satisfactory. The seed producers were also advised for thorough roguing by themselves for one more time before harvesting.

EXPLORATORY AND GENETIC STUDIES

Genetic diversity and selection of upland germplasm. Genetic diversity was studied for 50 Aus germplasm against 15 morpho-agronomic characters. The germplasm that selected from the BRRI Genebank were seeded directly under upland condition in two replications with unit plot size of 5 m x 3 rows with 25 cm spacing between the rows. Data were recorded on leaf area index (cm^2), culm diameter (mm), effective tiller number, plant height (cm), days to flowering, days to maturity, panicle length (cm), five panicle weight (g), filled and unfilled grains per panicle, grain length (mm) and breadth (mm), TGW (g) and yield/hill (g). Mahalonobis (D^2) and Canonical Vector Analysis methods were used to group the genotypes.

Table 3. Production (in kg) of breeder seed during T. Aman 2015.

Variety	GRS Division	Farm Division	BRRI RS Rangpur	BRRI RS Rajshahi	BRRI RS Habiganj	BRRI RS Comilla	BRRI RS Sonagazi	BRRI RS Barisal	BRRI RS Satkhira	Total
BR10	150								2000	2150
BR11	900			2700			4200			7800
BR21	100									100
BR22	160					1740				1900
BR23	200							300		500
BR25	50									50
BRRI dhan27	50									50
BRRI dhan30	640								1120	1760
BRRI dhan31	120									120
BRRI dhan32	200					560				760
BRRI dhan33	520			3100			680			4300
BRRI dhan34	280			1700			880			2860
BRRI dhan37	50									50
BRRI dhan38	100									100
BRRI dhan39	360	600								960
BRRI dhan40	50									50
BRRI dhan41	160									160
BRRI dhan42	50									50
BRRI dhan43	360									360
BRRI dhan44	160							330		490
BRRI dhan46	200									200
BRRI dhan48	120				800				520	1440
BRRI dhan49	720	720				3680			3520	8640
BRRI dhan51	840									840
BRRI dhan52	360				1800			3440		5600
BRRI dhan53	480									480
BRRI dhan54	160									160
BRRI dhan56	360		560	600						1520
BRRI dhan57	360		440							800
BRRI dhan62	500	2480	600			1600				5180
BRRI dhan66	360		520							880
BRRI dhan70	80									80
BRRI dhan71	100									100
BRRI dhan72	2360									2360
BRRI dhan73	60									60
Nizersail	50									50
Total	11770	3800	2120	8100	2600	7580	5760	4070	7160	**52,960**

Table 4. Production (in kg) of breeder seed during Boro 2015-16.

Variety	GRS Division	Farm Division	BRRI RS Rangpur	BRRI RS Rajshahi	BRRI RS Habiganj	BRRI RS Comilla	BRRI RS Bhanga	BRRI RS Sonagazi	BRRI RS Barisal	BRRI RS Satkhira	Total
BR3	760										760
BR14	920										920
BR16	640										640
BR26									3420		3420
BRRI dhan28	3480	2880	2880	4560	4740	9350	6900	4200		7880	46870
BRRI dhan29	1720		2120	3680	8700	9900	6000				32120
BRRI dhan36	200										200
BRRI dhan47	1200										1200
BRRI dhan50	240									2220	2460
BRRI dhan55	920										920
BRRI dhan58	200	2520	2340	960	2100	2700			7320	2580	20720
BRRI dhan59	200										200
BRRI dhan61	840								4040		4880
BRRI dhan63	1080										1080

Table 4. Continued.

Variety	GRS Division	Farm Division	BRRI RS Rangpur	BRRI RS Rajshahi	BRRI RS Habiganj	BRRI RS Comilla	BRRI RS Bhanga	BRRI RS Sonagazi	BRRI RS Barisal	BRRI RS Satkhira	Total
BRRI dhan64	640										640
BRRI dhan65	140										140
BRRI dhan67	240										240
BRRI dhan68	240										240
BRRI dhan69	350					6750					7100
Total	14010	5400	7340	9200	15540	28700	12900	4200	14780	12680	**124,750**

Table 5. Distribution of breeder seed in Boro 2015-16.

Organization	Organizations (no.)	BR3	BR14	BR16	BR26	BRRI dhan28	BRRI dhan29	BRRI dhan36	BRRI dhan47	BRRI dhan50	BRRI dhan55	BRRI dhan58	BRRI dhan59	BRRI dhan61	BRRI dhan63	BRRI dhan64	BRRI dhan67	BRRI dhan68	BRRI dhan69	Total
GO	12	30	30	70	580	11280	5932	0	340	30	50	12112	130	2150	660	60	620	10	1950	36034
NGO	8	0	0	30	0	1500	730	0	0	0	0	250	0	10	0	4200	10	20	4020	10770
PS	886	20	280	460	1230	31900	24750	210	260	2130	200	8390	40	120	340	220	50	80	100	70860
Total	906	50	310	560	1810	44680	31412	210	600	2240	250	20732	170	2280	1000	260	680	110	6070	113464

Table 6. Distribution of breeder seed in Aus 2016.

Organization	Organizations (no.)	BR3	BR14	BR16	BR21	BR24	BR26	BRRI dhan27	BRRI dhan42	BRRI dhan43	BRRI dhan48	BRRI dhan55	BRRI dhan65	Total
GO	5	310	60	90	100	0	1800	50	50	250	1428	540	35	4713
PS	6	0	0	0	0	0	0	0	0	20	20	10	40	90
Total	11	310	60	90	100	0	1800	50	50	270	1448	550	75	4803

Table 7. Distribution(in kg) of breeder seed(BS) in T. Aman 2016.

Organization	Organizations (no.)	GO	NGO	PS	Total
BR10	6	800	50	730	1580
BR11	14	1660	310	3801	5771
BR22	234	1400	20	430	1850
B R23	255	500	0	0	500
BR25		0	0	50	50
BRRI dhan30		1180	30	260	1470
BRRI dhan31		0	0	0	0
BRRI dhan32		300	0	450	750
BRRI dhan33		1000	340	1600	2940
BRRI dhan34		100	60	2510	2670
BRRI dhan37		0	0	10	10
BRRI dhan38		0	0	7	7
BRRI dhan39		300	20	340	660
BRRI dhan40		50	0	10	60
BRRI dhan41		150	0	0	150
BRRI dhan44		230	0	151	211
BRRI dhan46		0	0	210	210
BRRI dhan49		3790	170	3741	7701
BRRI dhan51		660	40	150	850
BRRI dhan52		1800	130	411	1841
BRRI dhan53		50	20	0	70
BRRI dhan54		50	100	0	150
BRRI dhan56		750	120	254	574
BRRI dhan57		450	10	270	330
BRRI dhan62		900	1810	147	457
BRRI dhan66		580	0	31	91
BRRI dhan70		0	0	41	41
BRRI dhan71		20	30	10	60
BRRI dhan72		10	1610	30	50
BRRI dhan73		10	20	0	30
Nizersail		50	0	0	50

Figure 2 shows the DNA profiles of Aus rice genotypes with RM21. A total of 162 alleles were detected across the 50 SSR markers. The number of alleles per locus ranged from 2 to 7, with an average of 3.24. The PIC values ranged from 0.04 to 0.75, with an average of 0.32. The result revealed that RM304 (0.75) was supposed to be the best marker for genotyping the studied germplasm. Finally, the UPGMA clustering analysis grouped the genotypes into five major clusters (Fig. 3).

Pure line selection of popular rice germplasm. After transplanting following panicle to row method and thoroughly rouging at each growth stage, four Balam varieties viz. acc. no. 516, 1011, 1013, 4836, seven Jesso-Balam; acc. no. 2456, 2459, 2464, 2469, 2472, 2473, 2480, four Sadamota; acc. no. 1040, 1576, 7788, 7923, three Lalmota; acc. no. 1583, 1584, 7889, three Khejur Jhupi; acc. no. 40, 2551, 2552, one Khejur Chhori; acc. no. 4246 and two Bashful; acc. no. 3996, 4010 lines were selected for next T. Aman 2016 for further rouging and purification.

Preliminary yield trial (PYT) of Monibandhobi genotype. Growth duration of Monibandhobi was 18 days longer than Rajashail but nine days shorter than BRRI dhan46 (Table 8). Plant height was 122.2 cm and can be treated as tall plant. The highest effective tiller was observed on BRRI dhan46 (25.2). Grains per panicle also showed moderate number i.e. less than 100 in all cases. Thousand grain weight of Monibandhobi was similar to BRRI dhan46. Grain yield of both the local varieties were less than three tons. The experiment will be repeated in next T. Aman with collaboration of Agronomy Division for identifying genotypes with lesser quantity of fertilizer.

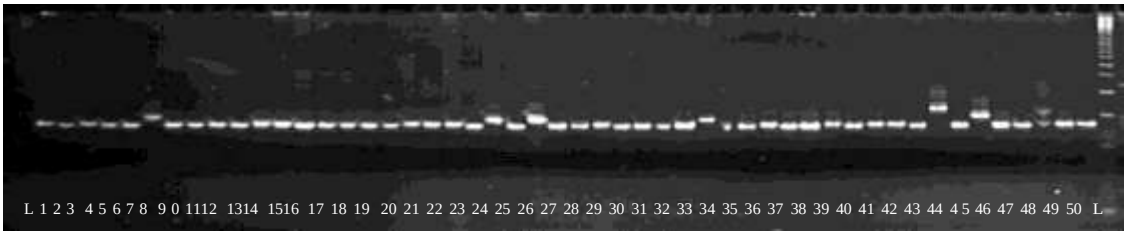

Fig. 2. DNA profile of 50 Aus rice genotypes with RM21.

Legend:1=Dharial, 2=Dular, 3=Hashikalmi, 4=Panbira, 5=Pashpai, 6=Pukhi, 7=Surjamukhi, 8=Laksmilata, 9=Kalamanik, 10=Burikatari, 11=Manikmodhu, 12=Kadamoni,13=Honumanjata, 14=Begunbahar, 15=Noyantara, 16=Matichak, 17=Benaful, 18=Binnatoha, 19=Pankiraj, 20=Baismuguria, 21=Benafmuri, 22=Chapla, 23=Pakiraj, 24=Kalisaita, 25=Surjamukhi, 26=Madabjata,27=Begunbichi, 28=Jameri, 29=Botwessor, 30=Sarisaful, 31=Khorajumri, 32=Beursona, 33=Saita, 34=Dhalisaita, 35=Sreerampuri, 36=Narikeljhupi, 37=Binnasopa, 38=Manikjor, 39=Boilam, 40=Tusha, 41=Parangi, 42=Beerpala, 43=Kharojamri, 44=Kerondol, 45=Khatomala, 46=Fullbadam, 47=Moisor, 48=Laithajhora, 49=Rateil, 50=Shibjhota.

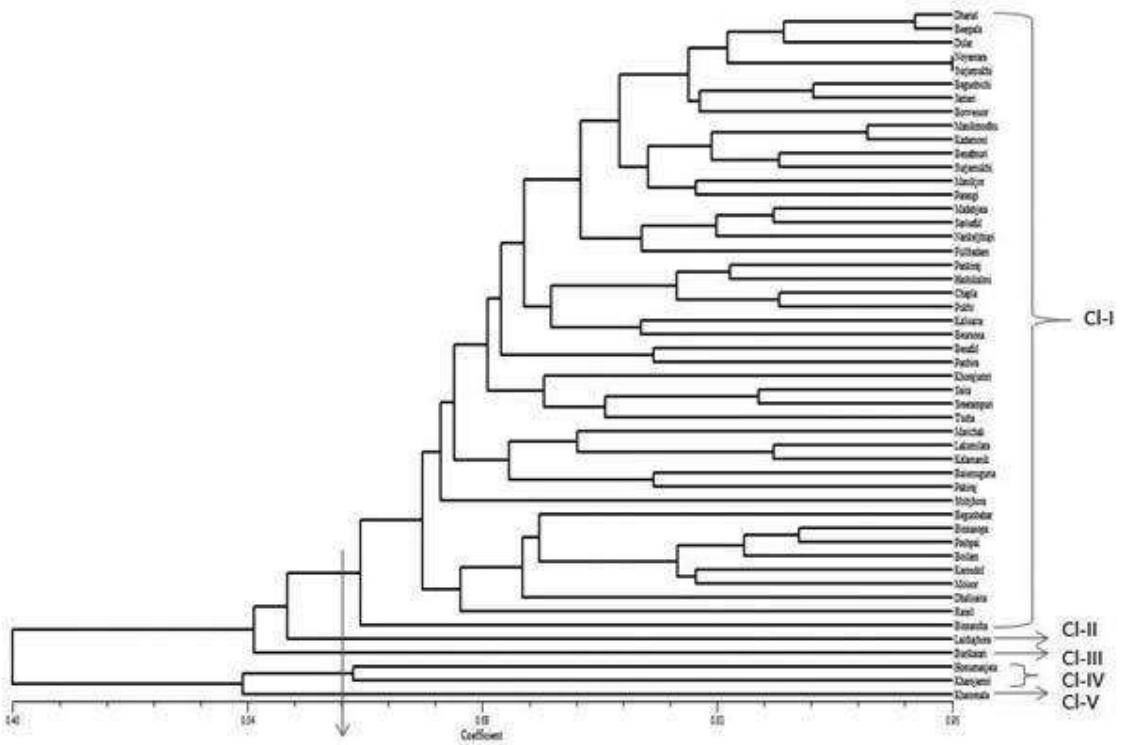

Fig. 3. A UPGMA cluster dendrogram showing the genetic relationships among 50 Aus rice genotypes.

Table 8. Performance of Monibandhobi genotype during T. Aman 2015.

Variety	Growth duration (day)	Plant ht (cm)	Effective tiller/hill	Grains/ panicle	1000-grain wt (g)	Grain wt (t/ha)
Monibandhobi	132	122.2	18.8	77.0	27.2	2.76
Rajasail	114	101.6	21.0	95.6	25.0	2.28
BRRI dhan46	141	120.0	25.2	67.6	27.7	3.10
LSD (5%)	15.56	12.80	3.68	16.13	1.63	0.47

DNA finger printing of BRRI varieties. Twenty-six BRRI varieties were characterized using well distributed 52 SSR markers for varietal identification and establishment of property right. DNA extracted, PCR products, temperature profiles, gel documentation and data analyses were performed as same as described earlier in genetic diversity and selection of upland germplasm experiment.

All the markers showed polymorphism of 156 alleles. The PIC ranged from 0.08 (RM5, RM487, RM178, RM214, RM542, RM500) to 0.79 (RM566). Primer RM566 is supposed to be the best marker for characterizing the studied BRRI varieties. Figure 4 shows the DNA profiles of BRRI rice varieties with RM224.

Identification of heat tolerant rice germplasm. Fifty-nine local Boro rice germplasm with N22 as tolerant and IR64 as sensitive check were evaluated for high temperature under natural condition as pot and field experiments during Boro season. At maturity, plant height, panicle length, number of fully filled spikelets, empty spikelets and date of heading were recorded. The mean spikelet fertility of first three headed panicles from healthy plant was used to evaluate the heat tolerance.

The growth duration was around 25 to 35 days higher in field experiment. Range of growth duration in pot experiment was 101 to 112 days and it was 135 to 168 days in field. Range of culm length in pot and field experiments were 55 to

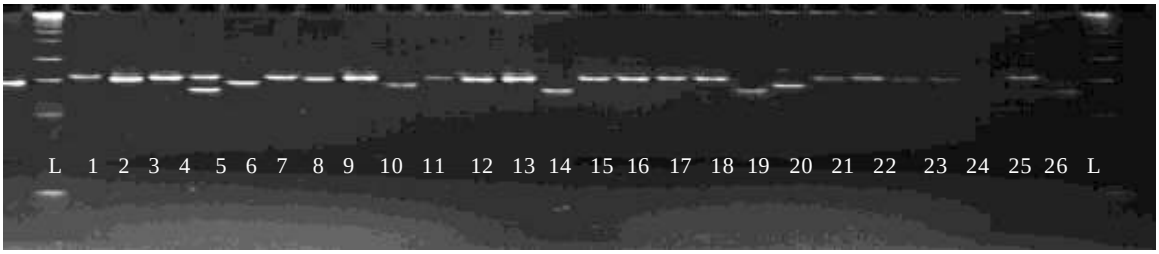

Fig. 4. DNA profile of 26 BRRI Rice varieties with RM224.

Legend: 1= BRRI dhan51 , 2= BRRI dhan52 , 3= BRRI dhan53, 4= BRRI dhan54, 5= BRRI dhan55, 6= BRRI dhan56, 7= BRRI dhan57 , 8= BRRI dhan58, 9= BRRI dhan59, 10= BRRI dhan60, 11= BRRI dhan61, 12= BRRI dhan62, 13= BRRI dhan63, 14= BRRI dhan64, 15= BRRI dhan65, 16= BRRI dhan66, 17= BRRI dhan67, 18= BRRI dhan68, 19= BRRI dhan69, 20= BRRI dhan70, 21= BRRI dhan71, 22= BRRI dhan72, 23= BRRI dhan73, 24= BRRI Hybrid dhan2, 25= BRRI Hybrid dhan3, 26= BRRI Hybrid dhan4.

120.33 cm and 66.2 to 134.8 cm respectively. The result revealed that the same germplasm with higher spikelet fertility (45.85 to 90.18 percent) in pot experiment also showed higher fertility (61.90 to 95.67 percent) in field. Finally, Tepi Boro, Kali Boro, Natel Boro, Shita Boro, Panpiaz, Laldinga, Rata, Sada Boro, Lal Boro and Lara (with <80 % fertility) may be treated as highly tolerant material and can be used as a parent after confirming under artificial heat treatment. Confirmed materials will be used for single nucleotide polymorphism (SNP) genotyping.

Grain Quality and Nutrition Division

SUMMARY

A total of 226 lines were evaluated for physicochemical and cooking properties for superior quality. Based on the performance on grain quality, we recommend some lines (BRRI dhan29-SC3-28-16-10-HR1(Com); BR7358-5-3-2-1-HR2(Com); BRH10-3-12-21-4B; BR9377-9-21-3B; BR10260-2-19-2B; BR9392-6-2-1-1B; BR9392-6-2-3B; BR10230-7-1; BR10247-14-18) further advancement.

A total of 33 BRRI HYV for Boro season were analyzed for mineral profiling of zinc, iron, calcium and phosphorus content at the level of $mgkg^{-1}$ (ppm) or gkg^{-1} by AAS (Atomic absorption spectrophotometer) to explore mineral composition. Our data reveal that BR1, BR6, BR7, BRRI dhan35, BRRI dhan36, BRRI dhan47, BRRI dhan50 are zinc enriched rice varieties along with BRRI dhan64 and BRRI dhan74, which are already released as Zn enriched varieties for Boro season in Bangladesh at unparboiled milled rice condition (ranges from 21.0 to 24.0 ppm). BR17, BRRI dhan35, BRRI dhan64 and BR6 are Fe enriched Boro varieties at unparboiled milled rice condition at the rate of 17.46, 14.52, 11.10 and 9.48 ppm ($mgkg^{-1}$) respectively. BRRI dhan64 and BRRI dhan45 have the most elevated level of phosphorus (3.1 gkg^{-1}) and calcium (47.1 ppm) content respectively among 33 Boro BRRI HYV at unparboiled milled rice condition. BRRI dhan35 is zinc and iron enriched BRRI variety at both unparboiled (21.6 and 14.97 ppm respectively) and parboiled milled rice (20.1 and 8.43 ppm respectively) condition which may be a good source of breeding materials in micronutrient enriched breeding programme for Boro season in Bangladesh.

In order to assess the effect of differently processed rice such as unparboiled, parboiled, pressure parboiled, double parboiled milled rice and brown rice on glycemic response in an invivo experimental rat model, we found that glycemic index (GI) of unparboiled milled rice reduces towards parboiled mill rice, then pressure parboiled mill rice then double parboiled milled rice and the lowest is in the brown rice. Our data reveal that thermal and pressuring process lowering GI value than original because of possible retrogradative changes in starch composition. Due to fiber content brown rice showed the lowest GI among all rice processing methods. High GI value rice BRRI dhan28 (GI 70.96 at unparboiled milled rice condition) shifted towards intermediate GI grouped rice (GI 65.01 at parboiled mill rice condition) due to temperature effect (forming a kind of resistant starch). We also concluded that GI of rice based products i.e. flattened, popped and puffed rice possess higher GI than rice itself because of lesser solid matters. Starch viscosity related further experiments may help us to reveal actual mechanism of intrinsic factors, which affect GI in starch metabolism.

Six rice varieties were field grown and characterized for physicochemical traits in relation to popping ability. BRRI dhan28 recorded the highest percent popping (55%) followed by Binni, BR16, Kanakchul, Nizersail and Rangabinni. Zinc and amylose content had positive correlation with popping ability.

The acceptability of six popped rice was assessed by 12 panelists. Appearance of the popped rice HYV produced popped rice variety (BRRI dhan28) got the highest score. Of the local rice variety (Kanakchul, Nizersail, Binni and Ranga Binni) produced popped rice, panelists tended to have a higher preference for taste and aroma.

Among the rice cultivars glutelin had the highest amount but prolamin had the lowest amount of protein fraction. Albumin was significant and positively correlated with protein content.

GRAIN QUALITY CHARACTERISTICS FOR VARIETY DEVELOPMENT

Determination of physicochemical and cooking properties of breeding lines

Two hundred twenty-six lines were analyzed for milling performance, physical and chemical properties of rough rice, brown rice and milled rice. All samples were analyzed using methods established at GQN Division. Out of 226 lines, 86 were analyzed for physicochemical and cooking properties, 140 were analyzed for amylose and 104 were analyzed for protein and alkali spreading value (ASV) only to evaluate their quality. Out of 122 lines, seven had more than 85% head rice yield

and 44 lines had unacceptable head rice yield. Out of 60 kernels, 41 were translucent (Table 1). Out of 57 lines, 21 were long slender, three were medium slender, five were long bold, 25 were medium bold and one were short bold. Among the lines, two had more than 20 minutes cooking time and 44 lines had cooking time between the ranges of 20-15 minutes (Table 1). Out of 232 lines, 99 were more than 25% amylose, 125 lines were amylose content between the range of (20.0-25.0) % and eight lines had less than 20% amylase (Table 2). Thirty-six lines had high (>9.0%), 102 had intermediate (7.0-9.0%) and 42 had low (<7.0%) protein content (Table 2). Out of 57 breeding lines, volume expansion ratio of seven lines were >4, 19 lines within 3.5-4.0 and 31 lines were less than 3.5 (Table 2). The elongation ratio is one of the important parameters for cooked rice. The elongation ratio of most of the lines varied between 1.3-1.5 (Table 3).

Table 1. Physical and cooking properties of breeding lines.

Property	Range	Variety/ Line
Milling outturn (%)	>70.0	35
	68.0-70.0	14
	<68.0	8
Head rice recovery (%)	>85.0	7
	75.0-85.0	4
	68.0-74.0	2
	<68.0	44
Chalkiness (%)	0 (Tr)	41
	<10.0	8
	10.0-20.0	6
	>20	1
	Opaque	1
Length (mm)	>6.0	30
	5.0-6.0	26
	<5.0	1
	>3.0	27
L/B ratio	2.0-3.0	30
	<2.0	-
	LS	23
	LB	5
	MS	3
	MB	25
	SS	-
	SB	1
Size and shape	SR	-
	>20	2
	15.0-19.0	42
Cooking time	<15.0	13

*Tr- Translucent, ELS-Extra long slender, LB-Long bold, MS-Medium slender, SR-Short round.

Table 2. Chemical properties of breeding line.

Property	Range	Variety / Line
Amylose content (%)	>25.0	99
	20.0-25.0	125
	<20.0	8
Protein content (%)	>9.0	36
	7.0-9.0	102
	<7.0	42
Volume expansion ratio	>4.0	7
	3.5-4.0	19
	<3.5	31
Elongation ratio	>1.5	8
	1.3-1.5	40
	<1.3	9
Alkali spreading value (ASV)	6.0-7.0	21
	3.5-5.9	32
	Less than 3.5	4

Table 3. Recommended line for further advancement, 2015-16.

AC#	Line	Head rice recovery (%)	Amylose content (%)	Elongation ratio
11635	BRRI dhan29-SC3-28-16-10-HR1(Com)	66.4	26.3	1.3
11638	BR7358-5-3-2-1-HR2(Com)	62.5	26.5	1.5
11641	BRH10-3-12-21-4B	65.2	27.2	1.3
11803	BR9377-9-21-3B	67.0	27.5	1.5
11812	BR10260-2-19-2B	65.1	24.7	1.6
11815	BR9392-6-2-1-1B	64.9	26.0	1.3
11817	BR9392-6-2-3B	64.6	27.7	1.5
11818	BR10230-7-1	64.6	26.9	1.6
11819	BR10247-14-18	64.6	26.5	1.6

GRAIN QUALITY PARAMETERS FOR CONSUMER PREFERENCE

Sensory evaluation of popped rice

Six rice varieties namely BR16, BRRI dhan28, Nizersail, Kanakchul, Binni and Rangabinni were collected from Grain Quality and Nutrition Division (GQN). Sensory evaluation was carried on popped rice. Parameters of the popped rice based on appearance, taste and aroma were scored by a panel of twenty using modified version of quantitative descriptive analysis as explained by Tomlins *et al.*, 2005. Appearance is the visible characteristics of the product. The assessor noted the appearance of the product and recorded any unusual features. In local rice varieties, 8.3 to 33.3% panelist categorized excellent and 16.7% categorized fair in appearance. In high yielding variety group, 41.7% panelist expressed excellent

appearance in BRRI dhan28, 16.7% categorized fair in appearance (Table 4). Twenty-five to 50% panelist scored excellent taste for Kanakchul and Rangabinni. In HYV 8.3% panelist scored excellent taste in BR16 (Table 5). Aroma described the sensation due to stimulation of the olfactory receptors in the nasal cavity. The aroma should be smelled and its character and strength recoded, particularly any unusual odors like chemical taints. Assessors encouraged to taste cooked samples as some compounds can only be detected by mouth. Twenty-five to 58.3% panelist categorized no aroma in all tasted rice varieties. Panelist found moderate aroma in Kanakchul, Binni and Rangabinni (Table 6).

NUTRITIONAL QUALITY ASSESSMENT OF RICE

Mineral profiling of BRRI varieties

A total of 33 BRRI HYV for Boro season were analyzed for mineral profiling of zinc, iron, calcium and phosphorus content at the level of $mgkg^{-1}$ (ppm) or gkg^{-1} by AAS (Atomic absorption spectrophotometer) to explore mineral composition. Since Zn and Fe are very important micronutrients, which contribute our health related issues a lot so, our special emphasis were on Zn and Fe among other minerals. Our data reveal that BR1, BR6, BR7, BRRI dhan35, BRRI dhan36, BRRI dhan47, BRRI dhan50 are zinc enriched rice varieties along with BRRI dhan64 and BRRI dhan74, which are already released as Zn enriched varieties for Boro season in Bangladesh at unparboiled milled rice condition (ranges from 21.0 to 24.0 ppm).

In parboiled condition BR6, BRRI dhan35, BRRI dhan36 are zinc enriched rice varieties along with BRRI dhan64 and BRRI dhan74 and zinc content ranges from 17.9 to 20.6 ppm (Table 9). BR17, BRRI dhan35, BRRI dhan64 and BR6 are Fe enriched Boro varieties at unparboiled milled rice condition at the rate of 17.46, 14.52, 11.10 and 9.48 ppm ($mgkg^{-1}$) respectively. In parboiled mill rice condition BR17, BR6, BRRI dhan35 and BRRI dhan64 posses iron content at the level of 9.12, 8.59, 8.43 and 8.35 ppm ($mgkg^{-1}$) respectively (Table 8). BRRI dhan64 and BRRI dhan45 have the most elevated level of phosphorus (3.1 gkg^{-1}) and calcium (47.1 ppm) content respectively among 33 Boro BRRI HYV at unparboiled milled rice condition (Table 7).

Table 4. Appearance of local and HYV popped rice.

Appearance	Local				HYV	
	Kanakchul	Nizersail	Binni	Rangabinni	BR16	BRRI dhan28
Excellent (%)	8.3	33.3	25	0	0	41.7
Very good (%)	50	25	41.7	41.7	50	16.7
Good (%)	25	41.7	33.3	41.7	33.3	41.7
Fair (%)	16.7	0	0	16.7	16.7	0
No. of respondent	12	12	12	12	12	12

Table 5. Taste of local and HYV popped rice.

Taste	Local				HYV	
	Kanakchul	Nizersail	Binni	Rangabinni	BR16	BRRIdhan28
Excellent (%)	25	0	50	33.3	8.3	0
Very good (%)	33.3	41.7	41.7	41.7	33.3	25
Good (%)	33.3	58.3	0	16.7	50	33.3
Fair (%)	8.3		8.33	8.3	8.3	41.7
No. of respondent	12	12	12	12	12	12

Table 6. Aroma of local and HYV popped rice.

Aroma	Local				HYV	
	Kanakchul	Nizersail	Binni	Rangabinni	BR16	BRRI dhan28
Strong (%)	0	8.3	0	0	0	8.33
Moderate (%)	41.7	0	58.3	41.7	8.3	0
Mild (%)	8.3	41.7	16.7	25	33.3	33.3
None (%)	50	50.0	25	33.3	58.3	58.3
No. of respondent	12	12	12	12	12	12

Table 7. Zn (mgkg^{-1}), Fe (mgkg^{-1}), Ca (mgkg^{-1}), and P (gkg^{-1}) content of 33 Boro BRRI HYV at unparboiled mill rice.

BRRI HYV	Zn(mgkg^{-1})	Fe(mgkg^{-1})	Ca(mgkg^{-1})	Phos(gkg^{-1})	BRRI HYV	Zn(mgkg^{-1})	Fe(mgkg^{-1})	Ca(mgkg^{-1})	Phos(gkg^{-1})
BR1	21.3	7.8	41.1	2.7	BRRI dhan35	21.6	14.5	26.8	2.4
BR2	19.9	8.6	42.1	2	BRRI dhan36	23.6	9.6	35.1	1.8
BR3	17.5	5.9	26.3	2.1	BRRI dhan45	18.5	10.9	41.7	2.3
BR6	24	9.5	34.2	2.4	BRRI dhan47	21.3	8.9	34.8	1.4
BR7	22.7	7.8	48.1	1.7	BRRI dhan50	19.6	8.7	33.2	2.2
BR8	19.6	6.1	37.6	1.5	BRRI dhan55	18.1	8	18.1	1.9
BR9	16.3	7.8	35.4	1.8	BRRI dhan58	17.8	9.9	31.9	2.1
BR12	19.8	9.8	26.7	2.3	BRRI dhan59	16.3	7.5	25.7	1.8
BR14	16.8	8.1	22.3	1.8	BRRI dhan60	19.6	5.8	26.3	1.6
BR15	17.6	7.3	33.7	2.3	BRRI dhan61	19.1	8	30.2	1.3
BR16	18.4	6.2	32.4	1.3	BRRI dhan63	18.8	7.3	37.3	1.7
BR17	19.8	17.5	37.2	1.9	BRRI dhan64	24	11.1	18.7	3.1
BR18	19	6.6	36.4	1.4	BRRI dhan67	18	8.9	35.3	1.3
BR19	18.2	9.6	39.9	2	BRRI dhan68	16.7	9.6	18	2.1
BRRI dhan27	16.1	7.8	32.2	1.6	BRRI dhan69	18.2	9.1	32.4	1.7
BRRI dhan28	18.8	7.8	41.8	2	BRRI dhan74	21	5.6	25.1	2.2
BRRI dhan29	18.8	8.2	30.3	1.8	Sample mean are given in tabualr form (n=3)				

Table 8. Fe (mgkg^{-1}) content of 33 Boro BRRI HYV at both unparboiled milled rice (UPMR) and parboiled mill rice (PMR) (mgkg^{-1} and ppm are equal unit).

Varieties	UPMR	PMR	Varieties	UPMR	PMR
BR1	7.8	4.1	BRRI dhan36	9.6	6.0
BR2	8.6	2.3	BRRI dhan45	10.9	7.6
BR3	5.9	5.8	BRRI dhan47	8.9	5.1
BR6	9.5	8.9	BRRI dhan50	8.7	3.7
BR7	7.8	3.1	BRRI dhan55	8.0	4.2
BR8	6.1	4.4	BRRI dhan58	9.9	4.0
BR9	7.8	2.3	BRRI dhan59	7.5	5.5
BR12	9.8	7.0	BRRI dhan60	8.7	4.5
BR14	8.1	7.0	BRRI dhan61	8.0	5.8
BR15	7.3	4.0	BRRI dhan63	7.3	6.2
BR16	6.2	4.7	BRRI dhan64	11.1	8.4
BR17	17.5	9.1	BRRI dhan67	8.9	5.7
BR18	6.6	6.1	BRRI dhan68	9.6	5.2
BR19	9.6	8.4	BRRI dhan69	9.1	8.1
BRRI dhan27	7.8	6.7	BRRI dhan74	5.6	4.8
BRRI dhan28	7.8	4.5	Mean±SE	8.75±0.40	5.69±0.32
BRRI	8.2	6.3	Max	17.5	9.1
BRRI dhan35	14.5	8.4	Min	5.6	2.3

Invivo experiment on glycemic index (GI) of differently processed rice

An invivo GI survey was conducted on 72 BRRI HYV in 2015 (Shozib, 2015) at GQN Division, BRRI. Three varieties named BR16, BRRI dhan46 and BRRI dhan69 were grouped as low GI (≤55) rice followed by 50 varieties grouped as intermediate (56-69) and 19 varieties grouped as high GI (70+) at unparboiled milled rice condition *(Atap)*. In this experiment we would like to account the effect of differently processed rice such as un-parboiled, parboiled, pressure parboiled and double parboiled milled rice on glycemic response in an invivo experimental rat model. We had selected three rice varieties from three GI groups namely BR16 (Low GI), BRRI dhan29 (Intermediate GI) and BRRI dhan28 (High GI) and processed all three varieties in different methods i.e. parboiled mill rice, pressure parboiled mill rice and double parboiled mill rice. Later on we have compared

Table 9. Zn ($mgkg^{-1}$) content of 33 Boro BRRI HYV at both unparboiled mill rice (UPMR) and parboiled mill rice (PMR). ($mgkg^{-1}$ and ppm are equal unit).

Varieties	UPMR	PMR	Varieties	UPMR	PMR
BR1	21.3	15.6	BRRI dhan36	23.6	19.7
BR2	19.9	14.7	BRRI dhan45	18.5	17.3
BR3	17.5	15.8	BRRI dhan47	21.3	15.7
BR6	24	19.8	BRRI dhan50	19.6	15
BR7	22.7	17.5	BRRI dhan55	18.1	14.9
BR8	19.6	16.5	BRRI dhan58	17.8	14.2
BR9	16.3	11.6	BRRI dhan59	16.3	14.4
BR12	19.8	16.1	BRRI dhan60	19.6	15.9
BR14	16.8	15.1	BRRI dhan61	19.1	17
BR15	17.6	12.4	BRRI dhan63	18.8	15.9
BR16	18.4	17.7	BRRI dhan64	24	20.6
BR17	19.8	15.3	BRRI dhan67	18	15.3
BR18	19	17.8	BRRI dhan68	16.7	13.6
BR19	18.2	17.8	BRRI dhan69	18.2	14.7
BRRI dhan27	16.1	15.2	BRRI dhan74	21	17.9
BRRI dhan28	18.8	16.6	Mean±SE	19.30±0.	16.22±0.
BRRI	18.8	17.5	Max	24	20.6
BRRI dhan35	21.6	20.1	Min	16.1	11.6

these methods with unparboiled milled rice regarding GI value changes. Most of the carbohydrates specially rice that we commonly consume are complex carbohydrate essentially made up of starches belonging to the different scales of amylose categories. The amount of amylose in proportion to amylopectin, basically determines the physical chemical nature of rice and their nutritional impact on human. The proportion of amylose/amylopectin can vary from one rice variety to another. For starches to be absorbed and enter our bloodstream, they have to be broken down into glucose. This decomposing process is the work of our digestive enzymes. Digestion of starch normally begins in the mouth where an enzyme, salivary amylase, is secreted, catalyzing the breakup of the starch by hydrolysis. After a quick passage through our stomachs, additional breakdown of starch occurs in the small intestine with pancreatic amylase secreted from the pancreas. GI corresponds to carbohydrates potential to raise blood sugar levels. In other words, GI tells us the degree to which certain carbohydrates make our bodies secrete insulin. Insulin is a hormone secreted by the pancreas that regulates glucose levels in the blood. Without insulin, cells cannot use the energy from glucose to carry out functions within the body. Since human volunteers are inadequate for much screening, experimental rat model is refereed world wide as scientific practices of measuring GI. In order to account the effect of differently processed rice such as unparboiled, parboiled, pressure parboiled and double parboiled rice on glycemic response in rat model, three rice varieties from three GI group namely BR16 (Low GI), BRRI dhan29 (Intermediate GI) and BRRI dhan28 (High GI) and processed all three varieties in different methods i.e. parboiled mill rice, pressure parboiled mill rice and double parboiled mill rice. Later on we have compared these methods with unparboiled milled rice regarding GI value changes. In an invivo GI survey conducted on 72 BRRI HYV in 2015 (Shozib,2015) at GQN Division, BRRI, BR16, BRRI dhan46 and BRRI dhan69 were grouped as low GI (≤55) rice followed by 50 varieties grouped as intermediate (56-69) and 19 varieties grouped as high GI (70+) at unparboiled milled rice condition (*Atap*). In this experiment, we would like to account the effect of differently processed rice such as unparboiled, parboiled, pressure parboiled and double parboiled milled rice on glycemic response in an in vivo experimental rat model.

We had selected HYV surveyed at unparboiled milled rice condition for GI experiment (Shozib, 2015). Three varieties named BR16, BRRI dhan46 and BRRI dhan69 were grouped as low GI (≤55) rice followed by 50 varieties grouped as intermediate (56-69) and 19 varieties grouped as high GI (70+) at unparboiled mill rice condition (*Atap*). In this experiment we would like to account the effect of differently processed rice such as unparboiled, parboiled, pressure parboiled and double parboiled rice on glycemic response in an invivo experimental rat model. We had selected three rice varieties from three GI groups namely

BR16 (Low GI), BRRI dhan29 (intermediate GI) and BRRI dhan28 (High GI) and processed all three varieties in different methods i.e. parboiled, pressure parboiled and double parboiled milled rice. Later on we had compared these methods with unparboiled milled rice regarding GI value changes. GI of unparboiled milled rice reduces toward parboiled mill rice then pressure parboiled mill rice, then double parboiled milled rice and the lowest is in the brown rice. Our data reveal that thermal and pressuring process lowering GI value than original because of possible retrogradative changes in starch composition. Due to fiber content brown rice showed the lowest GI among all rice processing methods (Table 10). High GI value rice BRRI dhan28 (GI 70.96 at unparboiled milled rice condition) becomes intermediate GI grouped rice (GI 65.01 at parboiled mill rice condition) due to temperature effect forming a kind of resistant starch. In addition, we also investigated GI of rice based products and found that rice products possessed higher GI than rice itself because of less solid matters (Table 11). Starch viscosity related further experiments will reveal actual mechanism of intrinsic factors, which affect GI in starch metabolism.

Evaluation of protein fraction of high, intermediate and low rice protein

Ten rice cultivars such as Neda, Dudkalam, Athabinni, Magoibalam, Molladigha, Boylam, Karailadhan, Motichak, Jol and BRRI dhan28 were collected from GRS Division. All parameters were analyzed by using modified Osborne's method, (1924). Rice proteins were classified by their solubility such as albumin (soluble in pure water), globulin (soluble in salt-water), prolamin (soluble in alcohol) and glutelin (soluble in aqueous alkaline solution) (Hoseney, 1986). Ten rice cultivars were selected for protein content and protein fraction. Among them protein content varied from 7.0-12.2% with the mean value of 9.4±1.31%. Magoibalam had the highest protein content but Dudkalam had the lowest protein content. Albumin varied from 7.3-12.2g100^{-1}g with the mean value of 9.9±1.52g100^{-1}g. Magoibalam had the highest albumin but Dudhkalam had the lowest. Among them globulin varied from 4.6-6.7 g100^{-1}g with the mean value of 5.4±0.73g100^{-1}g. Athabinni had the highest globulin but Molladigha and Karailadhan both had the lowest globulin. Prolamin varied from 4.0-4.9 g100^{-1}g with the mean value of 4.5±0.31g100^{-1}g. Dudkalam had the highest prolamin but Neda had the lowest prolamin. Glutelin varied from 78.0-82.8 g100^{-1}g with the mean value of 80.1±1.58g100^{-1}g. Molladigha had the highest glutelin but Magoibalam had the lowest glutelin (Table 12). Pearson correlation coefficients for relationships had among albumin, globulin, prolamin glutelin and protein content of 10 selected rice cultivars. Albumin was significant and positively correlated with protein content ($r=0.744$, $p<0.05$) whereas, globulin, prolaminand glutelin were negatively correlated with protein content. Albumin was highly significant and negatively correlated with glutelin ($r=0.858$, $p<0.01$) as well as albumin was only negatively correlated with globulin and prolamin (Table 13). Among the rice cultivars glutelin showed the higher amount of protein fraction followed by albumin than globulin and prolamin (Fig. 1).

Table 10. GI value of rice at different processed conditions.

Methods	BR16	BRRI dhan28	BRRI dhna29
Brown Rice (BR)	46.54^{c}	59.33^{C}	57.54^{d}
Pressure Parboiled Milled Rice (PPMR)	48.66^{bc}	61.04^{c}	59.28^{cd}
Doubled Parboiled Milled Rice (DMPR)	47.82^{bc}	60.65^{c}	60.65^{bc}
Parboiled Milled Rice (PMR)	48.23^{b}	65.01^{b}	61.02^{b}
Un- Parboiled Milled Rice (UMR)	52.41^{a}	70.96^{a}	62.36^{a}

Table 11. GI value of rice products.

Rice varieties	BR16	BRRI dhan28	BRRI dhan29
Flattened rice	56.35^{a}	69.98^{a}	72.47^{a}
Puffed rice	58.42^{b}	76.21^{b}	78.64^{b}
Popped rice	60.76^{c}	80.09^{c}	81.44^{c}

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

Table 12. Protein fraction ($g100^{-1}g$) for rice cultivars.

Cultivars	Protein content	Albumin	Globulin	Prolamin	Glutelin
Neda	10.5	10.3	5.9	4.0	79.8
Dudkalam	7.0	7.3	6.2	4.9	81.6
Athabinni	8.2	9.1	6.7	4.8	79.4
Magoibalam	10.7	12.2	5.0	4.8	78.0
Molladigha	10.3	8.3	4.6	4.3	82.8
Boylam	10.2	11.2	6.0	4.1	78.7
Karailadhan	7.9	9.1	4.6	4.5	81.8
Motichak	10.5	11.3	5.5	4.8	78.4
Jol	9.6	10.9	4.7	4.6	79.8
BRRI dhan28	8.6	9.6	5.3	4.4	80.7
Range	7.0-10.7	7.3-12.2	4.6-6.7	4.0-4.9	78.0-82.8
Mean±SD	9.4±1.31	9.9±1.52	5.4±0.73	4.5±0.31	80.1±1.58
CV %	14	15	13	7	2
SE	0.3091	0.5626	0.4485	0.3274	13.072
LSD (0.05)	0.6495	1.671	1.3326	0.9729	38.839

Table 13. The pearson correlation coefficient of protein content with protein fraction for rice cultivars.

	Correlations			
Protein fraction (g100-1g)	Albumin (g100-1g)	Globulin (g100-1g)	Prolamin (g100-1g)	Glutelin (g100-1g)
Albumin	1			
Globulin	-.168	1		
Prolamin	-.103	.105	1	
Glutelin	-.858**	-.323	-.148	1
Protein	.744*	-.277	-.411	-.502

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

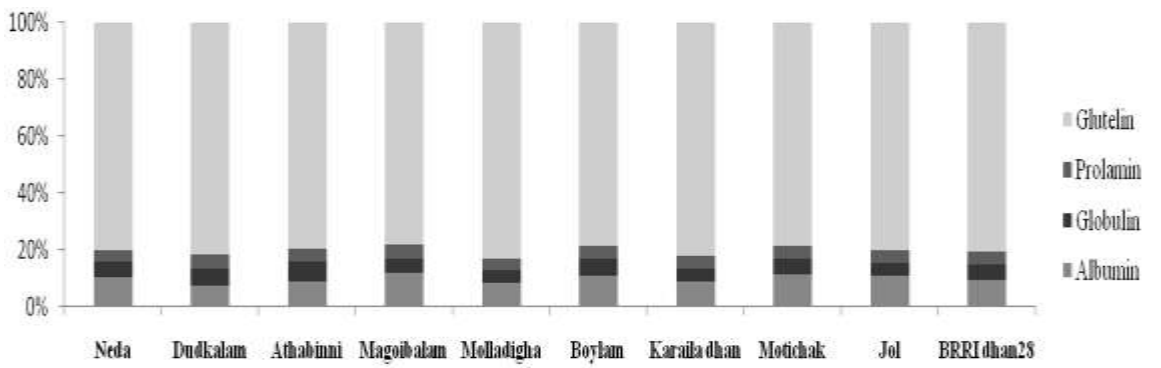

Fig. 1. Frequency distribution of protein fraction for rice cultivars.

COMMERCIAL RICE BASED PRODUCTS

Determination of physicochemical characterization of popped rice

Freshly harvested six rice varieties named BR16, BRRI dhan28, Nizersail, Kanakchul, Binni and Rangabinni were collected from GQN Division. These samples were analyzed for physicochemical properties as per GQN protocol. A known volume of grain was subjected for popping by roasting the rice grains on a hot pan till the kernel burst out of the hull. After cleaning the final volume of popped rice was recorded and percent popping was calculated. Milling quality is the measure of rough rice performance during milling process. It is the total quantity of head and broken grains recovered from unit quantity of milling process. Milling outturn of the studied cultivars ranged from 67.5 to 71.9%. The head rice outturn was the proportion of the whole grain in milled rice. It depends on varietal character as well as drying condition. The head rice recovery varied between 59.0 to 68.1%.

Rice cultivars are categorized as long, medium, short and slender, round or bold according to their milled rice length and L/B ratio respectively. The acceptable range for the thousand grain weight (TGW) is 20 to 30g. Value below 20 g indicates presence of immature, damaged or unfilled grains. The TGW values of the tested samples were within the range except Nizersail had less than 20 g. The cooking and eating qualities of rice largely depend on the individual. Amylose content, gel consistency, gelatinization temperature and grain elongation are the main characters for measuring cooking and eating quality and they directly affect the palatability characters. Cooking time of the six rice cultivars varied between 13.9 to 21.2 min. High elongation (>1.5) during cooking is a preferred trait. Elongation ratio and imbibitions ratio of the cultivars varied between 1.17 to 1.50 and 2.57 to 3.10. Alkali spreading value had inverse relationship with gelatinization temperature. Alkali spreading value of the tested varieties varied from 4.5 to 7.1. Amylose content influences the properties of cooked rice, sticky if the quantity is low. Amylose content varied from 9.4 to 27.6%. Protein content varied from 7.3 to 9.0%. Several fractions such as variety, environment and cultural practices may influence on the protein content of the grain. Zinc content of six rice cultivars varied from 21.0 to 27.3 $mgkg^{-1}$. Popped rice length and breadth varied from 10.3-14.1 and 4.7 to 6.0 mm. Volume of popped rice is the most important quality parameter for popped rice. Volume of popped rice of six rice cultivars varied from 114.8 to 143.0 (mm^3). Percentage of popping was estimated as the ratio of number of popped rice to the number of actual paddy grains taken for popping multiplied by 100. Popping percentage of six rice cultivars varied from 28.0 to 55.0%. Variances were statistically tested and found to be significant for all physicochemical characters. Genotypic correlation is more important as it explains association at genotypic level. Rice grain quality features are chiefly determined by the amylose content of rice starch. Amylose content varied within a narrow range except for Rangabinni (9.4%).

Amylose content had a negative correlation at genotypic level for volume of popped rice (-0.01667) and positive significant correlation for percent popping (0.781017), Zinc had a positive significant correlation with popping features (.943855). However, crude protein content had no significant influence on popping characteristics.

Hybrid Rice Division

SUMMARY

In T. Aman season 2015, a total of 152 test crosses and 126 (A×R) crosses were made from source nursery. Fifty-nine test crosses (F_1s) were evaluated for their pollen fertility status of which six entries have been found heterotic over check varieties. Pollen parents of those combinations were regarded as suspected restorers and selected for fertility restoration ability with other CMS lines in the next season. Two entries were found completely sterile and their corresponding male parents were regarded as suspected maintainer lines. All the backcross generations except three BC_1 generations were found stable in terms of pollen sterility with other desirable agronomic traits and advanced for next generation. Fifty-five CMS lines along with their respective maintainer lines were maintained by hand crossing. Five test crosses were made for disease resistant parental lines development. Matured seeds of BC_4F_1 populations were collected and preserved for three combinations against bacterial blight disease.

A total of 128 test crosses and 204 (A×R) crosses were made using 7 CMS lines in Boro season 2015-16. One hundred eight test crosses (F_1s) were evaluated for their pollen fertility status. Among them four entries showed complete sterility and immediately backcrossed with their corresponding male parents for conversion. On the other hand, three entries have been selected for their high yielding ability compared with check varieties. One BC_6 generation was found stable in pollen sterility and other desirable agronomic characteristics and designated as new CMS lines in the background of their corresponding male parents. Other generations were advanced as BC_4 and BC_2 generations. Sixty-six CMS lines along with their respective maintainer lines were maintained by hand crossing.

In T. Aman, out of 56 test hybrids under observational trials four (4) hybrid combinations were selected based on yield, duration and grain type and produced more than 16-44% yield advantage over check variety BR11, 9-36% over BRRI dhan49 and 2-25 % over BRRI hybrid dhan4 with two to three week shorter growth duration. Out of 130 test hybrids 10 hybrid combinations were selected based on yield, duration and grain type and showed yield advantage ranging from 6-26% over BRRI hybrid dhan3, 13-69% over BRRI dhan28 and 4-40% over BRRI dhan29 in Boro 2015-16 but most of the high yielding entries growth duration exceeded 150 days. Under preliminary yield trials three hybrids out of nine gave more than one ton yield advantage over BRRI dhan49 and around one ton over BRRI hybrid dhan4 in T. Aman 2015 and during Boro season 2015-16, Seventeen hybrids were evaluated and almost all the hybrids showed one ton yield advantage over BRRI dhan28 and one combination BRRI13A/EL108R gave 9.32 t/ha showing yield advantage 2.36, 1.48 and 1.14 t/ha over check varieties BRRI dhan28, BRRI dhan29 and SL8H with 4 days higher growth duration than BRRI dhan28. National hybrid rice yield trials were conducted through SCA in T. Aman 2015 and Boro 2015-16, which included 19 and 57 hybrids. Results were compiled by SCA. BRRI proposed one hybrid rice variety as BRRI hybrid dhan5 for Boro season and it has been finally nominated to declare as variety and would be finalized by national seed board soon.

Seed yield of 70 kg/plot (1.5 t/ha), 75 kg/plot (1.6 t/ha) and 18 kg/plot (1.1 t/ha) were obtained from BRRI10A, BRRI11A line and IR58025A respectively in T. Aman season. On the other hand, in Boro 2015-16 seasons, CMS seed yield of 120 kg (2.0 t/ha), 150 kg (2.15 t/ha) and 85 kg (1.6 t/ha) were obtained from BRRI10A/B, BRRI11A/B and IR58025A/B respectively. A total of 120 kg (1.6 t/ha), 60 kg (1.5 t/ha) and 18 kg (1.1 t/ha) hybrid seeds were produced from BRRI11A/BRRI15R, BRRI10A/BRRI10R and IR58025A/BRRI10R respectively during T. Aman 2015. During Boro 2015-16 seasons, a total of 150 kg (2.5 t/ha) from BRRI hybrid dhan2, 220 kg (2.65 t/ha) from BRRI hybrid dhan3 and 420 kg (1.7 t/ha) seeds were obtained from BRRI hybrid dhan4. A total of 71,450 kg F_1 seeds were produced during Boro 2015-16 season with the technical assistance from BRRI under 12 seed companies and regional

stations of BRRI. In the reporting year, Hybrid Rice Division supplied 2,222 kg of parental lines and F_1 seeds to 36 farmers, 10 seed companies, scientists and staffs of BRRI.

DEVELOPMENT OF PARENTAL MATERIALS

Source nursery

One hundred fifty-two test crosses and 126 (A×R) crosses were made using 8 CMS lines during T. Aman season 2015. One hundred twenty-eight test crosses and 204 (A×R) crosses were made using 7 CMS lines during Boro season 2015-16.

Test cross nursery

In T. Aman 2015, out of 59 testcrosses (F_1s) six entries have been found heterotic over check varieties expressing 19-26% yield advantage over check BR11 with two to three weeks earlier and two entries were found completely sterile. Pollen parents of heterotic combinations were regarded as suspected restorers and pollen parents of completely sterile combinations were regarded as suspected maintainer lines. In Boro 2015-16, out of 108 test crosses (F_1s), four tested entries showed complete sterility and they were immediately backcrossed with their corresponding male parents for conversion. On the other hand, three entries have been selected for their high yielding ability compared with the check variety.

Back cross nursery

In T. Aman 2015, all the backcross generations were stable in terms of pollen sterility and advanced for next generation except for four BC_1 generations. They were discarded due to fluctuation in pollen fertility. In Boro 2015-16, BC_6 generation was found stable in pollen sterility and other desirable agronomic characteristics and designated as new CMS lines in the background of their corresponding male parents. Other generations were advanced as BC_4, BC_3 and BC_2 generations (Table 1).

Table 1. Performance of backcross entries during Boro season of 2015-16.

BC gen	Designation	Sterility status	DFF	D50%F	DTM	Grain type	Base color	Remark
BC_6	BRRI53A/BR7873-5-(NILS)-51-HR6	CS	107	110	136	Slender	green	Advanced as New CMS line
BC_3	BRRI60A/EL140	CS	109	112	138	Slender	green	Advanced as BC_4 generation
BC_3	BRRI28A/EL140	CS	108	111	137	Slender	Mixed	Advanced as BC_4 generation
BC_3	BRRI60A/EL135	CS	97	100	126	Medium	purple	Advanced as BC_4 generation
BC_3	IR77803A/EL135	CS	99	103	129	Medium bold	purple	Advanced as BC_4 generation
BC_3	BRRI60A/EL110	CS	109	112	138	Slender	purple	Advanced as BC_4 generation
BC_3	PMS8A/EL30	CS	101	105	131	Medium bold	purple	Advanced as BC_4 generation
BC_3	BRRI7A/EL116	CS	114	117	142	Slender	purple	Advanced as BC_4 gen, little awn
BC_3	BRRI7A/EL125	CS	115	118	143	Slender	purple	Advanced as BC_4 generation
BC_3	BRRI7A/EL145	CS	111	114	140	Slender	Mixed	Advanced as BC_4 generation
BC_3	BRRI28A/EL256	CS	111	114	140	Slender	purple	Advanced as BC_4 generation
BC_3	BRRI71A/EL70	CS	99	102	128	Medium slender	purple	Advanced as BC_4 generation
BC_3	BRRI7A/EL211	CS	116	119	144	Medium slender	purple	Advanced as BC_4 generation
BC_3	BRRI7A/EL211	CS	116	119	144	Medium slender	purple	Advanced as BC_4 generation
BC_3	BRRI7A/EL210	CS	115	118	143	Medium slender	green	Advanced as BC_4 gen, little awn
BC_3	BRRI7A/EL207	CS	118	121	144	Medium slender	Mixed	Advanced as BC_4 generation

Table 1. Continued.

BC gen	Designation	Sterility status	DFF	D50%F	DTM	Grain type	Base color	Remark
BC_3	BRRI7A/EL196	CS	118	121	144	Medium slender	Mixed	Advanced as BC_4 generation
BC_3	BRRI7A/EL50	CS	113	116	141	Medium slender	purple	Advanced as BC_4 generation
BC_3	BRRI7A/EL195	CS	116	119	144	Medium slender	purple	Advanced as BC_4 generation
BC_3	BRRI56A/EL23	CS	102	105	131	Medium	purple	Advanced as BC_4 generation
BC_3	BRRI32A/EL36	CS	105	109	135	Medium slender	purple	Advanced as BC_4 generation
BC_2	BRRI33A/EL29	CS	110	114	140	Medium	purple	Advanced as BC_3 generation
BC_2	BRRI7A/EL87	CS	107	111	138	Medium	purple	Advanced as BC_3 generation
BC_2	BRRI7A/EL190	CS	110	113	139	Slender	green	Advanced as BC_3 generation
BC_2	BRRI36A/EL28	CS	105	108	136	Slender	green	Advanced as BC_3 generation
BC_1	BRRI33A/CHH-44	CS	109	112	139	Slender	purple	Advanced as BC_2 generation
BC_1	BRRI33A/CDE-1	CS	106	109	136	Slender	purple	Advanced as BC_2 generation

D/S: P_1 = 2 Dec 2015; P_2/F_1= 5 Dec 2015 P_3 = 8 Dec 2015; D/T: 8 Jan 2016; CS = completely sterile, S = sterile.

CMS maintenance and evaluation nursery

Fifty-five CMS lines were maintained by hand crossing for seed increase and genetic purity in T. Aman 2015 and in Boro 2015-16, 66 CMS lines were maintained through hand crossing for seed increase and genetic purity.

Pedigree nursery for development of BB resistance parental lines of hybrid rice

Five crosses were made in T. Aman season and matured F_1 seeds were properly collected and preserved and those would be grown in next season. Matured BC_4F_1 seeds were also collected and preserved. On the other hand, DNA extraction was done of each combinations and another molecular working on going processes in T. Aman 2015 and in Boro 2015-16 three crosses were made and matured F_1 seeds were properly collected and preserved those would be grown in next season and five crosses were confirmed and some of them were used making backcrosses. F_2 and backcross seeds were harvested at maturity and preserved with proper labeling.

EVALUATION OF PARENTAL LINES AND HYBRIDS

Out of 56 hybrids five hybrid combinations were selected based on yield, duration and grain type (Table 2). Around 15 to 20% yield advantage was observed of the selected hybrids over inbred check variety. Upon commercial seed production feasibility of these selected hybrid combinations, ALART trials would be conducted based on satisfactory yield advantage, hybrid combination would be submitted to SCA trials.

Out of 130 hybrids 10 hybrid combinations were selected based on yield, duration and grain type (Table 3) and it showed yield advantage over BRRI hybrid dhan3 ranged from 6-26%, 13 to 69% over BRRI dhan28 and four to 40% over BRRI dhan29. Upon commercial seed production feasibility of these selected hybrid combinations preliminary yield trials would be conducted and based on satisfactory yield advantage over check, hybrid combination would be submitted to ALART trials.

Preliminary yield trials of promising hybrids

There were three combinations such as IR79156A/BRRI20R, IR79156A/BasmatiR and BRRI7A/BRRI31R gave 1.58, 1.07 and 1.15 t/ha yield advantage with growth duration two to three weeks earlier than BRRI dhan49. On the other hand, same three combinations gave 1.42, 0.91 and 0.99 t/ha yield advantage over BRRI hybrid dhan4 with similar growth duration (Table 4). During Boro 2015-16, Seventeen hybrids were evaluated in preliminary yield trials with two inbred and two hybrid check variety. Seven hybrid combinations

Table 2. List of experimental hybrids found heterotic over check variety in T. Aman 2015.

Hybrid	PHT (cm)	E/T	SF (%)	DTM	Yld (t/ha)	Grain type	Yld adv over cks		
							Ck-1	Ck-2	Ck-3
BRRI21A/Getco14R	113.2	9.2	81.5	106	7.0	S	62.8	48.93	18.64
BRRI33A/ShaktiR	109	8.0	86.7	110	8.0	S	86.0	70.21	35.59
BRRI43A/507R	106.6	8.2	83.7	115	7.3	S	69.8	55.31	23.72
BRRI28A/BAU521R	127.4	8.0	82.3	108	7.0	M	62.8	48.93	18.64
BRRI30A/BR6839-41-5-1R	125	13	92.5	120	9.1	M	111.6	93.61	54.23
BR11 (ck-1)	110	8.8	77.9	147	4.3	B	-	-	-
BRRI dhan49 (ck-2)	102	9.0	80.7	136	4.7	MS	-	-	-
BRRI hybrid dhan4 (ck-3)	113	10.0	89.6	118	5.9	S	-	-	-
LSD (0.05)	7.99	1.51	4.46	13.15	1.5				
CV%	7.74	17.8	5.8	12.0	24.3				

DS: 05 Jul 2015; DT: 26 Jul 2015 S= Slender, M= Medium, B = Bold, MS= Medium slender.

Table 3. List of the hybrid combinations found heterotic from observational nursery during Boro season 2015-16

Combination	Plant height (cm)	No. of effective tillers /hill	Spikelet fertility (%)	Grain type	Day to maturity	Grain yield (t/ha)	Yield advantage over check		
							Ck-1	Ck-2	Ck-3
IR79156A/BRRI28R	134	11	90.4	Slender	154	10.8	25.6	68.7	40.2
IR79156A/727R	111	12	94.5	Slender	156	10.3	19.7	60.9	33.7
IR79156A/LP70R	121	10	85.2	Slender	152	9.8	13.9	53.1	27.2
IR79156A/PR416R	127	12	93.8	Slender	155	9.1	5.8	42.1	18.1
IR79156A/EL262R	118	10	89.8	Slender	154	8.8		37.5	14.2
BRRI30A/727R	101	9.0	91.9	Medium	150	8.4	-	31.2	9.0
BRRI30A/MongolR	105.3	9.0	96.0	Medium	152	8.0	-	25.0	3.8
BRRI30A/PR368R	107.6	8.0	93.3	Medium	149	7.7	-	20.3	-
IR75608A/PL-1R	106	9.0	85.2	Medium	144	7.6	-	18.7	-
BRRI13A/Heera5R	105.3	6.0	93.1	Bold	143	7.2	-	12.5	-
BRRI hybrid dhan3 (ck-1)	108	8.7	90.3	Bold	148	8.6			
BRRI dhan28 (ck-2)	105	11.8	87.5	Medium	142	6.4			
BRRI dhan29 (ck-3)	98	10.3	90.6	Medium	159	7.7			
	111.32	9.75	90.89	-	150.62	8.49			
	7.6	1.2	2.4	-	3.8	0.9			
	9.52	17.81	3.72		3.49	14.87			

DS: 5 Dec 2015 DT: 8 Jan 2016.

Table 4. Results of preliminary yield trials in T. Aman 2015.

Entry	Combination	Day to maturity	Plant height	Effective tiller/m^2	Spikelet fertility (%)	Grain type	Yield (t/ha)	Yield advantage over checks (t/ha)	
								Ck-1	Ck-2
1	IR79156A/BRRI20R	109	115.9	319	73	S	6.42	1.58	1.42
2	IR79156A/BasmatiR	115	118.4	299	75	S	5.91	1.07	0.91
3	IR79156A/PL-1	118	130.3	244	70	S	4.14	-	-
4	IR75608A/BRRI31R	104	112.5	260	82	S	5.78	0.94	0.78
5	BRRI21A/BasmatiR	109	110	284	76	S	4.73	-	
6	BRRI7A/ BRRI31R	106	110.8	253	74	S	5.26	0.42	0.26
7	BRRI33A/BRRI31R	110	119.3	286	76	S	4.77	-	-
8	UnknownA/BRRI10R	108	103.7	246	75	M	4.32	-	-
9	BRRI30A/BRRI15R	115	117.2	238	92	B	5.99	1.15	0.99
10	BRRI dhan49 (ck-1)	132	114.6	288	88	M	4.84		

Table 4. Continued.

Entry	Combination	Day to maturity	Plant height	Effective tiller/m^2	Spikelet fertility (%)	Grain type	Yield (t/ha)	Yield advantage over checks (t/ha)	
								Ck-1	Ck-2
11	BRRI hybrid dhan4 (Ck-1)	113	118.1	266	72	S	5.00		
	Mean	112.6	115.5	271.2	77.6		5.20		
	LSD(0.05)	5.97	5.24	20.11	5.37		0.57		
	CV (%)	6.81	5.83	9.53	8.90		14.18		

DS: 5.Jul 2015, DT: 26 Jul 2015; Plot size= 30m^2

such as BRRI7A/BRRI31R (1.66 t/ha), IR75608A/BRRI31A (1.52 t/ha), BRRI13A/ EL108R (2.36 t/ha), BRRI7A/EL253R (1.58 t/ha), BRRI3A/EL253R (1.64 t/ha), BRRI7A/EL254R (1.65 t/ha) and BRRI28A/EL254R (1.73 t/ha) showed more than 1.5 t/ha yield advantage over BRRI dhan28 with growth duration higher only 3 to 9 days. One very promising hybrid combination BRRI13A/EL108R exhibited yield advantage 1.48 t/ha and 1.14 t/ha over check variety BRRI dhan29 and SL8H with growth duration 7 to 9 days earlier than the check variety (Table 5).

SEED PRODUCTION OF PARENTAL LINES AND HYBRIDS

CMS line multiplication of released hybrids

During T. Aman 2015, seed yield 70 kg/plot (1.6 t/ha), 75 kg/plot (1.7 t/ha) and 18 kg/plot (1.2 t/ha) were obtained from BRRI10A, BRRI11A and IR58025A, respectively (Table 6). In Boro 2015-16, seed yield of 120 kg (2. 0 t/ha), 150 kg (2.15 t/ha) and 85 kg (1.62 t/ha) were obtained from BRRI10A/B, BRRI11A/B and IR58025A/B respectively (Table 7).

Table 5. Results of Preliminary Yield Trials in Boro 2015-16.

Entry	Combination	DTM	PHT (cm)	ET/m^2	SF (%)	Yield (t/ha)	Yield advantage over checks(t/ha)			
							Ck-1	Ck-2	Ck-3	Ck-4
1	BRRI7A/BRRI31R	150	106.0	238	85	8.62	1.66			
2	BRRI33A/BRRI31R	151	102.0	277	88	7.97	1.01			
3	IR79156A/BRRI20R	150	117.3	282	88	8.36	1.40			
4	IR79156A/PL-1	150	111.0	233	80	6.64	-			
5	IR75608A/BRRI31R	146	102.6	231	83	8.48	1.52			
6	BRRI7A/EL108R	146	098.6	268	90	8.10	1.14			
7	BRRI33A/EL108R	146	097.0	249	88	7.73				
8	BRRI13A/EL108R	145	104.6	235	89	9.32	2.36	1.48	-	1.14
9	BRRI28A/EL108R	145	103.3	255	89	7.50				
10	BRRI7A/EL253R	146	097.0	227	88	8.54	1.58			
11	BRRI33A/EL253R	146	093.3	241	87	7.88	0.92			
12	BRRI28A/EL253R	146	100.6	272	89	7.73				
13	BRRI13A/EL253R	146	104.6	231	91	8.60	1.64			
14	BRRI7A/EL254R	147	097.3	242	85	8.61	1.65			
15	BRRI33A/EL254R	144	098.6	253	89	7.91	0.95			
16	BRRI28A/EL254R	144	098.6	254	87	8.69	1.73			
17	BRRI13A/EL254R	145	103.0	207	87	6.66				
18	BRRI dhan28 (ck-1)	141	109.0	284	90	6.96				
19	BRRIdhan29 (ck-2)	154	106.3	311	84	7.84				
20	BRRI hybrid dhan3 (ck-3)	147	111.6	268	91	9.05				
21	SL-8 (ck-4)	152	107.3	213	87	8.18				
	Mean	147	103.4	251	87	8.07				
	LSD (0.05)	3.12	5.84	25.49	2.67	0.71				
	CV (%)	2.12	5.65	10.16	3.05	8.85				

DS: 5 Dec 2015, DT: 11Jan 2016; DTM= Days to maturity, PHT= Plant height, ET/m^2= Effective tillers meter^{-2}, SF (%) = Spikelet fertility.

Table 6. CMS multiplication of BRRI10A, BRRI11A and IR58025A lines in T. Aman 2015.

Combinations	Plant height (cm)		50% flowering (days)		PER (%)	OCR (%)	Yield	
							(kg/plot)	(t/ha)
	A line	B line	A line	B line	A line	A line		
BRRI10A/B	80	85	70	69	71	33	70	1.6
BRRI11A/B	81	82	72	70	74	35	75	1.7
IR58025A/B	84	89	76	76	70	30	18	1.2

DS: B_1=05 Jul 2015 A/B_2= 08 Jul 2015; B_3=11 Jul 2015; DT: A/B = 28 Jul 2015. DS: B_1=07 Jul 2015, A/B_2=10 Jul 2015, B_3=13 Jul 2015; DT: A/B=30 Jul 2015. DS: B_1=04 Jul 2015 A/B_2= 07 Jul 2015; B_3=10 Jul 2015; DT: A/B = 29 Jul 2015.

Table 7. CMS multiplication of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan4 in Boro 2015-16.

Combinations	Plant height (cm)		50% flowering (days)		PER (%)	OCR (%)	Yield (kg/ plot)	Yield (kg /ha)	Location
	A line	B line	A line	B line	A line	A line	F_1 seed		
BRRI10A/B	82	83	121	122	86	45	120	2000	
BRRI11A/B	84	85	124	125	85	47	150	2150	Gazipur
IR58025A/B	86	88	121	120	81	40	85	1620	

DS: B_1=29 Nov 2015, A/B_2 = 2 Dec 2015, B_3= 5 Dec 2015; DT: A/B=31 Dec 2015. DS: B_1=1 Dec 2015, A/B_2 = 4 Dec 2015, B_3=7 Dec 2015; DT: A/B= 4 Jan 2016. DS: B_1=3 Dec 2015, A/B_2 = 6 Dec 2015, B_3=9 Dec 2015; DT: A/B=5 Jan 2016. PER=Panicle Exertion Rate, OCR= Out Crossing Rate.

F_1 Hybrid seed production of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan4 in T. Aman 2015 and Boro 2015-16

During T. Aman 2015, seed yield were obtained 60 kg (1546 kg/ha) from BRRI10A/BRRI10R, 120 kg (1600 kg/ha) from BRRI11A/BRRI15R and 18 kg (1150 kg/ha) from IR58025A/BRRI10R (Table 8).

In Boro 2015-16, seed yield obtained 150 kg (2.5 t/ha), 220 kg (2.65 t/ha) and 420 kg (1.7 t/ha) respectively from BRRI10A/BRRI10R, BRRI11A/ BRRI15R and IR58025A/BRRI10R respectively (Table 9).

Seed production of promising CMS lines and hybrids

Seed yield 30 kg/plot (1.0 t/ha), 12 kg/plot (1.2 t/ha), 5 kg/plot (1.0 t/ha), 6 kg/plot (1.0 t/ha), 12 kg/plot (1.2 t/ha), 0.2 kg/plot (0.6 t/ha) and 80 kg/plot (2.0 t/ha) were obtained from BRRI8A, BRRI13A, BRRI21A, BRRI32A, BRRI35A, BRRI42A and BRRI79A/B, respectively during T. Aman 2015. From 12 promising hybrid combinations seed yield were obtained ranging from 2.3 to 7 kg /plot equivalent to 0.46 to 1.4 t/ha.

Dissemination of hybrid rice technology

In the reporting year, hybrid rice division supplied a total of 2,222.0 kg of parental lines and F_1 seeds to 10 seed companies along with farmers, BRRI staffs and different projects. A total of 71,450 kg F_1 seed was produced in Boro 2015-16 with the technical assistance from BRRI under twelve seed companies and regional station of BRRI.

Table 8. F_1 seed production of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan4 in T. Aman 2015.

Combination	PHT (cm)		Days to 50% flowering		PER (%)	OCR (%)	Yield /plot (kg)	Yield (kg/ ha)
	A line	R line	A line	R line	A line	A line		
BRRI hybrid dhan2 (BRRI10A/ BRRI10R)	76	101	87	85	74	43	60	1546
BRRI hybrid dhan3 (BRRI11A/ BRRI15R)	82	88	76	73	73	36	120	1600
BRRI hybrid dhan4 (IR58025A/ BRRI10R)	77	108	128	131	75	38	18	1150

DS: R_1=7 Jul 2015 A=10 July 2015 R_2=15 Jul 2015 DT R/A=1 Augl 2015. DS: R_1=7 Jul 2015 A=11 Jul 2015 R_2=15 Jul 2015 DT R/A= 3 Aug 2015. DS: R_1=7 Jul 2015 A=10 July 2015 R_2=15 Jul 2015 DT R/A=1 Augl 2015. PER=Panicle exertion rate, OCR= Out crossing rate.

Table 9. F_1 seed production of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan4 in Boro 2015-16.

Combination	Plant height (cm)		50% flowering (days)		PER (%)	OCR (%)	Yield (kg/plot)	Yield (kg /ha)	Location
	A line	R line	A line	R line	A line	A line	F_1 Seed		
BRRI hybrid dhan2	81	88	119	121	85	48	150	2500	BRRI Gazipur
BRRI hybrid dhan3	83	90	121	122	87	49	220	2650	BRRI Gazipur
BRRI hybrid dhan4	85	89	120	121	87	41	420	1700	BRRI Gazipur

DS: R_1=27 Nov 2015 A= 30 Nov 2015, R_2=3 Dec 2015 DT: A/R=30 Dec 2015. DS: R_1=3 Dec 2015, A= 7 Dec 2015, R_2=11Dec 2015 DT: A/R=6 Jan 2016. DS: R_1=27 Nov 2015 A= 30 Nov 2015, R_2=3 Dec 2015 DT: A/R=30 Dec 2015. PER=Panicle exertion rate, OCR= Out crossing rate.

Agronomy Division

SUMMARY

Seedbed with 50% mixed rice husk and bran + 50% soil produced good quality seedling in respect to seedling height, number of leaf and dry weight followed by 50% ash + 50% soil + 60 kg N ha^{-1} during Boro season.

In Aman, Nerica Mutant gave higher yield (35.24 kg/ha/day) over check varieties, BRRI dhan39 and BRRI dhan57 from 14 July to 13 August planting and WAS 161-B-4-B-1-TGR51 (NERICA-L-32) gave higher yield (33.59 kg/ha/day) over check varieties, BRRI dhan39 from 14 July to 28 August planting.

In Boro, none of the promising lines from favourable Boro nor micronutrient enriched line nor high yielding rice (HYR) nor green super rice (GSR) or ALART- short duration nor ALART -2 gave higher yield than the check variety.

Based on grain yield and physico-chemical properties, Swarna5 may be considered as a suitable variety for T. Aman in Bangladesh.

In rainfed condition (Rajshahi), optimum N rate was 49 kg N ha^{-1} and USG is better source of N for the highest grain yield of BRRI dhan62. But in Gazipur (optimum condition) optimum rate of N was 54 kg N ha^{-1} and prilled urea is better source.

All the evaluated herbicides effectively controlled weeds in transplanted rice field except two herbicides from Pendamethiline group.

All bacterial population surged 10 days after herbicide application (DAHA) but fungal population surged 3DAHA. Bactarial and fungal population increased as it is like natural population after 10-15DAHA.

BRRI dhan63 and BRRI hybrid dhan3 showed positive response on modified N management technique (gave 0.4 t ha^{-1} higher yield over BRRI N management technique).

USG treated plot gave 19-23% higher grain yield in Aus season and 8-17% higher yield in T. Aman season over farmer's practice plot at Barisal region. But the grain yield of NPK briquette treated plot was higher compared to USG in Boro at all locations of Barisal region. On average 12% grain yield was increased over variety and locations by the practice of BRRI recommended fertilizer management compared to farmers practice in Pirojpur, Gopalganj and Bagerhat districts.

About 60% weeding cost of rice can be reduced by using herbicide whereas it can be reduced by 46% with BRRI weeder+1HW in Pirojpur, Gopalganj and Bagerhat districts in T. Aman season.

BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI dhan58 may be replaced by BRRI dhan29 in Boro-Fallow-Fallow system and local Aus variety, Nurseratul can be replaced by BRRI dhan48 at PGB site considering yield performance and growth duration.

SEEDS AND SEEDLINGS

Effect of different seed bed media on raising quality rice seedling in Boro season

The study was carried out at BRRI, Gazipur during 2015-16 Boro season. The experiment was laid out in a RCB design and replicated thrice. The nursery bed media were applied and thoroughly mixed with soil in the upper 2 cm layer before seven days of sowing. Sprouted seed of BRRI dhan29 was used as planting material. The experimental treatments (nursery bed media) were: T_1 = 50% mixed rice husk and bran + 50% soil, T_2= 50% chopped rice straw+ 50% soil, T_3 = 50% saw dust+ 50% soil, T_4= 50% compost + 50% soil, T_5 = 50% ash + 50% soil + 60 kg N ha^{-1} and T_6= Conventional seed bed. Treatment 1 (T_1) (50% mixed rice husk and bran + 50% soil) produced good quality seedling in respect to seedling height, number and dry weight followed by T_5 (50% ash + 50% soil + 60 kg N ha^{-1}) and T_3 (50% saw dust + 50% soil) (Table 1).

Table 1. Effect of different seed bed media on rice seedling quality, BRRI, Gazipur, Boro 2015-16.

Treatment	Shoot length (cm)	Root length (cm)	No. of plants/ 30 cm^2	Dry weight (g) (20 seedlings)	Leaf no. /plant
T_1	25.15	14.36	284	10.14	5.72
T_2	16.23	12.77	174	4.64	3.95
T_3	18.81	13.89	235	7.30	4.35
T_4	18.52	13.05	197	5.40	4
T_5	23.64	14.04	255	8.36	5.03
T_6	16.14	12.07	137	4.18	3.95
LSD (0.05)	1.69	1.00	17.42	0.35	0.58

PLANTING PRACTICES

Effect of planting time on yield of advanced lines in Aman season

Three field trials were conducted at BRRI farm, Gazipur in T. Aman season 2015 to find out optimum planting time and to select best promising lines. The promising lines were: 1. NERICA Mutant, 2. WAS 122-IDSA 14-WAS B-FKR 1(NERICA-L-8), 3. WAS 161-B-6-B-1 (NERICA-L-36), 4. WAS 161-B-4-B-1-TGR 51 (NERICA-L-32), 5. BRC245-4-19-2-1, 6. BR11 (Sus. and Std. ck), 7. BRRI dhan31(Res ck), 8. NERICA Mutant (Kudrat), 9. BR7941-41-2-2-2-4, 10. BR7941-116-1-2-1, 11. BR7840-54-3-2-2, 12. BR7879-17-2-4-HR3-P1, 13. BR8143-15-2-1including check varieties of BR25, BRRI dhan32, BRRI dhan39, BRRI dhan44, BRRI dhan56, BRRI dhan57, BRRI dhan62 were planted from 14th July to 12 September with 15 days interval. Twenty-five-day-old seedlings were transplanted at 20-×20-cm spacing.

The treatments were distributed in RCB design with three replications. N-P-K-S was applied @ 22-8-14-9 kg bigha^{-1} as urea, TSP, MOP and gypsum. All fertilizers except urea were applied during final land preparation. Urea was applied at 15 DAT, 25 DAT and finally at 5-7 days before panicle initiation (PI) stage. NERICA Mutant gave higher yield (35.24 kg ha^{-1} day^{-1}) over check varieties, BRRI dhan39 and BRRI dhan57 from 14 July to 13 August planting and WAS161-B-4-B-1-TGR51(NERICA-L-32) gave higher yield (33.59 kg ha^{-1} day^{-1}) over check varieties, BRRI dhan39 from 14 July to 28 August planting (Tables 2a, b; 3a, b and 4).

Table 2a. Effect of planting time on yield of advanced lines (ALART- (RLR) in Aman, 2015, BRRI, Gazipur.

Advanced line/variety	Grain yield (t ha^{-1})				
	14 Jul	29 Jul	13 Aug	28 Aug	12 Sep
NERICA Mutant	3.70(105)	4.00(105)	3.20(103)	2.50(103)	1.2(110)
WAS 122-IDSA 14-WAS B-FKR 1 (NERICA-L-8)	3.83(133)	3.90(136)	3.57(128)	3.23(125)	*NF
WAS 161-B-6-B-1 (NERICA-L-36	3.07(135)	3.73(138)	2.93(130)	2.73(126)	*NF
WAS 161-B-4-B-1-TGR 51 (NERICA-L-32)	4.30(128)	4.57(132)	4.03(124)	3.60(120)	1.58(116)
BRRI dhan39(ck)	3.93(131)	4.20(129)	3.87(127)	3.67(123)	*NF
BRRI dhan57(ck)	3.80(108)	4.30(110)	3.30(108)	2.90(106)	1.90(112)
BRRI dhan62(ck)	3.90(107)	4.00(107)	3.50(105)	3.00(108)	2.30(110)

Table 2b. Effect of planting time on yield of advanced lines (ALART- (RLR) in Aman, 2015, BRRI, Gazipur.

Advanced line/variety	Grain yield (kg ha^{-1}day^{-1})				
	14 Jul	29 Jul	13 Aug	28 Aug	12 Sep
NERICA Mutant	35.24	38.10	31.07	24.27	10.91
WAS 122-IDSA 14-WAS B-FKR 1. (NERICA-L-8)	28.80	28.68	27.89	25.84	*NF
WAS 161-B-6-B-1 (NERICA-L-36	22.74	27.03	22.54	21.67	*NF
WAS 161-B-4-B-1-TGR 51 (NERICA-L-32)	33.59	34.62	32.50	30.00	13.62
BRRI dhan39(ck)	30.00	32.56	30.47	29.84	*NF
BRRI dhan57(ck)	35.19	39.09	30.56	27.36	16.96
BRRI dhan62(ck)	36.45	37.38	33.33	27.78	20.91

Table 3a. Effect of planting time on yield of advanced lines (disease resistant) in Aman, 2015, BRRI, Gazipur.

Advanced line/variety	Grain yield (t ha^{-1})				
	14 Jul	29 Jul	13 Aug	28 Aug	12 Sep
BRC245-4-19-2-1	3.0(129)	3.77(133)	2.37(125)	2.10(120)	*NF
BR7941-41-2-2-2-4	4.20(143)	4.45(145)	3.60(140)	2.80(138)	*NF
BR7941-116-1-2-1	4.20(138)	4.25(140)	3.70(136)	3.20(135)	*NF
NERICA Mutant (Kudrat)	3.70(110)	3.90(110)	3.20(108)	2.50(108)	1.45(114)
BR11 (Sus. and Std.ck)	4.20(125)	4.40(129)	3.50(121)	2.90(118)	1.75(116)
BRRI dhan31(Res ck)	4.50(132)	4.57(136)	4.20(129)	3.50(125)	1.25(121)
BRRI dhan44(ck)	5.10(145)	5.20(147)	4.70(142)	4.20(140)	2.80(142)
BRRI dhan56(ck)	4.30(114)	4.50(115)	3.70(112)	3.00(110)	2.0(114)

Table 3b. Effect of planting time on yield of advanced lines (disease resistant) in Aman, 2015, BRRI, Gazipur.

Advanced line/variety	Grain yield (kg ha^{-1}day^{-1})				
	14 Jul	29 Jul	13 Aug	28 Aug	12 Sep
BRC245-4-19-2-1	23.26	28.35	18.96	17.50	-
BR7941-41-2-2-2-4	29.37	38.70	25.71	20.29	-
BR7941-116-1-2-1	30.43	30.36	27.21	23.70	-
NERICA Mutant (Kudrat)	33.64	35.45	29.63	23.15	12.72
BR11 (Sus. & Std. ck)	33.60	34.11	28.93	24.58	15.09
BRRI dhan31(Res. ck)	34.09	33.60	32.56	28.00	10.33
BRRI dhan44(ck)	35.17	35.37	33.57	30.00	19.72
BRRI dhan56(ck)	37.72	39.13	33.04	27.27	17.54

Table 4. Effect of planting time on yield of advanced lines in Aman, 2015, BRRI, Gazipur.

Advanced line/variety	Grain yield (t ha^{-1})			Grain yield (kg ha^{-1}day^{-1})		
	02 Aug	16 Aug	31 Aug	02 Aug	16 Aug	31 Aug
BR7840-54-3-2-2	3.75(135)	3.10(133)	2.0(135)	27.78	23.31	14.81
BR7879-17-2-4-HR3-P1	3.60(137)	3.00(135)	*NF	26.28	22.22	-
BR8143-15-2-1	3.80(133)	3.15(131)	*NF	28.57	24.04	-
BR25(ck)	3.90(133)	3.20(130)	2.10(129)	29.32	24.61	16.28
BRRI dhan32(ck)	4.20(128)	3.50(126)	2.8(130)	32.81	27.28	21.54
LSD(0.05)	1.08					

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

Field trials were conducted at the BRRI farm, Gazipur in Boro 2015-16 to find out optimum planting time and to select best promising lines. The promising lines of favourable Boro were: BRRI dhan29-SC3-18-16-10-8HR1(Com), BR7358-5-3-2-1-HR2(Com) and check variety was BRRI dhan28; In case of micronutrient enriched lines-, BR7831-59-1-1-4-3-1-7-P2, BR7831-59-1-1-4-9-1-2-P3 and check variety was BRRI dhan28; for high yielding rice (HYR) line- BRH10-3-12-21-4B , BRRI dhan29-SC3-8-HR1(Com), BRRI dhan29-SC3-28-16-15-HR2(Com) and check variety was BRRI dhan28; for GSR lines- HHZ15-DT4-DT1-Y1, HHZ6-SAL3-Y1-SUB2 and check variety was BRRI dhan58; In case of ALART-short duration- BR(BIO)8072-AC5-4-2-1-2-1, BR(BIO)8072-AC8-1-1-3-1-1 and check was BRRI dhan28; for ALART-2 lines were- BR(BE)6158RWBC2-1-2-1-1 and check was BRRI dhan29. Planting was started from 16th January to 1 March 2016. Forty-day-old seedlings were transplanted at 20-×20-cm spacing. The treatments were distributed in RCB design with three replications. Fertilizers were applied @ 120-35-60-10 kg ha^{-1} N-P-K-S as urea, TSP, MOP and Gypsum. All fertilizers except urea were applied during final land preparation. Urea was applied as top dress in three equal splits at 20 DAT, 35 DAT and finally at 5-7 days before panicle initiation (PI) stage. All the tested entries from favourable Boro or micronutrient enriched line or high yielding rice (HYR) or green super rice (GSR) or ALART- short duration or Rice×Wheat (ALART-2) gave higher yield at 16 January planting and it gradually decreased with advancement of planting dates. None of the promising line from favourable Boro nor micronutrient enriched line nor high yielding rice (HYR) nor green super rice (GSR) nor ALART- short duration nor ALART -2 gave higher yield than check variety.

FERTILIZER MANAGEMENT

Performance of Swarna cultivars to different fertilizer management options

This experiment was conducted in T. Aman 2015 at BRRI farm, Gazipur. Five Swarna cultivars (Swarna5, Lalgooty Swarna, Nepali Swarna, Gooty Swarna, Sumon Swarna) and two BRRI varieties (BR11 and BRRI dhan52) were tested under two fertilizer management options viz BRRI recommended and farmer's practice (N-P-K @ 100-6-5 kg ha^{-1} and N was splitted as 2/3 at 10-15DAT and 1/3 at 35-40DAT). The experiment was conducted in split plot design (main plot in fertilizer management and sub plot was genotypes) and replicated thrice. Both Swarna cultivars and BRRI varieties produced significantly higher number of grains in researcher fertilizer management plot compared to farmers' fertilizer managed plots (Table 5). All Swarna cultivars gave

Table 5. Yield and yield components of Swarna cultivars under different fertilizer management options, BRRI, Gazipur, T. Aman 2015.

Variety	Panicle m^{-2}		Grain m^{-2}		1000 grain wt. (g)		Grain yield (t ha^{-1})	
	FP	RM	FP	RM	FP	RM	FP	RM
Swarna5	172	182	30565	30867	19.2	20.3	5.45	6.07
Lalgooty Swarna	194	200	26192	27468	22.0	23.3	5.20	5.74
Nepali Swarna	171	212	23713	28809	21.8	23.0	5.70	5.77
Gooty Swarna	186	207	23047	28624	23.1	23.2	5.53	6.11
Sumon Swarna	195	201	30513	32059	19.7	20.8	5.27	5.78
BR11	199	210	23619	24079	23.0	24.8	5.11	6.24
BRRI dhan52	176	196	20575	23553	26.9	27.9	5.15	6.34
Analysis of variance								
Factor A (Var.)	NS		*		*		NS	
Factor B (Mgn.)	NS		*		*		*	
A X B	NS		*		*		*	
Lsd (0.05)	-		3790.8		0.4182		0.8552	

*=significant at $P = 0.05$, NS = not significant at $P = 0.05$. FP= Farmer's practce, R1= Researcher practice.

higher yield than BR11 and BRRI dha52 with farmers' fertilizer management options than BRRI fertilizer management options but vice versa in BRRI fertilizer management options. Nepali Swarna gave higher grain yield (5.70 t ha^{-1}) with farmer's fertilizer practice and it was higher than BR11 and BRRI dhan52 but Gooty Swarna gave higher yield (6.11 t ha^{-1}) with BRRI fertilizer management practice. Nepali Swarna is less responsive to balanced fertilizer whereas, Swarna5 and Gooty Swarna are responsive i.e Nepali Swarna gave 0.2 t ha^{-1} yields over farmer's fertilizer practice but Swarna5 and Gooty Swarna gave 0.62 and 0.58 t ha^{-1} yield over farmer's fertilizer practice respectively. All Swarna cultivars had high amount of amylose (>26.3%) and it was higher (28.3%) in Swarna5 than the others. Moreover, Swarna5 had higher head rice recovery (64.1%), higher protein content (7.8%) and grain size is longer (5.5 mm). But elongation ratio (ER) had higher (1.4) in Nepali Swarna (Table 6).

All Swarna cultivars were partially lodged at hard dough stage both in researcher's and farmer's fertilizer management techniques. So, it needs to adjust fertilizer rate of Swarna cultivars for maximum grain yield without lodging. Based on grain yield and physico-chemical properties, Swarna5 may consider as a suitable introduced variety for T. Aman in Bangladesh.

Performance of BRRI dhan62 under different spacings and levels of nitrogen

The experiment was conducted at the Bangladesh Rice research Institute (BRRI) farm, during T. Aman 2014-15. Three spacings 20 cm×15 cm, 15 cm×15 cm, 15 cm×10 cm and five levels of nitrogen ; 0, 25, 50, 75 and 100 kg N ha^{-1} were tested following RCB design, replicated thrice. Initial soil N% was 0.12 and .21 during 2014 and 2015 respectively in two separate fields. The variation of grain yield of short duration BRRI dhan62 at different levels of N with different spacing was determined through regression equation (Fig. 1) during both 2014 and 2015 T. Aman season.

The relationship of grain yield and interaction of applied nitrogen×spacing was quadric in nature. Requirement of N was determined with different spacing. In 2014 Aman season soil N% was 0 .12% and the nitrogen rate of BRRI dhan62 was calculated 61 kg ha^{-1} with 15×15 cm spacing. But in 2015 the N rate of BRRI dhan62 was calculated 48 kg ha^{-1} where soil N% was 0.21%. So, having low to medium N concentration in soil the N% of BRRI dhan62 would be 55 kg N ha^{-1} with 15×15 cm spacing.

Table 6. Physico-chemical properties of different Swarna cultivars (By GQN Division, BRRI, 2016).

Cultivar	Milling outturn (%)	Head rice yield (%)	Appear.	Chalkiness	Length (L) mm	Breadth (B) mm	Amylose (%)	Protein (%)	ER
Nepali Swarna	72.6	55.3	Good	Tr	5.43	2.34	26.9	7.7	1.4
Swarna5	71.7	64.1	Good	Tr	5.50	2.25	28.3	7.8	1.2
Sumon Swarna	72.5	61.7	Good	Tr	5.50	2.24	26.8	7.8	1.2
Lalgooty Swarna	72.6	59.8	Good	Tr/Wb_1	5.40	2.52	26.3	7.5	1.3
Gooty Swarna	72.9	63.6	Good	Tr/Wb_1	5.39	2.44	26.9	7.7	1.2

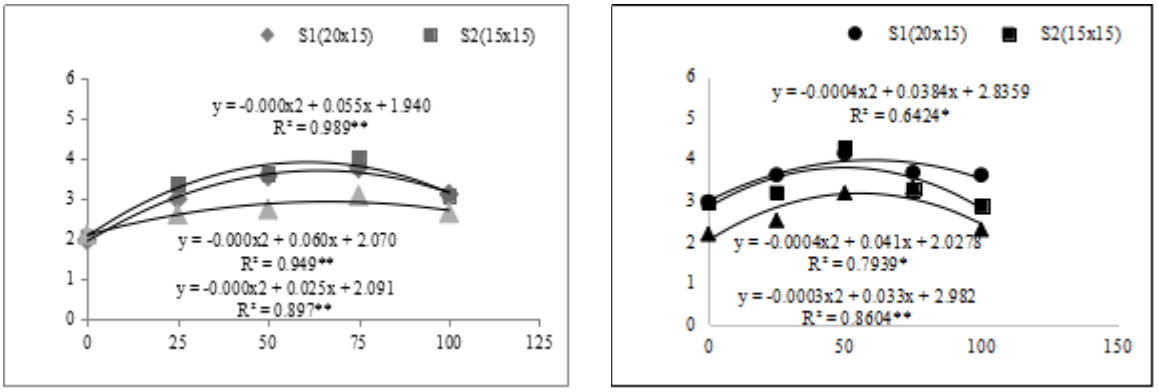

Fig. 1. Determination of optimum N rate regression with grain yield and N rate.

Nitrogen management in short duration varieties in rainfed condition

Two experiments were conducted at Rajapur upazila, Rajshahi and BRRI farm, Gazipur in rainfed and optimum condition respectively during T. Aman 2015 using short duration variety BRRI dhan62. The experimental treatments were i. Control (-N), ii. USG apply at 3DAT iii. Prilled urea application with BRRI recommended rate and iv. Farmers practice. Both the experiments followed by RCB design. At Gazipur it was replicated forth and at Rajshahi it was replicated thrice. In both sides prilled urea were applied at 150 kg (69 kg N) ha^{-1}. In Gazipur, farmers applied 174 kg urea (80 kg N) ha^{-1} and at Rajshahi farmers were applied 176 kg urea (81 kg N) ha^{-1}. Other fertilizers were applied during final land preparation followed by BRRI recommended rate.

In Gazipur site, prilled urea applied (4.28 t ha^{-1}) plot and USG treated plots produced similar grain yield (4.19 t ha^{-1}) followed by farmers' practiced plot (3.95 t ha^{-1}) (Table 7). But at Rajshahi, panicle m^{-2} and grain $panicle^{-1}$ were the highest in USG treated plots and produced the highest grain yield (4.57 t ha^{-1}) followed by prilled urea treated plots. The variation of grain yield of short duration BRRI dhan62 at different nitrogen management practices was determined through regression equation (Fig. 2) in both Gazipur and Rajshahi sites. The relationship of grain yield and interaction of applied nitrogen from different sources were quadric in nature. Differentiating the quadratic equation of yield response with respect to applied N doses from different nitrogen management practices the optimum N rate appeared as 54 and 49 kg ha^{-1} for Gazipur and Rajshahi respectively.

Therefore, Nitrogen rate @ 54 kg ha^{-1} is appropriate for maximum grain yield for BRRI dhan62 in Gazipur site and 49 kg N ha^{-1} is appropriate for maximum grain yield for BRRI dhan62 in T. Aman season 2015 at Rajshahi site.

WEED MANAGEMENT

Evaluation of candidate herbicides

Field trials were conducted at the BRRI, Gazipur during Aman 2015 and Boro 2015-16 to evaluate the efficacy of candidate herbicides on transplanted rice. Weed control efficiency was calculated on

Table 7. Yield and yield character of BRRI dhan62 under different N management options in Rajshahi (Rainfed) and Gazipur (Optimum) during T. Aman 2015.

Treatment	N rate (kg ha^{-1})		Panicle m^{-2}		Grain $panicle^{-1}$		1000-grain weight (g)		Grain yield (t ha^{-1})	
	G	R	*G*	R	*G*	R	*G*	R	*G*	R
Prilled urea	69	69	286	287	104	91	26.6	25.8	4.28	3.90
USG	50	50	282	342	101	104	26.7	26.0	4.19	4.57
Farmers practice	80	81	255	306	94	102	26.4	25.7	3.95	3.83
Control (-N)	0	0	187	236	82	77	25.77	25.25	2.40	2.49
LSD(.05)	-	-	29.60	26.13	10.56	10.60	ns	Ns	0.21	0.38

G= BRRI farm,Gazipur, R= Rajabari upazila of Rajshahi district.

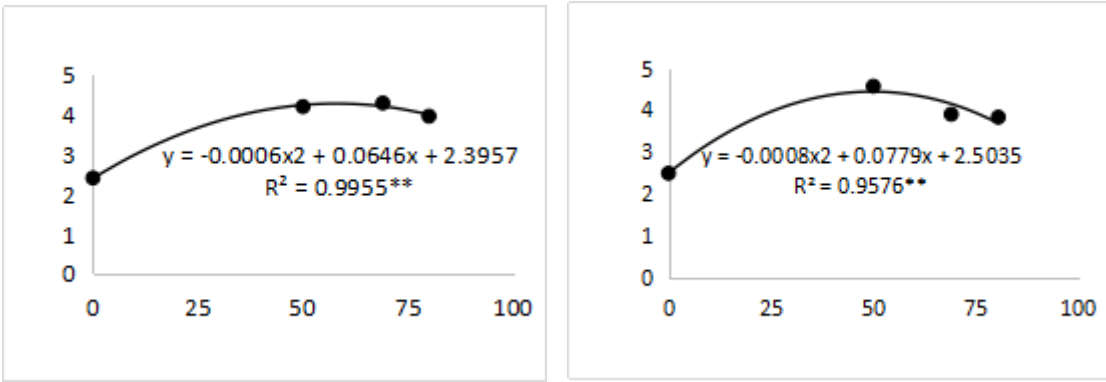

Fig. 2. Determination of optimum N rate regression with grain yield at Gazipur and Rajshahi.

weed dry weight basis. The tested materials were Bensulfuron1.1%+Metsulfuron 0.2%+Acetachlor 14%WP group (Pre emergence), Pyrazosulfuran-ethyl group (early post emergence), Bensulfuran methyl+Acetachlor group (Pre emergence), Pyrazosulfuron ethyl 0.6%+Pretilachlor 34.4% (pre to post emergence), Pendamethiline group (pre emergence), Bispyribac sodium (post emergence), Metsulfuron Methyl 10%+Chlorimuron Ethyl 10% (post emergence), Bensulfuran methyl 3%+Quinclorac 33% (Pre emergence), Bispyribac sodium 18%+Bensulfuran methyl 12% (Early post emergence), Oxadiazone 25EC (Pre emergence), Ethoxysulfuron 10EC group (Early post emergence).

All the evaluated herbicides effectively control weeds in transplanted rice field except two herbicides from pendamethiline group.

Effect of herbicides on soil microbial population

The present investigation was carried out to understand and predict the effect of two popular herbicides viz, pyrazosulfuron ethyl and mafenacet+bensulfuran methyl on the growth of soil microorganisms and their activities.

An experiment was conducted in Agronomy research field and microbiology lab, BRRI Gazipur in Aus season 2015 with RCB design following four replications in field condition and CRD in laboratory condition.

Results indicated that, natural soil consist higher microbial population. Significant herbicidal effect was found in soil 10 to 15 days after herbicide application (Fig. 3). All bacterial population surged 10 days after herbicide application but fungal population surged three days after herbicide application. Bactarial and fungal population increased as it is like natural population after 10-15 days of herbicide application. The Nitrogen fixing bacteria fluctuated over the growth period (Fig. 3). Mefanecet 490 g kg^{-1} + Bensulfuran-methyle 40 g kg^{-1} inhibited highest growth of all bacteria and fungus than Pyrazosulfuron ethyl 10WP.

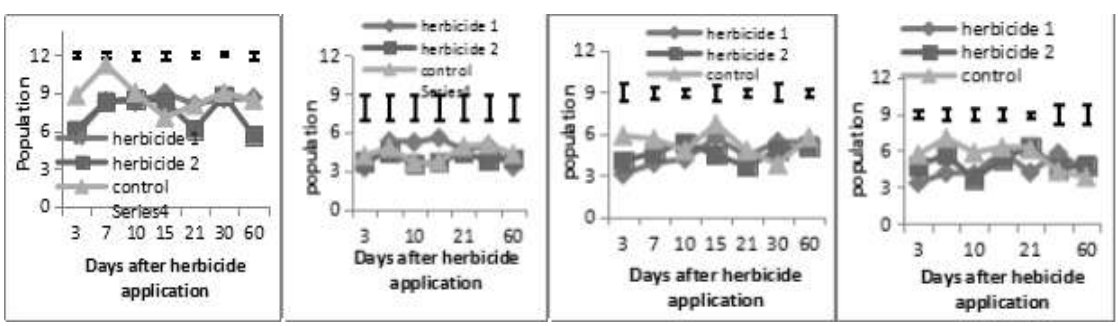

Fig. 3. Effect of herbicides on total population of bacteria, fungus, nitrogen fixing bacteria and phosphate solubulizing bacteria.

Yield maximization of Boro rice through adjustment of ratio of N splitting

This experiment was conducted to increase higher grain yield of rice in Boro 2015-16 at BRRI farm, Gazipur. Three rice varieties (BRRI dhan28, BRRI dhan63 and BRRI hybrid dhan3) were tested under two N splitting techniques (BRRI: N: 33.3% at 20DAT + 33.3% at 35DAT + 33.3% at BPI and modification: N: 20% at 20DAT + 50% at 35DAT + 30% at BPI + Additional 1/4th of total MP at 35DAT). BRRI recommended (N-P-K-S-Zn @ 120-18-75-20-3.6 kg ha^{-1}) fertilizer was used (Adhunik Dhaner Chash 2015). The experiment followed split plot design (main plot- N splitting and sub plot- varieties) with four replications. Forty-day-old seedling was transplanted on 16 January with one seedling per hill at a spacing of 20×20 cm. BRRI dhan28 and BRRI dhan63 produced statistically similar number of panicles but significantly higher over BRRI hybrid dhan3. Spikelet fertility was higher in BRRI dhan28 and BRRI hybrid dhan3 with modified N management techniques. Significantly higher number of grain was found in BRRI hybrid dhan3 with modified N management technique whereas, BRRI dhan28 was lower with BRRI N management technique. Grain weight varied significantly among the varieties and N management techniques with varieties. BRRI hybrid dhan3 produced significantly higher grain yield with both the N management techniques over BRRI dhan28 and BRRI dhan63 and it gave 0.4 t ha^{-1} higher yield over BRRI N management technique (Table 8).

Integrated Agricultural Development Project (IAPP)

Validation of nutrient management options for increasing Aus rice yield of Aus rice. The experiment was conducted at two locations- Bakerganj, Barisal and Rajapur, Jhalokathi to determine the optimum level of fertilizer requirement for growing rice in Aus season at farmer's field. The panicle number m^{-2}, grains panicle^{-1} and spikelet sterility (%) varied significantly among the treatments. The panicle number m^{-2} showed maximum at USG treatment followed by BRRI recommended treatment and farmer's practice. The grain panicle^{-1} was also found maximum at USG treatment. The variation of grain yield among the treatments was statistically significant; where 19-23% higher grain yield was found in USG treatment over farmers practiced plot compared to the others.

Validation of nutrient management options for increasing rice yield. The experiment was conducted at Babuganj, Barisal; Nolchiti, Jhalokathi; Barisal Sadar; Amtoli, Barguna and Kolapara, Patuakhali in T. Aman season 2015. The variation of grain yield among the treatments was statistically significant. The highest yield was observed in USG treated plots followed by BRRI recommended practice. The USG treatment gave 8-17% higher grain yield over farmer's practice (Table 9) compared to the others in T. Aman season at Barisal region.

Table 8. Yield and yield components of BRRI varieties under N management techniques, BRRI, Gazipur, Boro 2015-16.

Variety	Panicle m^{-2}		Grain pan^{-1}		1000 grain wt. (g)		Grain yield (t ha^{-1})	
	BRRI N	Modi N	BRRI N	Modi N	BRRI N	Modi N	BRRI N	Modi N
BRRI dhan28	295	293	102	109	20.3	20.5	4.93	4.90
BRRI dhan63	277	286	111	109	21.1	20.6	5.50	5.60
BRRI H3	229	240	108	119	27.2	28.8	5.90	6.31
Analysis of variance								
Factor A (Var.)	*		*		*		*	
Factor B (N Mgn.)	NS		*		NS		NS	
A × B	*		*		*		*	
Lsd (0.05)	32.724		4.542		1.3636		0.5984	

* = significant at $P = 0.05$, NS = not significant at $P = 0.05$.

Table 9. Effect of nutrient management options on yield and yield components in T. Aman 2015 at Barisal region.

Treatment	Plant height (cm)	Panicle m^{-2}	Grain panicle^{-1}	Sterility (%)	Grain yield (t ha^{-1})
		Babuganj, Barisal			
BRRI recm.	108	247	70	19.48	3.75
USG	107	265	77	15.76	3.99
Farmer's practice	108	230	65	24.01	3.21
LSD $_{(0.05)}$	4.20	14.46	6.47	5.20	0.29
		Nolchiti, Jhalokathi			
BRRI recm.	114	236	85	16.78	4.74
USG	115	252	87	14.43	5.24
Farmer's practice	115	220	82	20.90	4.04
LSD $_{(0.05)}$	1.76	11.04	4.54	1.91	0.21
		Barisal Sadar			
BRRI recm.	112	257	84	16.66	4.62
USG	112	270	86	15.67	4.97
Farmer's practice	114	235	74	18.33	4.36
LSD $_{(0.05)}$	1.30	18.47	5.43	1.76	0.25
		Amtoli, Barguna			
BRRI recm.	114	321	92	14.66	5.73
USG	114	354	96	14.33	5.84
Farmer's practice	113	287	88	19.00	5.17
LSD $_{(0.05)}$	2.87	10.39	9.08	1.84	0.19
		Kolapara, Patuakhali			
BRRI recm.	113	310	95	14.33	5.24
USG	115	326	95	12.00	5.58
Farmer's practice	113	278	86	15.33	4.66
LSD $_{(0.05)}$	1.19	5.06	4.39	5.59	0.23

Validation of nutrient management options for increasing Boro rice yield at farmer's condition

The experiment was conducted at four locations- Muladi, Aguiljhara, Barisal; Nolchiti, Jhalokathi and Amtoli, Barguna to determine the optimum level of fertilizer requirement for growing rice in Boro season at farmer's field.

Performance of balanced fertilization, weed management technologies and validation of modern varieties

Field demonstrations were carried out with balanced fertilizer application and to show the cost effective weed management in the farmer's field of Pirojpur, Gopalganj and Bagerhat districts during T. Aman 2015 and Boro 2015-16 under the project of IADP-PGB.

In T. Aman, BRRI recommended fertilizer management practice showed over yielded compared to farmers practice in all locations. Average 12% grain yield were increased over variety and locations by the practice of BRRI recommended fertilizer management (Fig. 4).

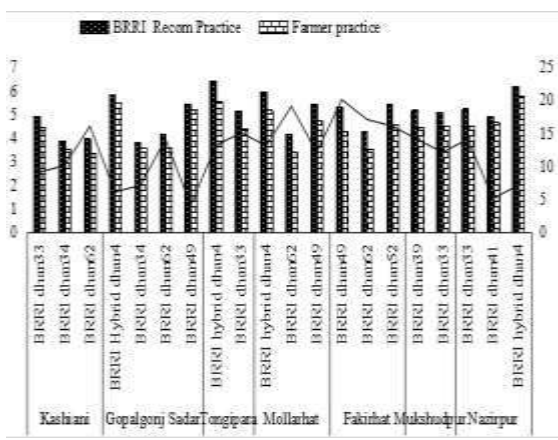

Fig. 4. Grain yield of T. Aman varieties and yield improvement of BRRI recommended practice compared to farmers practice.

Among the varieties, BRRI hybrid dhan4 obtained higher grain yield over locations followed by BRRI dhan52 and BRRI dhan33. Lower yield was observed in BRRI dhan34. In all locations BRRI dhan62 produced comparable yield with 99-102 growth durations.

In all the locations of pirojpur, Gopalganj and Bagerhat, herbicide+1HW and BRRI weeder+1HW produced more grain yield compared to farmers practice. For herbicide treatment, average yield improvement over farmers practice were 14% and for BRRI weeder+1HW treatment, average yield improvement over farmers practice were 1% whereas, 46% cost was reduced when used BRRI weeder + 1HW for weed management of rice.

During Boro 2015-16, a total of 75 field validation trials were conducted imposing BRRI recommended practices of modern Boro rice in different upazilas of Pirojpur, Gopalganj and Bagerhat district. BRRI dhan28, BRRI dhan29, BRRI dhan47, BRRI dhan63, BRRI dhan58, BRRI dhan67, BRRI hybrid dhan2 and BRRI hybrid dhan3 were demonstrated with BRRI recommended balanced fertilizer and cultural practice. Results indicated that, in Gopalganj sadar, BRRI hybrid dhan3 produced higher grain yield (8.30 t ha^{-1}) followed by and BRRI hybrid dhan2 (6.97-7.57 t ha^{-1}). Considering growth duration, BRRI hybrid dhan3 and BRRI hybrid dhan2 produced higher yield (kg ha^{-1} day^{-1}) followed by BRRI dhan58 and BRRI dhan28. So, in this area farmer can choice BRRI hybrid dhan2 or BRRI hybrid dhan3. If someone chooses fine and slender grain they can cultivate BRRI dhan58 or BRRI dhan28. Therefore, BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI dhan58 may be replaced with BRRI dhan29 in Boro-Fallow-Fallow system.

In Mollarhat of Bagerhat district, BRRI dhan58 produced higher grain yield (kg ha^{-1} day^{-1}) followed by BRRI dhan29 and BRRI dhan28. But in Fakirhat, BRRI hybrid dhan2 and BRRI hybrid dhan3 produced higher grain yield which is followed by BRRI dhan58.

In Mukshedpur BRRI dhan67 and BRRI dhan28 produced higher grain in kg ha^{-1} day^{-1} and in Kashiani BRRI hybrids produced higher grain yield followed by BRRI dhan29.

BRRI hybrids perform better in Kotalipara, Nazirpur and in Tungipara districts followed by BRRI dhan58. So, there is a great possibility to dissemination of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI dhan58 in that area to obtain higher grain yield for sustainable agriculture.

Evaluation of modern rice varieties in Pirojpur-Gopalganj-Bagerhat areas

The major cropping pattern in Gopalganj area is Boro-Fallow-Fallow. In Aus season, most of the land remains fallow and submerged under water. Farmer's normally cultivate local Aus varieties like Nunseartul in some pocket areas, where grain yield was low. In T. Aman season, there is a possibility of short duration rice production after jute harvest. In Boro, they cultivate BRRI dhan28 and BRRI dhan29 and company hybrid such as SL-8H, Heera, Aloron, ACI and Sonar Bangla.

The experiment was conducted in two upazilas (Gopalganj Sadar and Tungipara) of Gopalganj district in Aus season. The tested varieties were i) BRRI dhan43, ii) BRRI dhan65, iii) BRRI dhan48 and iv) local variety, Nunseratul. In case of local variety Nunseratul, the fertilizer rate was @ urea 97 kg/ha, TSP 97 kg/ha, MOP 75 kg/ha, $ZnSO_4$ 5 kg ha^{-1}. In T. Aman season, the tested varieties were i) BRRI dhan44 ii) BRRI dhan49 iii) BRRI dhan52 iv) BRRI dhan56 v) BRRI dhan57 vi) BRRI dhan62 vii) BRRI dhan66 and viii) BRRI hybrid dhan4. In Boro season, the tested varieties were i) BRRI dhan58 ii) BRRI dhan63 iii) BRRI dhan67 iv) BRRI dhan74 v) BRRI hybrid dhan2 and vi) BRRI hybrid dhan3. The fertilizers were applied according to variety wise BRKB factsheets. The number of experiments was set up about 150 at Gopalganj, 15 at Bagerhat and ten at Pirojpur district.

In Aus season, BRRI dhan48 produced the highest grain yield (4.07 t ha^{-1}) followed by BRRI dhan65 (3.12 t ha^{-1}), BRRI dhan43 (2.76 t ha^{-1}) and the lowest grain yield was found in local variety Nunseratul (1.83-1.87 t ha^{-1}). In T. Aman season, among the tested varieties BRRI hybrid dhan4 produced higher grain yield followed by BRRI dhan66, BRRI dhan62, BRRI dhan49 and BRRI dhan52 while the lowest was recorded in BRRI dhan57 in Gopalganj district (Fig. 5). In Boro season, BRRI hybrid dhan3 produced the highest grain yield (8.46 - 8.82 t ha^{-1}) in all the three districts followed by BRRI hybrid dhan2, BRRI dhan58 and BRRI dhan63 (Fig. 6). Farmers preferred to cultivate BRRI hybrid rice varieties instead of company hybrid like Heera, SL-8H in next Boro season if they get available seed in time.

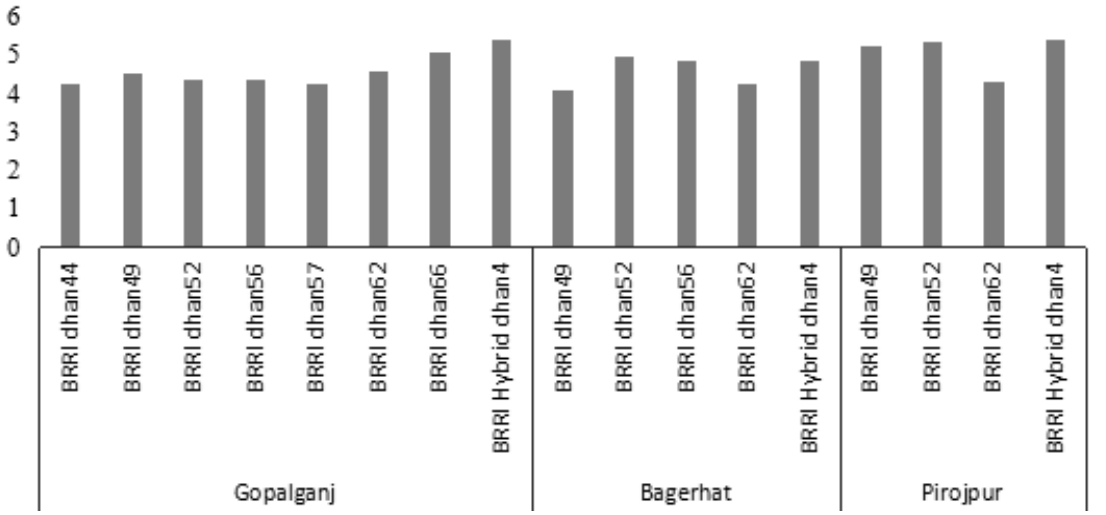

Fig. 5. Grain yield of modern T. Aman and BRRI hybrid rice varieties in Pirojpur, Gopalganj and Bagerhat districts.

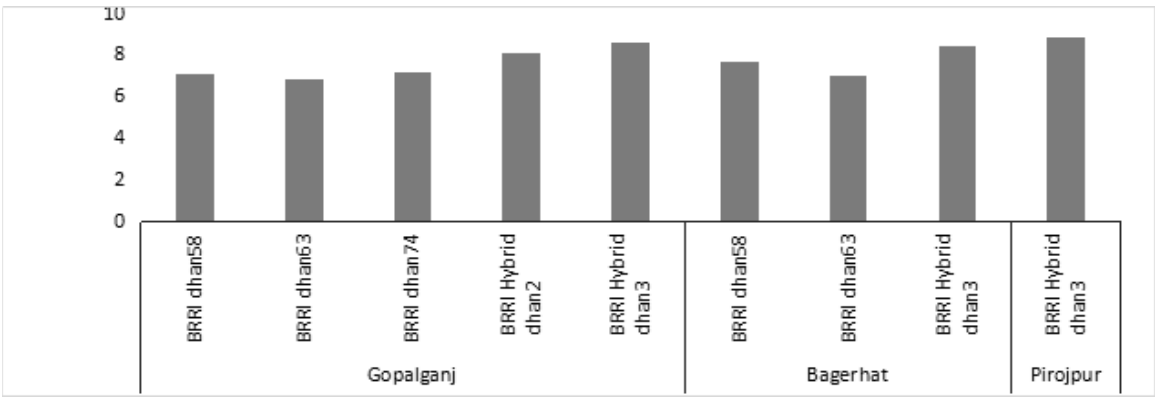

Fig. 6. Grain yield of modern Boro and BRRI hybrid rice varieties in Pirojpur, Gopalganj and Bagerhat districts.

Technology transfer. Pirojpur-Gopalgonj-Bagherhat Integrated Agricultural Development Project funded to conduct two batches rice production training to SAAO, one batch RPT programme to agriculture officer of the project areas. Training Division of BRRI imparted these training to 90 participants and the duration of each training programme was three days. In this project, One day rice production farmer's training was conducted with 900 participants under the project areas. About 5,000 kg quality seeds of BRRI dhan47, BRRI dhan58, BRRI dhan60, and BRRI dhan63 were produced under the supervision of this project at the farmer's field, stored properly and would be distributed in the consequent Boro season. Furthermore, hybrid rice cultivation is very much popular in the single cropped area of that region. To fulfill their demand about 1,130 kg of BRRI hybrid rice seed were produced in collaboration with BRRI Hybrid Rice Division.

Soil Science Division

SUMMARY

In T. Aman, BR8143-15-2-1 (MER) produced the highest grain yield (5.82 t ha^{-1}) under NPK fertilization. Its fertilizer requirement is 98-10-44 kg ha^{-1} of N-P-K. IR77092-B-2R-B-10 (SalTol) produced the highest grain yield (6.26 t ha^{-1}) with added NPK fertilizers than BRRI dhan53 (5.33 t ha^{-1}) and it requires 74-10-29 kg ha^{-1} of N-P-K for satisfactory grain yield. In Boro, BR (BIO) 8072-AC8-1-1-3-1-1 produced the highest grain yield (5.81 t ha^{-1}) followed by BRRI dhan28 (5.28 t ha^{-1}) and needed 127-10-47 kg ha^{-1} of N-P-K respectively. Grain yields of MER genotypes (8.12-8.32 t ha^{-1}) were higher than BRRI dhan28 (7.70 t ha^{-1}) under complete fertilization. BRRI dhan29-SC3-8-HR1 (com) produced the highest grain yield (7.30 t ha^{-1}) followed by BRRI dhan29-SC3-28-16-15-HR2 (com) with 178-17-49, 178-35-19 kg ha^{-1} of N-P-K, respectively.

A combination of 50 kg K and 75 kg N ha^{-1} for BRRI dhan49 and 50 kg K ha^{-1} and 100 kg N ha^{-1} for BRRI dhan29 cultivation were suitable in grey terrace soil. Under AWD, grain yield in BRRI dhan57 and BRRI dhan65 could be increased with 25% additional N and K application than recommended dose. At BRRI, Gazipur (AEZ 28), BRRI dhan33 and HUA565 were able to produce 4.17 and 4.59 t ha^{-1} grain yield, respectively with 30% less of recommended fertilizer dose. Phosphorus uptake was higher in HUA565.

Long-term omission of N, P, K adversely affected rice yield though S and Zn omission had no negative effect on rice production at BRRI farm, Gazipur. Long-term application of IPNS based chemical fertilizer showed increasing trend of rice yield. Intensive rice cultivation without fertilizer reduced Boro rice to 0.50 t ha^{-1}. Soil yield potential could be restored to its original state by addition of complete fertilizer dose. In Boro under double and triple cropping pattern, STB and 50% STB + MM fertilizer dose produced statistically similar grain yield.

Vermicompost at 0.5 Mg ha^{-1} with full doses of chemical fertilizers could be used for sustaining rice productivity and paddy soil health. BRRI dhan49 produced higher grain yield than BRRI dhan29 with same soil P levels under P deficient conditions.

In Boro season, fertilizer deep placement significantly increased grain yield and NUE compared to broadcast PU. Urea deep placement reduced cumulative N_2O-N emissions compared to PU in T. Aman under AWD condition.

Application of N either deep placed or broadcast gave similar grain yield (about 4.5 t ha^{-1}) at similar N rate in both AWD and CSW conditions. Deep placement of urea improved N uptake by 15-19%. Irrespective of N rate and seasons, floodwater NH_4^+-N was higher in PU treatment application than UDP treatments. Deep placement of N fertilizer reduces (N_2O) emission.

About 50% of recommended fertilizer dose can be reduced for Boro rice if mustard crop is grown under standard practices. Greenhouse gas emission can be reduced by about 11% through the introduction of short duration rice variety alone. Onion-Jute-Fallow (2125 CO_2eq kg ha^{-1}), Fallow-Jute-T. Aman (2348.2 CO_2eq kg ha^{-1}), Wheat-Mungbean-T. Aman (3315.2 CO_2eq kg ha^{-1}) and Maize-Fallow-T. Aman (3987.9 CO_2eq kg ha^{-1}) patterns could be better options for mitigation of GHG emission in Bangladesh. Grain yield of direct-seeded Boro rice (5.4-5.7 t $ha^{-1)}$ with one or two passes of power tiller was similar to hand transplanting by farmers with 3-4 passes. In general, high temperature and nutrient management affected C, N, P, K mineralization and soil biology. Considering critical maximum temperature (35° C) for chickpea, cotton, groundnut, maize, rice and sorghum, there will be no problem for cultivation of those crops by 2050. BRRI recommended fertilizer dose and IPNS based chemical fertilizer maximized rice yield in Barisal and Rangpur regions. BRRI dhan67 was fully damaged at 12 dS m^{-1}.

Compost prepared with urban waste (95%) + rock phosphate (5%) is environment friendly. Use of 1 t ha^{-1} of mature compost had potential to supply 100% P and 25% K for rice production.

SOIL FERTILITY AND PLANT NUTRITION

Determination of N, P and K fertilizer doses

In site specific nutrient management (SSNM) technique N, P and K fertilizer recommendations are calculated based on i) nutrient requirement for selected yield goal, ii) indigenous nutrient supply capacity and iii) recovery of applied nutrients.

However, nutrient requirements vary depending on genotypes, season and growing conditions. So, it is necessary to determine the requirement of these primary nutrients before releasing a new variety. Field trials were conducted at BRRI farm, Gazipur (AEZ 28) during T. Aus, T. Aman and Boro seasons of 2015-16. Fertilizer requirements of 26 advanced rice genotypes were determined in comparison to standard varieties. Fertilizers used were: T_1= NPK (AEZ-basis), T_2 = N omission, T_3 = P omission and T_4 = K omission. Fertilizer treatments were imposed in the main plots and rice genotypes in the subplots with three replications. Sulphur was applied as blanket dose. NPKS @ 160-25-65-10 kg ha^{-1} in Boro, 120-15-60-8 kg ha^{-1} in T. Aman and 77-10-38 kg ha^{-1} in T. Aus were used.

T. Aman season. In MER genotypes, BR8143-15-2-1 produced the highest grain yield (5.82 t ha^{-1}) followed by BRRI dhan32 (5.41 t ha^{-1}) under NPK treatment. Nitrogen, P and K requirements (kg ha^{-1}) for BR8143-15-2-1 were 98-10-44. NERICA-L-32 produced the highest grain yield (4.26 t ha^{-1}) with NPK treatment followed by BRRI dhan39. Requirements of N, P and K (kg ha^{-1}) were 83-3-46 for NERICA-L-32. IR77092-B-2R-B-10 SalTol genotype produced the highest grain yield (6.26 t ha^{-1}) with added NPK fertilizers than BRRI dhan53 (5.33 t ha^{-1}). Nutrient requirements (kg ha^{-1}) were 74-10-29 for IR77092-B-2R-B-10.

Boro season. BR (BIO)8072-AC8-1-1-3-1-1 produced the highest grain yield (5.81 t ha^{-1}) followed by BRRI dhan28 (5.28 t ha^{-1}). The N, P and K requirements (kg ha^{-1}) were 127-10-47 for BR (BIO) 8072-AC8-1-1-3-1-1. Grain yields of MER genotypes (8.12-8.32 t ha^{-1}) were higher than BRRI dhan28 (7.70 t ha^{-1}) under complete fertilization. Nitrogen, P and K requirements (kg ha^{-1}) for MER were 81-0-55, 168-17-40 for BR7831-59-1-1-4-3-1-7-P2 and BR7831-59-1-1-4-9-1-2-P3 respectively. BRRI dhan29-SC3-8-HR1 (com) produced the highest grain yield (7.30 t ha^{-1}) followed by BRRI dhan29-SC3-28-16-15-HR2 (com) (7.28 t ha^{-1}) and BRRI dhan28 (6.30 t ha^{-1}). The N, P and K requirements (kg ha^{-1}) were 178-17-49, 178-35-19 for BRRI dhan29-SC3-8-HR1(com) and BRRI dhan29-SC3-28-16-15-HR2(com) respectively.

Nitrogen and K rates

Potassium influences N uptake and improves plant's resistance to insect pests and diseases. The main broad differences between K and N properties in relation to their chemical reactions in soil, uptake by plants and their roles in plant physiology raise the question of possible interactions or competition between N and K. So, the objectives of 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. The experiments were conducted at BRRI farm, Gazipur (AEZ 28) during 2015-16 seasons. Potassium was used at 0, 50, 100, 150 and 200 kg ha^{-1} in the main plot and N at 0, 50, 75 and 100 kg ha^{-1} in T. Aman and 0, 100, 120 and 140 kg ha^{-1} in Boro season in the subplots. Indicator varieties were BRRI dhan49 in T. Aman and BRRI dhan29 in Boro season. Phosphorus and S was applied as blanket dose.

Grain and straw yields. In T. Aman, effect of NK and their interaction on grain yield of BRRI dhan49 was significant (Table 1). At K_0, N rates significantly decreased grain yield. At N_0, K rate up to 100 kg ha^{-1} progressively increased grain yield; but K at 50 and N at 75 kg ha^{-1} were the suitable combination. Straw yields were significantly affected by N applications only. In Boro, K, N and their interaction significantly influenced grain yields of BRRI dhan29 (Table 2). Under K deficient condition, 100 kg N ha^{-1} produced the highest grain yield (4.45 t ha^{-1}). Application of 50 kg K ha^{-1} produced the highest grain yield (5.92 t ha^{-1}) with 120 kg N ha^{-1}, which was identical with 100 kg N ha^{-1} (5.79 t ha^{-1}). So, 50 kg K and 100 kg N ha^{-1} was suitable for desired yield of BRRI dhan29.

Uptake of P and K. In T. Aman, total P and K uptakes were influenced by K and N rates. The highest P uptake (18.65 kg ha^{-1}) was recorded with 50 kg K ha^{-1} and the lowest in K_0 (13.10 kg ha^{-1}) and N_0 (13.41 kg ha^{-1}) treatment. The highest K uptake (103.74 kg ha^{-1}) was recorded at 75 kg N ha^{-1} and the lowest K uptake was observed in K_0 (31.49 kg ha^{-1}) and N_0 (76.22 kg ha^{-1}) treatment.

Nitrogen and K doses for rice under AWD situation

Water and fertilizer managements are the key components of rice production. Both the

Table 1. Effect of N and K rates on grain and straw yields (t ha^{-1}) of BRRI dhan49, T. Aman 2015, BRRI, Gazipur.

K dose (kg ha^{-1})	N doses (kg ha^{-1})								K mean	
	0		50		75		100			
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
0	3.13	3.68	2.13	4.99	1.91	4.51	2.10	4.84	2.32	4.51
50	3.93	4.03	5.02	5.35	5.29	5.58	5.02	6.33	4.82	5.32
100	4.02	3.93	4.85	5.65	5.19	5.23	5.24	6.52	4.83	5.33
150	3.66	3.78	5.04	5.50	4.75	5.79	4.93	5.92	4.59	5.25
200	3.84	4.09	5.07	6.40	5.06	5.62	5.42	6.09	4.85	5.55
N mean	3.72	3.90	4.42	5.58	4.44	5.35	4.54	5.94		
$LSD_{0.05}$	Grain yield, K = 0.70 N= 0.23 K×N= 0.52									
	Straw yield, K = NS N= 0.45 K×N= NS									

Table 2. Effect of N and K on grain and straw yields of BRRI dhan29, Boro 2015-16, BRRI, Gazipur.

K dose (kg ha^{-1})	N dose (kg ha^{-1})								K mean	
	0		100		120		140			
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
0	3.28	2.88	4.45	3.27	3.86	3.75	3.70	2.98	3.82	3.22
50	2.79	2.20	5.79	4.85	5.92	4.86	5.78	5.05	5.07	4.24
100	2.89	2.39	5.33	4.22	6.19	4.41	6.34	4.47	5.19	3.87
150	3.26	2.32	5.52	4.41	5.22	4.19	4.90	4.75	4.73	3.92
200	2.90	2.23	6.02	4.53	6.37	5.48	6.01	5.38	5.33	4.40
N mean	3.02	2.40	5.42	4.26	5.51	4.54	5.35	4.53		
$LSD_{0.05}$	Grain yield, K = 0.59 N= 0.32 K×N= 0.71									
	Straw yield, K = NS N= 0.49 K×N= 1.10									

components require judicious decisions to make them environment friendly. Alternate wetting and drying (AWD) play an important role in saving irrigation water requirement. However, there is little information available on nutrient requirement under AWD conditions. Nutrient uptake by rice plants under AWD conditions also needs to be delineated. So, the objective of the present study was to find out optimum N and K doses with standard P and S rates under AWD situations for saving 10-20% water in rice cultivation.

BRRI dhan56, BRRI dhan57, BRRI dhan65 and BRRI dhan66 in T. Aman 2015 and IR83140-B-36-B-B and IR83142-B-71-B-B in Boro 2015-16 along with BRRI dhan28 and BRRI dhan29 were tested at BRRI, Gazipur with T_1 = control (no fertilizer), T_2 = standard NPKS dose, T_3 = 25% more NK + standard dose of P and S, T_4 = 50% more NK + standard dose of P and S and T_5 = 75% more NK + standard dose P and S. Standard doses of NPKS for Boro and T. Aman seasons were @ 138-18-64-11 and 92-12-42-9 kg ha^{-1}, respectively. Experiment was laid out in a split-plot design with three replications. Fertilizer management was placed in the main plots and rice genotypes in the subplots. Forty-five-day-old seedlings in Boro and 23-day-old in T. Aman seasons were transplanted at 20- × 20-cm spacing. Irrigation was applied following AWD technique. In T. Aman, no AWD technique was followed. All plots were surrounded by 30 cm soil levee. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis.

Grain yield. In comparison to standard fertilizer dose, application of 25% more NK significantly increased grain yield from 2.96 t ha^{-1} to 3.38 t ha^{-1} in BRRI dhan57 and from 2.28 t ha^{-1} to 3.64 t ha^{-1} in BRRI dhan65. Recommended dose was enough for desired yield of BRRI dhan56 (3.67 t ha^{-1}) and BRRI dhan66 (4.49 t ha^{-1}). In Boro, grain yield increased significantly due to application of recommended fertilizer dose compared to control (Table 3). Additional 50% NK application significantly increased grain yield of BRRI dhan28.

Uptake of P and K. In T. Aman, the highest P uptake (7.20 kg ha^{-1}) was recorded with BRRI dhan66. BRRI dhan65 and BRRI dhan66 absorbed the highest amount of K (58.62 and 58.30 kg ha^{-1}, respectively) with 25% additional K; while the highest K uptake by BRRI dhan56 and BRRI dhan57 was 53.79 and 50.96 kg ha^{-1} respectively with 50% additional NK dose.

Table 3. Grain yield of rice genotypes as influenced by fertilizer management under AWD conditions, Boro 2015-16, BRRI, Gazipur.

Treatment	Yield (t ha^{-1})				
	IR83140-B-36-B-B	IR83142-B-71-B-B	BRRI dhan28	BRRI dhan29	Treat. Mean
T_1 = Control	2.80	3.15	3.24	3.21	3.10
T_2 = *Std. NPKS	6.04	5.73	6.01	5.54	5.83
T_3 = 25% more NK + Std. PS	6.47	5.93	6.48	5.41	6.07
T_4 = 50% more NK + Std. PS	6.13	5.97	6.56	5.32	6.00
T_5 = 75% more NK + Std. PS	5.90	5.46	6.17	5.67	5.80
Variety mean	5.47	5.25	5.69	5.03	
CV (%)	5.8				
$LSD_{0.05}$	Treat. = 0.51	Variety = 0.23	Treat × Variety = 0.52		

*Std. = Standard dose for Boro season.

Fertilizer package for low input rice variety

Most of the MVs express their yield potential under higher fertilizer dose; but farmers generally apply lower levels of fertilizers to reduce production cost. Moreover, application of higher N doses usually invites pests and diseases resulting in additional costs. Under such circumstances, the varieties that provide reasonable grain yields with moderate fertilizer rates are desirable. So, determination of fertilizer package for low input variety is essential. A field experiment was conducted in T. Aman 2015 at BRRI farm, Gazipur with five fertilizer treatments: T_1=recommended dose (RD), T_2=15% less of RD, T_3=30% less of RD, T_4=45% less of RD, T_5=control (no fertilizer). The recommended fertilizer dose was 92-12-42-9 kg ha^{-1} of N-P-K-S respectively. All fertilizers except urea were applied at basal. Urea was applied in three equal splits. Yield performance of HUA565 was compared with BRRI dhan33. Experimental design was split-plot with three replications, where fertilizer treatments were in the main plots and varieties in the subplots.

Grain and straw yields. The highest grain yields in HUA565 (4.59 t ha^{-1}) and BRRI dhan33 (4.17 t ha^{-1}) were recorded with 30% less of recommended fertilizer dose. There was no significant straw yield reduction with same treatment.

Phosphorus and K uptake. Fertilizer doses significantly affected both P and K uptake. The highest P uptake (14.20 kg ha^{-1}) was recorded when 30% less fertilizer was used compared to recommended dose. Phosphorus uptake was more with HUA565 than BRRI dhan33. Potassium uptake was not reduced because of 30% less fertilizer use. Both varieties had similar K uptake of 65 kg ha^{-1}.

MANAGEMENT OF NUTRITIONAL DISORDERS IN RICE

Long-term use of organic and inorganic nutrients in lowland rice

Long-term missing element trial provides plant growth behaviour under deficit conditions and thus opportunity to take corrective measures. A long-term experiment was initiated on a permanent layout at BRRI farm, Gazipur in 1985 Boro season having 12 treatments (Table 4) assigned in RCB design with four replications. In Boro 2000, each plot was divided into two to include a reverse treatment and additional varieties, BRRI dhan29 and BRRI dhan31 to evaluate the reverse trends of missing elements. In Boro, NPKSZn was used @ 120-25-35-20-5 kg ha^{-1}, but in T. Aman it was 100-25-35-20-5 kg ha^{-1}. After 47th crop, treatments were modified with omission of Zn because of its sufficiency in the soil. The STB dose of NPKS was 138-10-80-5 kg ha^{-1} and 100-10-80-5 kg ha^{-1} for Boro and T. Aman respectively after 47th crop (BARC, 2005). Higher levels of available S in control plot compared to initial condition might be due to recent industrialization effect and thus S dose was reduced. Urea N was applied in three equal splits at final land preparation, at active tillering and at 5-7 days before PI. The rest of the fertilizers were applied at final land preparation.

In Boro 2009-10, organic materials were used as third modification in T_5, T_8, T_9, T_{10} and T_{11}. Oil cake (OC, 2 t ha^{-1}), saw dust (SD, 3 t ha), cow dung (CD, 3 t ha^{-1}), mixed manure (CD: PM: SD: OC = 1:1:1:0.5) and poultry manure (PM, 2 t ha^{-1}) in T_{10}, T_9, T_5, T_{11} and T_8. Only N @ 138 kg ha^{-1} was applied as top dress with organic amended treatments. However, both missing and reverse management plots were merged for making 12

Table 4. Treatments of long-term missing element experiment, BRRI, Gazipur 1985-2015.

Original 1985	Reverse 2000	2009-2010	2011-2015
NPKSZn	All missing	NPKSZn	NPKSZn @138/100-7-80-3-5 kg ha^{-1}
NPSZn (-K)	NSZn (+K)	NPSZn (-K)	NPSZn (-K)
NKSZn (-P)	NKSZn (+P)	NKSZn (-P)	NKSZn (-P)
PKSZn (-N)	PKSZn (+N)	PKSZn (-N)	PKSZn (-N)
NSZn (-PK)	NSZn (+PK)	Cow dung @ 3.0 t ha^{-1}	Cow dung (3 t ha^{-1}) + IPNS fert.
NPKS (-Zn)	NPKS (+Zn)	NPKS (-Zn)	NPKS (-Zn)
NPKZn (-S)	NPKZn (+S)	NPKZn (-S)	NPKZn (-S)
NPK (-SZn)	NPK (+SZn)	PM @ 2 t ha^{-1}	PM (2 t ha^{-1}) + IPNS fert.
NP (-KSZn)	NP (+KSZn)	Saw dust @ 3 t ha^{-1}	NPKSZn @ 138/100-7-60-3-5 kg ha^{-1}
NK (- PSZn)	NK (+PSZn)	Oilcake @ 2.0 t ha^{-1}	Oil cake (2 t ha^{-1}) + IPNS fert.
N (-PKSZn)	N (+PKSZn)	Mixed Manure	NPKSZn @ 138/100-7-40-3-5 kg ha^{-1}
All missing	+ NPKSZn	Control	Control

treatments. In T. Aman 2011-12, T_9 and T_{11} 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}. From T. Aman 2015, vermicompost (VC) was used in place of mustard OC with same rate. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis.

Grain and straw yields. In T. Aman, omission of N, P and K decreased rice yield than complete fertilization (Table 5). Cow dung and PM treated plots had higher grain yields (4.94 and 4.91 t ha^{-1} respectively) followed by VC (4.70 t ha^{-1}). The highest rice yield (4.60 t ha^{-1}) was obtained with 80 kg K ha^{-1} and the lowest (3.88 t ha^{-1}) with 40 kg K ha^{-1}. In Boro 2015-16, complete fertilization gave grain yield of 5.40 t ha^{-1}, which decreased significantly due to omissions of all nutrients, N, P and K. The decrease in grain yield due to S and Zn omission was insignificant. Application of PM @ 2 t ha^{-1} and CD @ 3 t ha^{-1} with IPNS based fertilization gave the highest grain yield (6.92 t ha^{-1}). Application of VC with IPNS based fertilizer produced statistically similar grain yield than complete fertilizer treatment. Straw yield in CD @ 3 t ha^{-1} with IPNS fertilizer treatment was the highest (5.51 t ha^{-1}) followed by PM + IPNS and VC+IPNS based fertilization (5.23 and 5.25 t ha^{-1}).

Yield trend. Long-term omission of N, P, K, S adversely affected rice yield though S and Zn omission had no negative effect on rice yield in Grey Terrace soil of BRRI farm, Gazipur. 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.

Table 5. Effect of organic and inorganic nutrients on grain and straw yields (t ha) of BRRI dhan49 and BRRIdhan29, BRRI, Gazipur.

Treatment	T. Aman 2015		Boro 2016	
	Grain (t ha^{-1})	Straw (t ha^{-1})	Grain (t ha^{-1})	Straw(t ha^{-1})
NPKSZn@100-7-80-3-5 kg ha^{-1}	4.60	6.22	5.40	4.57
NPSZn (-K)	4.11	6.29	4.04	3.67
NKSZn (-P)	4.29	6.32	3.94	4.44
PKSZn (-N)	4.03	5.99	3.01	2.37
CD (3 t ha) + IPNS	4.94	6.40	6.14	5.51
NPKS (-Zn)	4.45	6.36	5.32	4.97
NPKZn (-S)	4.63	6.64	5.39	4.42
PM (2 t ha^{-1}) + IPNS	4.91	6.50	6.40	5.23
NPKSZn@100-7-60-3-5 kg ha^{-1}	4.29	6.43	5.37	4.95
VC (2 t ha^{-1}) + IPNS	4.70	6.49	5.87	5.25
NPKSZn@100-7-40-3-5 kg ha^{-1}	3.88	5.12	4.45	4.12
Control	2.92	3.82	2.16	1.98
LSD(0.05)	0.66	0.69	0.69	0.84
CV (%)	8.97	6.73	8.38	11.42

Intensive wetland rice cropping and grain yield

Population in Bangladesh is increasing but cultivable land is decreasing. This means we have to produce more from less area with less water to feed our people. So, this experiment was designed to harvest three rice crops per year and to evaluate the consequences of intensive cropping under continuous wet land conditions on soil fertility over time. This 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. This is a non-replicated trial.

Rice production. Annual rice production is in decreasing trend because of continuous rice cultivation without fertilizer application (Fig. 1). In 2015, grain yield in control plot was 0.50, 1.25 and 3.08 t ha^{-1} in Boro, Aus, T. Aman seasons respectively. When NPKSZnCu fertilizers were used as reverse treatment, total rice production jumped to 12.49 t ha^{-1} against 4.83 t ha^{-1}, which is similar to complete fertilization (12.14 t ha^{-1} yr^{-1}).

Grain and straw yields. In Boro 2015-16, grain and straw yields in control plot were 1.17 t ha^{-1} and 1.70 t ha^{-1} respectively. Addition of NPKSZnCu (reversed management) resulted in 5.58 t ha^{-1} grain yield, which was comparable to complete fertilizer treatment (4.83 t ha^{-1}) indicating that soil has capability to produce optimum yield when it receives balanced fertilizers. Additional use of Cu was not necessary.

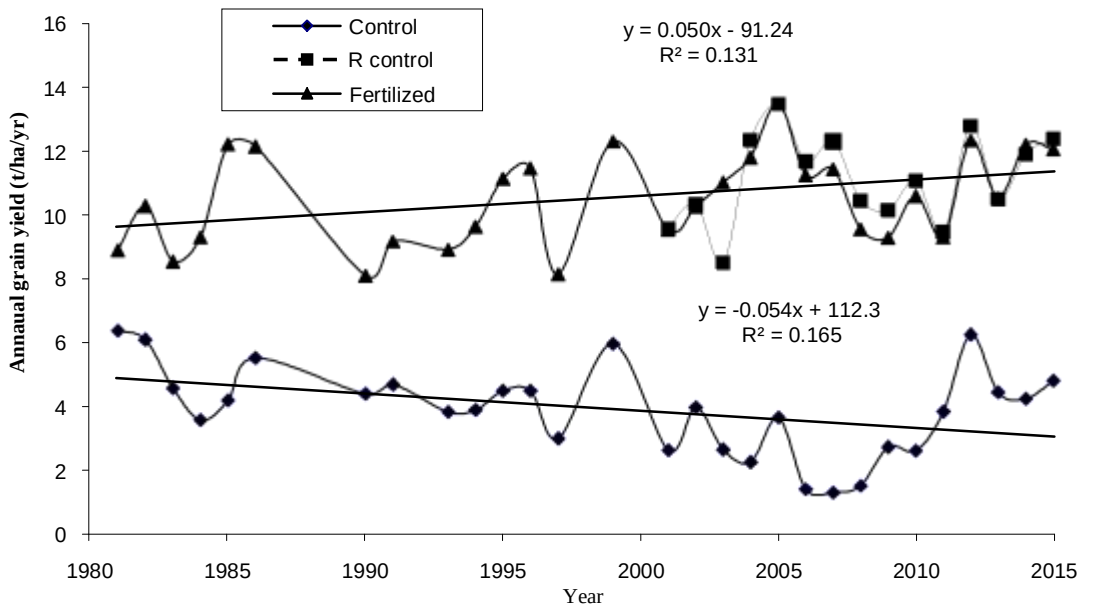

Fig. 1. Changes in annual rice production under perpetually wetland conditions over 36 years.

Nutrient uptake. In Boro 2015-16, the highest N uptake (70.45 kg ha^{-1}) by BRRI dhan50 was found with NPKSZn fertilization. Phosphorus uptake (23.84 kg ha^{-1}) was more in reverse control treatment. Potassium and sulfur uptake was higher in NPKS treatments.

Integrated nutrient management

Integrated nutrient management (INM) could be a viable option to improve yield and soil health. So, a field experiment was conducted to evaluate the effects of INM under continuous wetland culture for sustainable soil health and productivity. The

experiment was initiated in Boro 2008-09 at BRRI farm Gazipur in clay loam soil. In Boro-F-Aman pattern, BRRI dhan29 and BRRI dhan49 were used. In Boro-Aus-Aman pattern, BRRI dhan29, BRRI dhan43 and BR46 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} + oven dried ash @ 1 t ha^{-1}), 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 2014-15 under double and triple cropping patterns, STB and 50% STB + MM fertilizer dose produced statistically similar grain yield (Table 6). In T. Aus 2015, the highest grain yield (1.90 t ha^{-1}) of BRRI dhan43 was found in 50% STB + MM treatment, which was statistically similar with STB dose (1.79 t ha^{-1}). In T. Aman 2015 under triple cropping pattern, 50% STB + MM fertilizer dose produced significantly higher yield than STB dose and FP. In double cropping pattern, STB and 50% STB + MM fertilizer dose produced statistically identical yield. Cumulative yield of triple cropping was always higher than double rice cropping pattern irrespective of treatment.

In Boro 2015-16 under double cropping pattern, STB and 50% STB + MM fertilizer treatments produced significantly higher grain yield than FP. The highest grain yield (5.69 t ha^{-1}) was found in STB treatment, which was statistically similar with 50% STB + MM fertilizer treatment (5.17 t ha^{-1}). In triple cropping pattern, STB, 50% STB + MM and FP fertilizer treatments produced statistically identical grain yield (4.46-5.15 t ha^{-1}). It may be concluded that STB and INM based fertilizations are good options for obtaining higher rice yields in double or triple rice cropping pattern.

Nutrient uptake. In Boro, N uptake under double cropping pattern was 60.91 kg ha^{-1} with STB fertilizer dose and 63.66 kg ha^{-1} with 50% of STB + MM, which was significantly higher than FP (40.33 kg ha^{-1}). Phosphorus uptake was 21.52 kg ha^{-1} in STB and 21.04 kg ha^{-1} in 50% of STB + MM treatment. Potassium uptake was the highest (about 73.5 kg ha^{-1}) with ST and 50% of STB + MM treatments. Similar patterns were followed under triple cropping pattern, but amounts were less than double cropping pattern.

Vermicompost and poultry manure in rice cultivation

Long-term rice culture shows declining yield trends. Poor soil OM and imbalanced nutrient management were the main factors for reduction in rice yield. FAO (1993) recommended greater addition of OM to paddy soils as a major remedial measure to protect agricultural productivity and sustainability. The present study was undertaken to find out the effect of PM and vermicompost (VC) with chemical fertilizers on yield and yield attributes of T. Aman and Boro rice and its impacts upon soil nutrient status and uptake of nutrients by rice plants.

Table 6. Annual grain production (t ha^{-1}) in double and triple cropping patterns under continuous wetland condition, BRRI farm, Gazipur.

Treatment	Double cropping			
	Boro 2014-15 (BRRI dhan29)	Fallow	T. Aman 2015 (BRRI dhan49)	Annual (t ha^{-1})
T_1 = Control	1.69	-	2.29	3.98
T_2 = STB	5.13	-	4.63	9.76
T_3 = 50% STB+MM	4.96	-	4.73	9.69
T_4 = FP	3.98	-	3.90	7.88
$LSD_{0.05}$	0.86	-	0.56	
CV (%)	10.96	-	7.23	
	Triple cropping			
	Boro 2014-15 (BRRI dhan29)	T. Aus 2015 (BRRI dhan43)	T. Aman 2015 (BRRI dhan 46)	Annual yield (t ha^{-1})
T_1 = Control	1.53	0.64	1.60	3.77
T_2 = STB	5.22	1.79	3.19	10.20
T_3 = 50% STB+MM	5.07	1.90	3.79	10.76
T_4 = FP	4.04	1.22	2.89	8.15
$LSD_{0.05}$	0.71	0.16	0.44	
CV (%)	8.93	5.74	7.68	

The experiment was conducted at BRRI farm, Gazipur in Boro 2015. Initial soil (0-15 cm) properties were: soil texture, clay loam; pH, 6.78; organic C content, 12.3 g kg^{-1}; total N, 1.3 g kg^{-1}; available P, 1.8 mg kg^{-1} and exchangeable K, 50 mg kg^{-1} soil. The PM and VC contained 50% moisture, 3.0% total N, 6.0 g kg^{-1} P_2O_5, and 17.5 g kg^{-1} K_2O (wt wt^{-1} dry weight). The PM and VC were used at 0.5, 1.0, 1.5, 2.0 and 2.5 t ha^{-1} and compared with control. Treatment was assigned in 4-×5-m sized plot and repeated thrice in a randomized block design. Forty-five-day-old seedlings of BRRI dhan29 and 25-day-old seedlings of BRRI dhan49 seedlings were transplanted at 20- × 20-cm spacing. Fertilizers (N-P-K-S-Zn=138-10-80-5-5 kg ha^{-1}) were applied one day before rice transplanting. Flooded water depth maintained was 5-7 cm and at 21 days before harvesting.

Rice productivity and nutrient uptake. Grain yield was 2.52-2.80 t ha^{-1} in control plot, which increased with increasing VC rates ($Y=3.46+1.57X-0.459X^2$, $R^2=0.628$). Based on this model, maximum yield could be obtained through the addition of 2 t ha^{-1} VC. Among the treatments, use of 0.5 t ha^{-1} VC showed higher yield than other treatments during T. Aman and Boro seasons. Nitrogen, P, K uptake by rice plants increased significantly to ca. 47-40-44% over control because of NPKSZn + 0.5 t ha^{-1} VC fertilization in T. Aman season and improved by ca. 42-68-81% in Boro season.

Performance of MV rice under P deficit conditions. Acute P deficiency reduces rice yield based on variety. The P efficient varieties may have internal and/or external mechanisms that allow greater soil P extraction, which needs to be investigated. An experiment was laid out in a randomized complete block design having four levels of soil available P (1.8-2.50, 2.51-3.20, 3.21-3.90 and 3.91-4.60 mg kg^{-1}) with three replications at BRRI farm, Gazipur. Soil P levels were determined after harvesting of T. Aman rice in 2015. BRRI dhan49 and BRRI dhan58 were tested in T. Aman 2015 and Boro seasons 2015-16 respectively. Each plot received 92 kg N, 42 kg K and 9 kg S ha^{-1} in T. Aman and 150 kg N, 60 kg K and 20 kg S ha^{-1} in Boro seasons as flat dose. Unit plot size was 6- ×3-m.

Grain and straw yields. The lowest grain and straw yields were recorded in the lowest soil P level of 1.80-2.50 and 2.51-3.20 mg kg^{-1} (Table 7). BRRI dhan49 performed better than BRRI dhan58 under same soil P level. Phosphorus deficiency showed negative effect in Boro season. BRRI dhan49 produced the highest grain yield (4.93 t ha^{-1}) when grown in the soil with maximum P level, but BRRI dhan58 produced only 4.78 t ha^{-1} with same soil P. So, BRRI dhan58 needs higher available soil P to produce desired yield.

Phosphorus and K nutrition. The P content in grains and straw of BRRI dhan49 increased progressively with higher soil P levels. Potassium concentration increased in grains but decreased in straw with higher soil P levels. Total P uptake was the highest (15.7 kg ha^{-1}) when soil P was 3.91-4.6 ppm. Requirement of P was 1.7-3.2 kg t^{-1} and that of K was 11-21 kg t^{-1} depending on soil available P.

SOIL AND ENVIRONMENTAL PROBLEMS

Nitrogen and water management and N_2O and NO emissions. Use efficiency of reactive N is only about 30-40% and the rest is responsible for environmental pollution. Soil is considered to be one of the most important sources and sinks of greenhouse gases (GHG). So, experiments were conducted to study the effects of broadcast urea (BU), urea deep placement (UDP) and NPK briquette on flood water NH_4^+-N dynamics, NH_3 volatilization biomass, grain yield and total NPK uptake and N_2O and NO emission under ADW and CSW conditions.

Field experiments were conducted at BRRI farm, Gazipur during T. Aman 2015 and Boro 2015-16 under both AWD and CSW conditions. Eight treatments with different sources and rates of N fertilizer were tested. BRRI dhan46 and BRRI dhan28 were used. Prilled urea (PU) was applied as broadcast in three equal splits in Boro season and two splits in T. Aman season at 7-10 DAT, while UDP and NPK briquette were applied only once during first top dressing (TD). The UDP and NPK briquette were placed at 7-10 cm below the soil surface between four hills at alternate rows. Under CSW condition, plots were flooded until two weeks before harvesting. Under AWD condition, irrigation water was applied when water falls below 15 cm of soil surface. Grain yield was adjusted at 14% moisture content and straw yield was adjusted as oven dry basis.

Table 7. Effect of soil P levels on rice yield, BRRI farm, Gazipur.

P level (mg kg^{-1})	Grain (t ha^{-1})		Straw (t ha^{-1})	
	T. Aman 2015 (BRRI dhan49)	Boro 2015-16 (BRRI dhan58)	T. Aman 2015 (BRRI dhan49)	Boro 2015-16 (BRRI dhan58)
1.80-2.50	2.81	1.61	4.52	2.11
2.51-3.20	3.04	2.05	4.89	1.97
3.21-3.90	4.86	3.27	5.49	3.37
3.91-4.60	4.93	4.78	5.44	3.78
CV (%)	2.60	3.80	10.00	8.90
$LSD_{0.05}$	0.20	0.22	1.02	0.50

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. NO were measured with a Teledyne API T200 Chemiliminescence Analyzer and N_2O with a Teledyne API T320U Gas Filter Correlation Analyzer. Calibration was done using Teledyne API T700 Dynamic Dilution Calibrator. Gas sampling and analysis system were controlled by Campbell Scientific CR3000 Datalogger.

Rice yield and N uptake. In T. Aman, grain yields recorded were 3.55 t ha^{-1} in AWD and 3.67 t ha^{-1} in CSW condition under control treatment. Application of N either deep placed or broadcast gave similar grain yield (about 4.5 t ha^{-1}) at similar N rate in both AWD and CSW conditions. Deep placement of urea improved N uptake by 15-19% and recovery efficiency by 47-65% compared to broadcast urea. In Boro 2016, grain yields were 4.8-5.25 t ha^{-1} with UDP at variable N rates under AWD, but it was 4.94-5.44 t ha^{-1} under CSW. At different N rates, grain yield with PU was 4.02-4.38 t ha^{-1} in AWD and 4.08-4.45 t ha^{-1} in CSW condition. Total N uptake was 70-82 kg ha^{-1} with UDP fertilizer under AWD and it was 70-86 kg ha^{-1} under CSW. Total N uptake because of PU use was 51-65 kg ha^{-1} in CSW, while it was 49-63 kg ha^{-1} in AWD practice depending on water management and N rates.

Flood water NH_4^+-N and NH_3 volatilization. Irrespective of N rate and season, the amount of floodwater NH_4^+-N was higher in PU treatment after 1-2 days of fertilization than UDP (Figs. 2 and 3). Deep placement of N significantly reduced NH_3 volatilization compared to PU treatment irrespective of N rate (Figs. 4 and 5). In T. Aman, N loss as NH_3 volatilization from PU treatment was 8-9%, while it was only about 4% during Boro 2016.

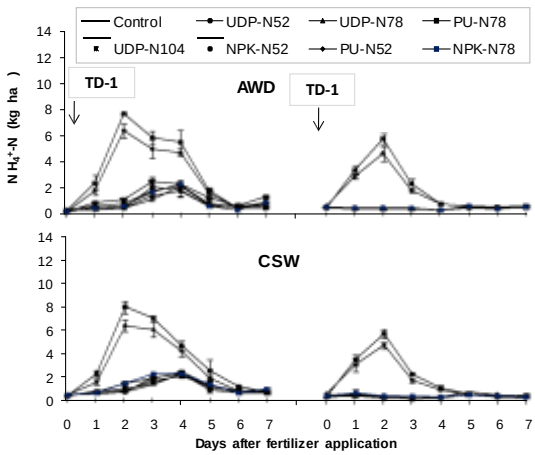

Fig. 2. Floodwater NH_4^+-N as influenced by N and water management, BRRI, Gazipur, T. Aman 2015. TD-1 and TD-2 represent first and second topdressing of PU. Vertical bars indicate standard error of means (n=3).

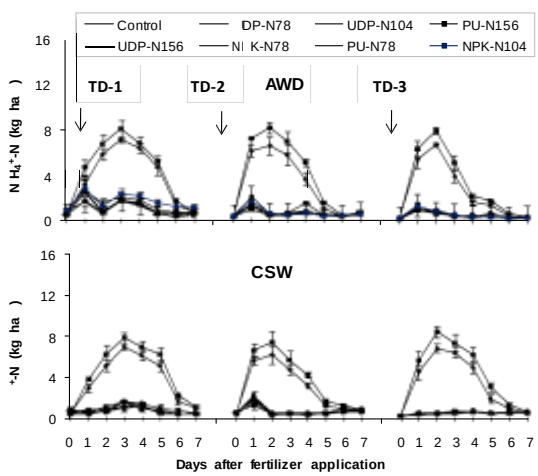

Fig. 3. Floodwater NH_4^+-N as influenced by N and water management, BRRI, Gazipur, Boro 2016. TD-1, TD-2 and TD-3 represent first, second and third topdressing of PU. Vertical bars indicate standard error of means (n=3).

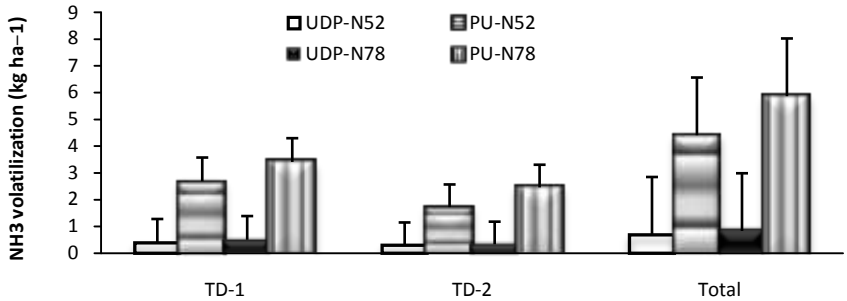

Fig. 4. Ammonia volatilization under AWD condition, BRRI, Gazipur, T. Aman 2015; TD-1 and TD-2 represents first and second topdressing of PU. Vertical bars indicate least significant difference at the 5% level of probability.

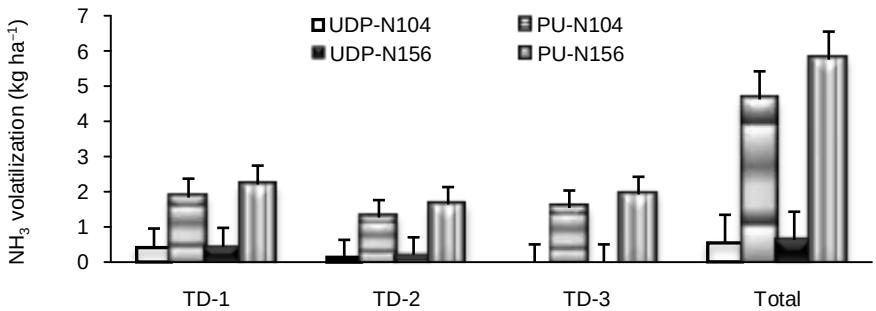

Fig. 5. Ammonia volatilization under AWD condition, BRRI, Gazipur, Boro 2016; TD-1, TD-2 and TD-3 represent first, second and third topdressing. Vertical bars indicate LSD at the 5% level of probability.

Cumulative N_2O-N emissions. In T. Aman, broadcast application of PU significantly increased cumulative N_2O-N fluxes compared to UDP and control treatment (Fig. 6a). In Boro 2016, N_2O-N fluxes reduced significantly in control treatment compared to UDP and PU treatments under AWD condition (Fig. 6b). Although UDP treatment showed slightly higher N_2O fluxes over PU, the differences were insignificant. Under CSW condition, UDP significantly reduced cumulative N_2O-N fluxes.

Cumulative NO-N emissions. In T. Aman, total NO emissions were negative indicating soil uptake of NO from atmosphere. The uptake was higher in control plot (-15 g NO-N ha^{-1}) than UDP (-8 g NO-N ha^{-1}) and broadcast PU (-4 g NO-N ha^{-1}) plots. Uptake of NO or N_2O by soils are observed when soil is poor in N content. However, negative emissions were due to high background NO concentration, particularly in night time from Oct to Dec. In Boro, cumulative NO emission varied from 8.13 to 10.43 g N ha^{-1} under AWD.

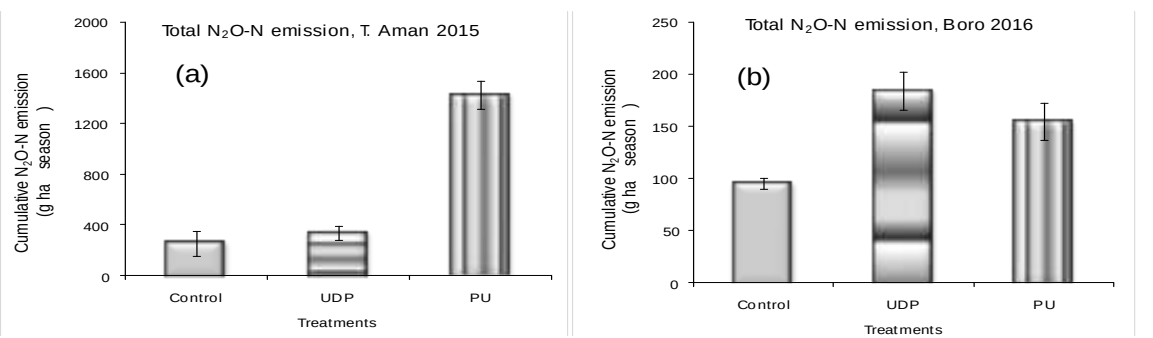

Fig. 6. Cumulative N_2O-N emissions under AWD condition, BRRI farm, Gazipur. Vertical bars indicate SE of mean (n=3). A = T. Aman season, b = Boro season.

Climate smart agricultural practices

Agriculture in Bangladesh varies in 30 agro-ecological zones and 88 sub-zones. These zones have been developed based on physiography, soil type, nature of seasonal flooding and agro-climatology. Although different crops are grown across the country, climate change impacts are visible on their performances. Sustaining food security under changing climatic conditions requires adoption of climate resilient production technologies. So, activities on climate smart agricultural practices were initiated at three villages of Gazipur and Kishoreganj districts in 2015.

In T. Aman season, BRRI dhan62 was introduced with rice crop manager (RCM) based cultural practices and compared with farmer's practices (FP). Mustard was grown after T. Aman rice with recommended fertilizer dose (Urea-TSP-MOP-Gypsum-Boric acid @ 197-145-66-132-7 kg ha^{-1}). In Boro season, fertilizer was used at RCM and farmer's dose. Mustard plots were divided into two parts to accommodate full doses of RCM fertilizer (T_1) and 50% reduction of RCM dose except urea (T_2). Reduced tillage practices along with direct-seeded Boro rice culture were introduced. Cool Farm Tool Beta3 Xcel based model was used to determine global warming potential (GWP).

The GWP was 1389.6 CO_2 eq kg ha^{-1} when BRRI dha62 was cultivated but it was 1564.3 CO_2 eq kg ha^{-1} with FP. Moreover, mustard litters were also deposited and thus carbon was added to the soil by about 2% of the total dried biomass produced, which was about 28 kg carbon. Rice equivalent yield (REY) with introduced pattern was 13.9-14.6 t ha^{-1} but it was only 8.1-8.9 t ha^{-1} with FP. Grain yield of Boro rice was 4.5-5.9 t ha^{-1} with NPKSZn@140-20-60-6-3 and yield with 50% reduction in fertilizer rate except urea was 4.47-5.6 t ha^{-1}. In machine and hand transplanting after one pass by tractor gave higher yield than 3-4 passes conditions (Table 8). In hand transplanting, rice yield was lower than machine transplanted crop because of older seedlings. In direct-seeded Boro rice culture, grain yields were 5.4-5.7 t ha^{-1} with one or two passes of power tiller that were similar to hand transplanting by farmers with 3-4 passes.

Global warming potential and cropping patterns

Many cropping patterns existed in Bangladesh depending on land suitability and demand for crops. No greenhouse gas (GHG) emission data are available from those cropping patterns. Cool Farm Tool Beta-3 software was used for determination of total GHG emissions from selected patterns. Inclusion of non-rice crops in a rice based pattern had the lowest global warming potential (GWP) than rice based cropping patterns. Onion-Jute-Fallow (2125 CO_2eq kg ha^{-1}), Fallow-Jute-T. Aman (2348.2 CO_2eq kg ha^{-1}), Wheat-Mungbean-T. Aman (3315.2 CO_2eq kg ha^{-1}) and Maize-Fallow-T. Aman (3987.9 CO_2eq kg ha^{-1}) patterns could be better options for mitigation of GHG emission in Bangladesh.

Soil process vs increased temperature

Soil temperature and nutrient management practices may influence nutrient mineralization and soil microbial community in different soils. An incubation study was conducted at BRRI to determine the effect of chemical fertilizer and IPNS and temperature regimes (28° C and 45° C) on nutrient mineralization and soil biology of terrace and saline soils. High temperature (45°C) enhanced 33% C mineralization in IPNS treatment of terrace soil and 41% in chemical fertilizer treated saline soil. High temperature increased N mineralization by about 3-fold in saline soil. High temperature significantly enhances P mineralization in IPNS compared to chemical fertilizer amended treatments. At 28° C, K mineralization was high in chemical fertilizer amended terrace soil. Soil biology also affected due to treatment and the highest change occurred in bacteria and the least for actinomycetes. Phosphate solubilizing bacteria were more resistant to high temperature compared to free-living N_2 fixing bacteria. In general, high temperature and nutrient management affected C, N, P, K mineralization and soil biology.

Table 8. Rice yield productivity under machine and hand transplanting system.

Location	Machine transplanting		Hand transplanting	
	1 pass	3-4 pass	1 pass	3-4 pass
Toke, Gazipur	5.86-5.90	4.95-4.97	5.63-575	4.30-4.55
Pakundia, Kishoreganj	5.96-6.15	5.22-5.24	5.54-5.89	4.98-5.12
Kotiadi, Kishoreganj	5.64-6.09	4.98-5.57	5.86-6.12	4.66-5.14

Future climatic scenario for Bangladesh

Future climatic scenario was analyzed for 2050 and 2100. Considering critical maximum temperature (35°C) for chickpea, cotton, groundnut, maize, rice and sorghum, there will be no problem for cultivation of those crops by 2050 (Fig. 7). In 2100, critical temperature limit will cross during March through October under RCP8.5; during March under RCP4.5 and RCP6.0. Optimum temperature for rice and maize growth will be prevailing during March, April and October for rice and during March for maize in 2050; these periods are likely to be reduced in 2100. Critical minimum temperature will be existed during January in 2050 and 2100, which is similar to 2010. Total rainfall is likely to reduce in 2050 compared to 2010 and will be increased again in 2100. Solar radiation is likely to increase during December to April and reduce during June to November.

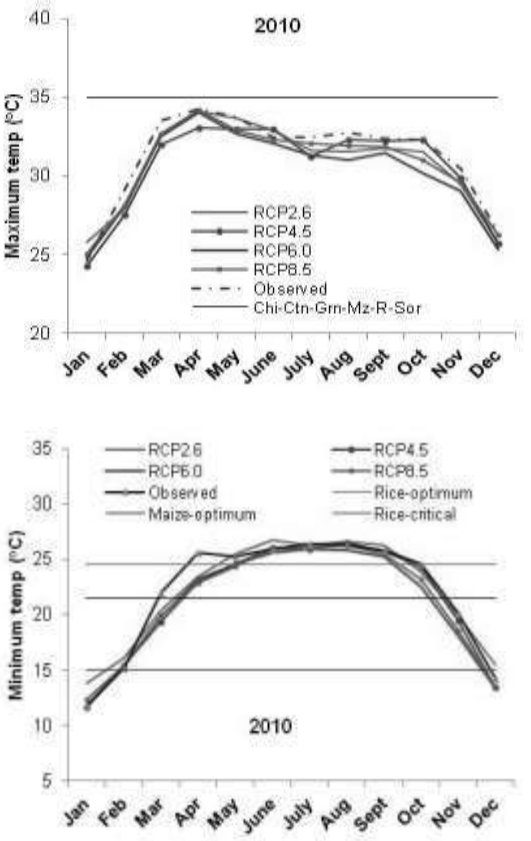

Figure 7.

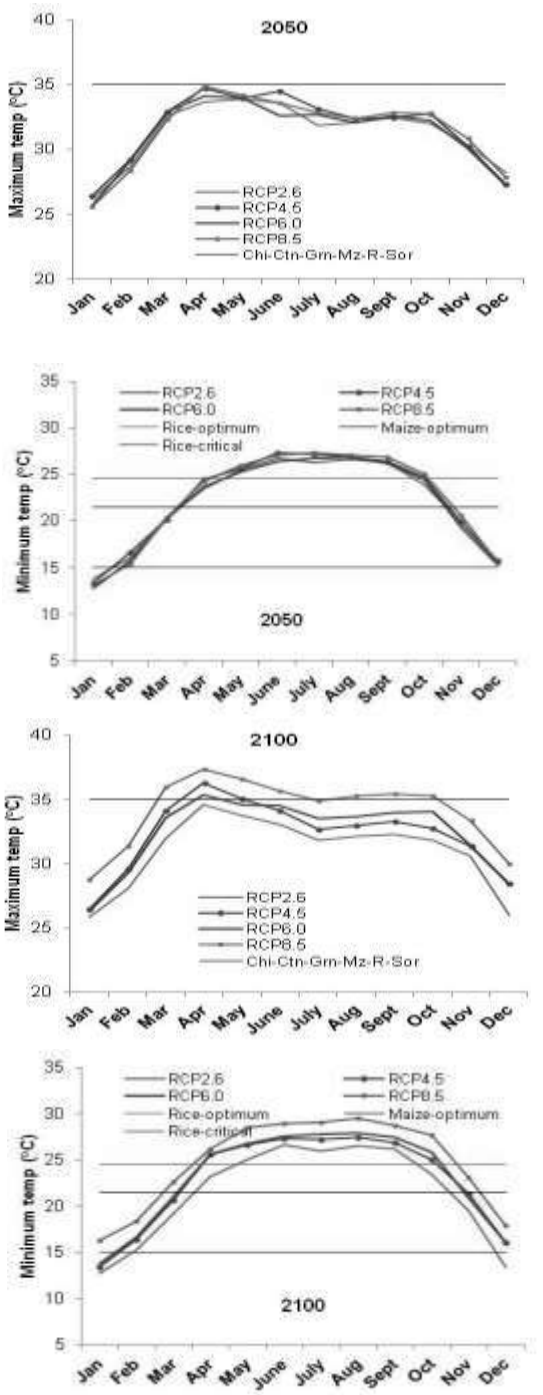

Fig. 7. Predicted maximum and minimum temperatures in Bangladesh during 2010, 2050 and 2100 based on different RCPs along with critical and optimum temperature requirements for chickpea, cotton, groundnut, maize, rice and sorghum (Chi-Ctn-Grn-Mz-R-Sor).

Validation of BRRI developed fertilizer management technology

Soil Science Division of BRRI has developed technologies on soil and fertilizer management for rice based cropping systems. Among them, use of available organic materials and IPNS based fertilizer management is superior to the existing farmers' production technology. Therefore, the present investigation at farmers' field was: to increase productivity of MV rice through BRRI developed fertilizer management options in rice-based cropping systems under Tidal Flood Ecosystem and submergence and cold areas and to increase farmer's awareness about soil health.

Demonstrations were conducted during T. Aus 2012 through T. Aman 2015 at the farmers' fields in Barisal (AEZ 13) and Rangpur (AEZ 3) regions. Treatments included were: T_1=BRRI recommended dose (BRRI dose), T_2 = Rice straw (RS)/Cow dung (CD)/Poultry manure (PM)+IPNS based chemical fertilizer (IPNS) and T_3=Farmers' practice (FP). BRRI dhan27, BRRI dhan55, BRRI dhan43 and BRRI dhan48 were used in T. Aus, BRRI dhan49, BRRI dhan54, BRRI dhan11 and BRRI dhan52 in T. Aman and BRRI dhan47, BRRI dhan29 and BRRI dhan58 in Boro seasons in Barisal region. BRRI dhan49, BRRI dhan52 were used in T. Aman season, while BRRI dhan28, BRRI dhan29 and BRRI dhan58 in Boro season in Rangpur region.

Grain yield. In Aus season, BRRI dose and IPNS produced the higher grain and straw yield over FP. In IPNS treatment, grain yields were 4.04-4.76 t ha^{-1}. BRRI recommended fertilizer dose produced 3.87-4.75 t ha^{-1} grain yields. In T. Aman season, BRRI recommended fertilizer dose and IPNS produced higher grain and straw yields over FP. Grain yields with IPNS were 3.69-5.56 t ha^{-1}. BRRI dose produced 3.66-6.06 t ha^{-1} grain yields. The variations in yields were because of locations and soil types. In Boro season, IPNS based fertilizer management gave 6.91-8.01 t ha^{-1} grain yields, which were about 8-20% higher than FP. BRRI dose produced 6.70-7.98 t ha^{-1} grain yields that were about 7-12% higher than FP.

Technological benefits. Application of RS/CD/PM with IPNS technique saved good amounts of chemical fertilizers. The RS @ 4.5 t ha^{-1} saved 50 kg urea, 18 kg TSP, 144 kg MoP and 25 kg gypsum ha^{-1}. Cow-dung @ 3 t ha^{-1} substituted 78 kg urea, 120 kg TSP, 78 kg MoP and 25 kg gypsum per hectare. Poultry manure @ 2 t ha^{-1} saved 82 kg urea, 56 kg TSP, 30 kg MoP and 137 kg gypsum ha^{-1}.

SOIL MANAGEMENT FOR UNFAVOURABLE ECOSYSTEMS

Evaluation of salt tolerant rice varieties

Accumulation of excessive salt in paddy soils reduces rice yield, although it has different degrees of salt resistance. Researchers are trying to develop salt tolerant rice varieties to overcome such problem. Recently, BRRI has developed some salt tolerant rice varieties and some are in the pipelines. Performances of these genotypes need to be evaluated under natural saline conditions than artificially created environment.

An experiment was conducted in complete randomized design without replication at BRRI net house, Gazipur in Boro 2015-16. Saline soils were collected from Kalapara, Patuakhali and different levels of salinity were created with natural saline sea water. Salinity levels were <4, 8, 10, 12 dS m^{-1} and compared with BRRI farm soil, Gazipur (<1 dS m^{-1}). Volume of each tank, made by concrete, was 208.5-×208.5-×38.5-cm. Polythene shade over the tank was made at 56 days after transplanting (DAT). Table 9 shows the initial soil properties. Forty-four-day-old seedlings of BRRI dhan67 (salt tolerant) and 74-day-old seedlings of BRRI dhan28 were transplanted at 20-×20-cm spacing. Nitrogen, P, K and S were applied @ 140-20-80-10 kg ha^{-1} respectively. All fertlizers except urea were applied at basal. Urea was applied in equal three splits. Crops were grown under fully irrigated condition with 0.3 dS m^{-1} water. At maturity the crop was harvested from 1.8 m^2 area, excluding border line. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis.

BRRI dhan67 was fully damaged after transplanting at 12 dS m^{-1} and BRRI dhan28 was fully damaged at 10 dS m^{-1}. Grain yield of BRRI dhan28 and BRRI dhan67 were gradually decreased with increasing soil EC and drastically reduced when EC value was over 8 dS m^{-1} (Figs. 8 and 9).

Table 9. Initial soil properties (0-15 cm) of different tanks, BRRI-Gazipur, Boro 2015-16.

Tank	Exch. (cmol kg^{-1})				Water soluble (meq l^{-1})					pH	EC	SAR	ESP	CEC
No.	Na	K	Ca	Mg	Na	K	Ca	Mg	S		(dS m^{-1})			(cmol kg^{-1})
1	0.3	0.2	16.1	4.3	4.4	0.2	6.65	0.2	0.04	7.4	0.5	2.3	1.4	20.82
2	2.4	0.4	2.6	4.2	59.8	1.5	11.6	13.2	5.53	5.8	10.0	17.0	25.1	9.63
3	3.4	0.4	4.4	4.1	65.3	1.9	14.9	14.5	4.69	5.6	12.0	17.0	27.8	12.22
4	3.3	0.4	2.6	4.9	54.4	1.7	11.6	13.5	4.34	5.4	8.0	15.3	29.6	11.19
5	1.8	0.4	2.7	3.7	21.8	0.6	10.0	9.0	1.12	6.3	3.2	7.1	20.8	8.61

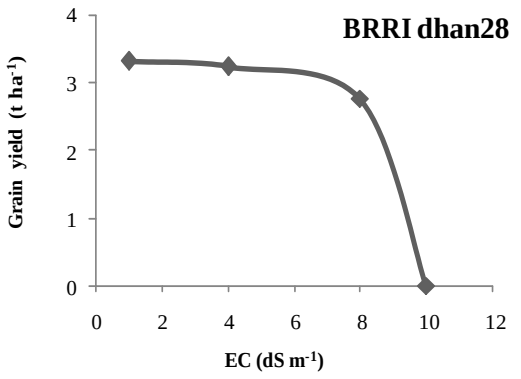

Fig. 8. Effect of soil EC on grain yield of BRRI dhan28.

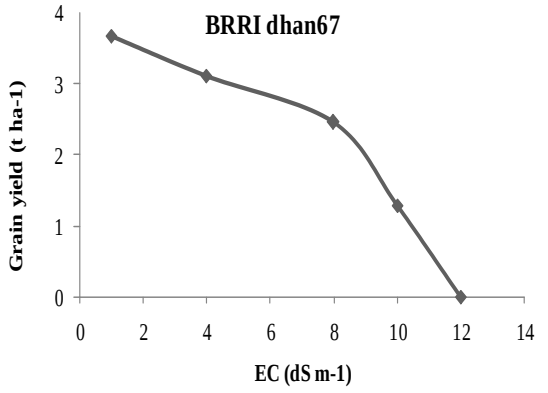

Fig. 9. Effect of soil EC on grain yield of BRRI dhan67.

SOIL MICROBIOLOGY

Co-composting and nutrient mineralization

Co-composting urban waste, crop residues and rock phosphate (RP) is an efficient way of waste management and to avoid P fertilizer use for rice production. A study (120 days) was conducted at BRRI-Gazipur in 2015 to determine bio-chemical process, nutrient content and compost maturity for mixed organic materials: P_1- urban waste (50%) + rice straw (RS, 30%) + saw dust (SD, 10%) + RP (8%) + sugarcane trash, (ST, 2%), P_2- urban waste (50%) + RS (23%) + SD (10%) + mustard oil cake (MOC, 15%) + ST, 2%) and P_3- urban waste (95%) +rock phosphate, RP (5%). Samples were collected at every 30 days following completely randomized block design. Temperature, microbial population, CO_2 evolution, pH, C:N, decomposition rate, P and K content, humification and germination index (GI) were determined.

Changes in OC and OM decomposition rate. Total organic carbon (OC) and C:N ratio gradually decreased over composting period. The OM degradation rates followed first order kinetics. Initially (30 days) total OC mineralization was low in P_1 (4.1%) compared to P_2 (42.26%) and P_3 (52.42%) treatment. Rapid decomposition occurs in P_3, where initial C:N was 31.13 and at 90 days it became plateau. Total N decreases over period. After 120 days of co-composting, the C:N was 9.6, 11.22 and 13 for P_1, P_2 and P_3, respectively. Maximum degradation (%) of OM was 77.67± 1.55 in P3 followed by 73.99±0.05 in P1 and 71.95± 2.5 in P2. The degradation rate with P_3 was best fitted as exponential model (R^2 = 0.9) and the rest as power model. Depending on age of composting, the OM decomposition rate constants were 5×10^{-4} to 1×10^{-2} in P1, 4-6 $\times10^{-3}$ in P2 and 1×10^{-3} to 4×10^{-4} in P3.

Temperature, microbes, CO_2 evolution and mineralization. Compost temperature was thermophilic for first two weeks. The highest bacteria population was found in P_2 having high cumulative CO_2 evolution of 53.76 mg g^{-1} VS. Incidence of PSB was 2.0 to 6.3 Log_{10}Cfu g^{-1} dry wt, mostly in RP amended piles. The highest free-living N_2 fixing bacteria (5.2-6.4 Log_{10}Cfu g^{-1} dry wt) were found in P_1. Initially fungus population was high and only visible upto 60 days. In composting period, actinomycetes population (3.1 to 5.5 Log_{10}Cfu g^{-1} dry wt**)** was always present with P_2. In P_1, the highest actinomycetes

population (5.55 Log_{10}Cfu g^{-1} dry wt) was found at 90 days and declined. Phosphorus released from co-composting material over time and it was higher when RP was used. Phosphorus content was slightly lower at 60 days may be due to microbial immobilization. At 120 days, maximum P content of P_3 was 2.33% having potential to supplement 20 kg P fertilizer. Exchangeable K was high in P_1 (0.99%) followed by P_2 (0.88%) at 90 days and then decreased. Potassium content was higher with rice straw added treatment (P_1 and P_3).

Humification and compost maturity. About 90 to 95% of OC was in humic acid and trace amount in fulvic acid. Humic acid of three piles were classified as rotteprudukte. Humic acid of this group (log Δ k=0.81-1.10) was originated from lignin. Compost exhibited a stable pH (7.5 to 8.1), suitable temperature (25 to 28°C), lower CO_2 evolution, low C:N and humified OM without phytotoxic effects (GI> 90).

Irrigation and Water Management Division

SUMMARY

The moisture holding capacity also varied with the soil texture. Most of the cases the top soil moisture removed faster with an exception to Kaharole. It was found that clay-loam soil (Thakurgaon) retained more water compared to silt-loam (Kaharole). Available moisture ranges 15.52-25.85%, 10.59-28.77% and 12.11-31.03% in silt-loam to loam soil, clay-loam to loam soil and silty-loam to loam soil at Tanore, Thakurgaon and Kaharole respectively.

Potato-Braus-T. Aman cropping pattern gave the highest yield with comparatively less amount of irrigation. BRRI dhan48 performed better as a Braus variety compared to BRRI dhan28.

Considering the growth duration, rainfall and yield performances BRRI dhan31, BRRI dhan53 and BRRI dhan56 were found more drought stress tolerant among the long, medium and short duration varieties, respectively.

The rooftop catchment area has a runoff coefficient of 0.48**.** Runoff volume produced from the catchment depend not only the roughness of the catchment but also the amount of rainfall.

Water salinity of Burishor, Bishkhali and Boleshor rivers remains less than 1dS/m throughout the year at upstream of Golbunia Bazar, Kakchira Ferryghat and Telikhali Launchghat, Vandaria respectively.

Two year research findings showed that, 1.5 hp capacity solar pump can irrigate maximum 1 ha land for Boro rice.

WATER USE EFFICIENCY IMPROVEMENT IN IRRIGATED AGRICULTURE

Determination of physical and hydraulic properties in different soil types

The study was conducted in Tanore, Rajshahi; Ishwardi, Pabna; Kaharol, Dinajpur; and Thakurgaon sadar to document the soil physical properties in different layers of soil profile. Soil samples were collected from different layers of the soil profile (upto 100 cm) by different layers of 0-10, 10-25, 25 and 50, 50-100 cm using standard protocols. The moisture status was determined in 0.33 bar, 1 bar, 3 bar, 5 bar and 15 bar by using pressure plate apparatus. Field capacity (1/3 bar) and wilting point (15 bar) are the upper and lower limits of available moisture. The constant infiltration rates or near-saturated hydraulic conductivity of the selected sites were determined by double-ring infiltrometer. The infiltration rate versus time was plotted to find out the constant infiltration rate, which ultimately indicate the hydraulic conductivity of that soil.

The soil texture of different locations varied from clay-loam to loam. It also varied within the soil sample depths. The moisture holding capacity also varied with the soil texture (Fig. 1). Available moisture range in different depths of Tanore soils was found 15.52-25.85%, whereas wilting point varied from 9.5-14.15% for silt-loam to loam soil. Similarly available moisture range of Thakurgaon area soils were 10.59-28.77% and wilting started from 5.69 to 7.40%, respectively in clay-loam to loam soil. The available moisture range of Kaharole areas was 12.11-31.03% and wilting point varied from 5.09-11.36% respectively (Fig. 1) in silty-loam to loam soils. The silty-clay to silt-loam soils of Ishurdi was found that the upper and lower limit of available moisture were 16.01-32.59% and 14.71-17.24% respectively (Fig. 2).

The constant infiltration rates or near-saturated hydraulic conductivity was faster in light textured soil. The constant infiltration rate was the highest at Kaharole (9.6 mm/hr) in silt-loam to loam soil, whereas, it was lowest in Ishurdi (1.8 mm/hr) in silty-clay to silt-loam soil (Fig. 2).

Soil moisture characteristic curve and constant infiltration rate (i.e. saturation hydraulic conductivity) is helpful for determining suitable schedule of irrigation water for crops at farm level. Therefore optimum water use and estimation of irrigation interval can be determined by using the developed soil-moisture characteristic curves and hydraulic conductivity.

Optimization of irrigation water for maximum year round production

The experiment was conducted at BRRI experimental farm, Gazipur during 2015-16. Six cropping patterns were tested. Productivity and irrigation water requirements for selected cropping patterns were evaluated. Table 1 presents six cropping patterns selected for the study.

Table 1. Selected cropping patterns to evaluate the productivity and water requirements.

Pattern	T. Aman	Rabi	Boro/Braus/ T. Aus
P_1	BRRI dhan49 (long duration)	-	BRRI dhan29 (long duration)
P_2	BRRI dhan62 (short duration)	Mustard	BRRI dhan28
P_3	BRRI dhan62 (short duration)	Potato	BRRI dhan28 & BRRI dhan48
P_4	BRRI dhan62 (short duration)	Lentil	BRRI dhan28 & BRRI dhan48
P_5	BRRI dhan62 (short duration)	Wheat	BRRI dhan28 & BRRI dhan48
P_6	BRRI dhan62 (short duration)	Maize	BRRI dhan28 & BRRI dhan48

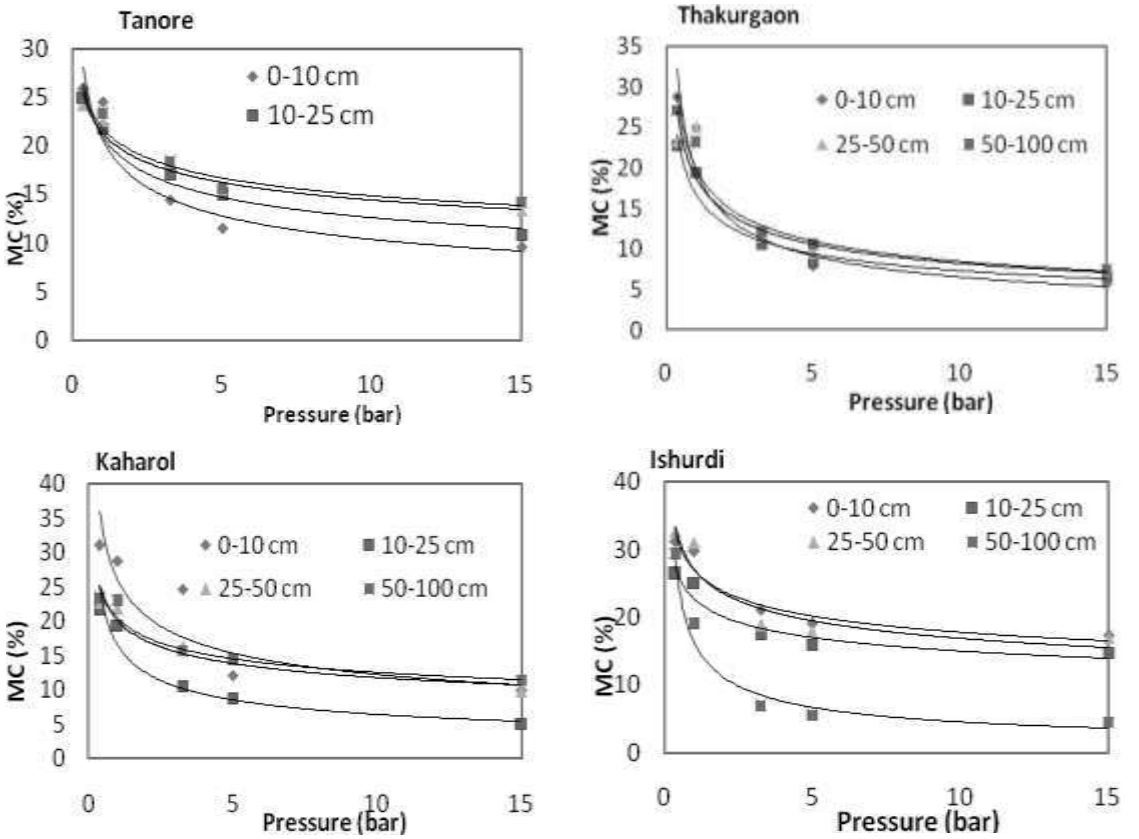

Fig. 1. Soil moisture characteristics curve of different soil depths in different locations.

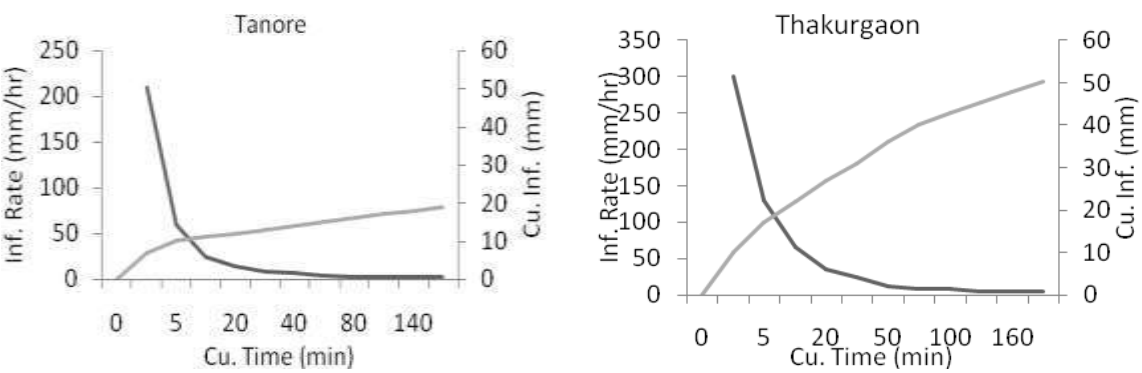

Fig. 2. Constant infiltration rate (hydraulic conductivity) and cumulative infiltration in different locations.

Fig. 2. Continued.

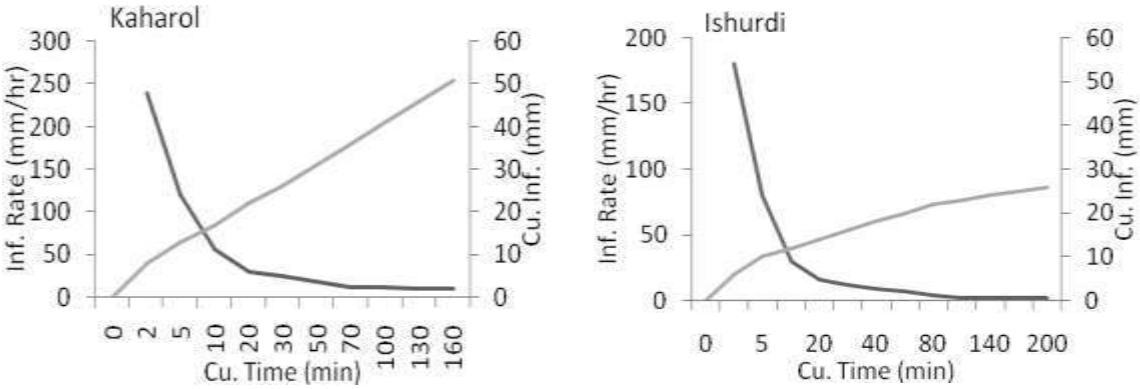

Fig. 2. Constant infiltration rate (hydraulic conductivity) and cumulative infiltration in different locations.

In the Boro/Braus/Aus seasons, BRRI dhan29, BRRI dhan28 and BRRI dhan48 were grown in different crop sequences. Six transplanting dates were planned for the Boro, Braus and Aus crops. The dates were: P_1=Transplanting date 15 January (after Aman harvest); P_2=Transplanting date 15 February (after Mustard harvest); P_3=Transplanting date 1 March (after Potato harvest) P_4=Transplanting date 15 March (after Lentil harvest); P_5=Transplanting date 5 April (after Wheat harvest); P_6=Transplanting date 25 April (after Maize harvest).

The results of the experiment indicate that as a Braus or Aus variety BRRI dhan48 is better than BRRI dhan28. The study result also indicate that BRRI dhan28 is a good option as late Boro after Mustard harvest (Table 2).

Table 3 shows the total irrigation requirement and rice equivalent yield of different cropping patterns. The highest rice equivalent yield was obtained from P_3 (Potato-BRRI dhan48- BRRI dhan62 and Potato-BRRI dhan28- BRRI dhan62) followed by P_4 (Lentil-BRRI dhan48- BRRI dhan62and Lentil-BRRI dhan28- BRRI dhan62), P_1 (Fallow- BRRI dhan29-BRRI dhan49), P_5 (Wheat-BRRI dhan48-BRRI dha62 and Wheat-BRRI dhan28-BRRI dha62) and P_6 (Maize-BRRI dhan48-BRRI dhan62 and Maize-BRRI dhan28-BRRI dhan62). Irrigation requirement is the highest for P_1 (940 mm) followed by P_2 (660 mm), P_3 (500 mm), P_6 (290 mm), P_4 (280 mm) and P_5 (230 mm).

Potato-BRAUS-T. Aman cropping pattern gave the highest yield with comparatively less amount of irrigation. BRRI dhan48 performed better as a Braus variety compared to BRRI dhan28.

WATER MANAGEMENT FOR RICE CULTIVATION IN CLIMATE CHANGE SITUATION

Effect of drought on different T. Aman varieties

The experiment was conducted at BRRI farm, Gazipur during T. Aman season 2015. The aim of the experiment was to study the relative drought tolerance of the T. Aman varieties based on the yield performance. The nine popular T. Aman varieties were grown under different water management. These varieties were classified into three groups based on the growth duration. There were three short duration, three medium duration and three long duration varieties. The water management treatments were: T_1=Application of supplementary irrigation if perched water table reached 20 cm below ground surface T_2=Rainwater conservation with levees protected by polythin and T_3=Rainfed condition.

Table 4 shows that the highest yield under supplementary irrigated condition was obtained from BRRI dhan54 (4925 kg/ha) followed by BRRI dhan31 (4370 kg/ha), BRRI dhan49 (4205 kg/ha), BRRI dhan53 (4183 kg/ha), BRRI hybriddhan4 (4143 kg/ha), BRRI dhan33 (3748 kg/ha), BRRI dhan56 (3601 kg/ha), BRRI dhan57 (3539 kg/ha) and BRRI dhan62 (3337 kg/ha). It also shows that the highest yield under rainfed condition was obtained from BRRI dhan54 (3685

Table 2. Seedling age, date of transplant, date of harvest, growth duration and yield of different varieties during Boro/Braus/Aus season 2015.

CP	Variety	Date of transplant	Age of seedling (day)	Date of harvest	Growth duration (day)	Yield (t/ha)
P_1	BRRI dhan29	15-Jan-15	45	18-May-15	167	6.38
P_2	BRRI dhan28	20-Feb-15	26	25-May-15	120	4.58
P_3	BRRI dhan28	15-Mar-15	23	15-Jun-15	115	3.78
P_3	BRRI dhan48	15-Mar-15	23	17-Jun-15	117	4.13
P_4	BRRI dhan28	21-Mar-15	21	19-Jun-15	111	3.49
P_4	BRRI dhan48	21-Mar-15	21	20-Jun-15	112	4.34
P_5	BRRI dhan28	5-Apr-15	25	1-Jul-15	110	2.77
P_5	BRRI dhan48	5-Apr-15	25	2-Jul-15	111	3.15
P_6	BRRI dhan28	25-Apr-15	21	21-Jul-15	107	2.80
P_6	BRRI dhan48	25-Apr-15	21	22-Jul-15	108	3.11

Table 3. Yield of crops under different cropping patterns and rice equivalent yield during 2015-16.

Pattern	Season and crop			Crop yield (t/ha)			Total irrigation (mm)	REY (t/ha)
	Rabi	Boro/ Braus /Aus	Aman	Rabi	Boro/Braus/ Aus	Aman		
P_1	-	BRRI dhan29	BRRI dhan49	-	6.38	4.75	940	11.13
P_2	Mustard	BRRI dhan28	BRRI dhan62	1.18	4.58	3.71	660	12.22
P_3	Potato	BRRI dhan28	BRRI dhan62	29.07	3.78	3.46	500	21.78
P_3	Potato	BRRI dhan48	BRRI dhan62	29.07	4.13	3.46	500	22.13
P_4	Lentil	BRRI dhan28	BRRI dhan62	1.39	3.50	3.41	280	13.86
P_4	Lentil	BRRI dhan48	BRRI dhan62	1.39	4.34	3.41	280	14.70
P_5	Wheat	BRRI dhan28	BRRI dhan62	2.94	2.77	3.56	230	10.25
P_5	Wheat	BRRI dhan48	BRRI dhan62	2.94	3.15	3.56	230	10.63
P_6	Maize	BRRI dhan28	BRRI dhan62	3.52	2.80	3.47	290	9.79
P_6	Maize	BRRI dhan48	BRRI dhan62	3.52	3.11	3.47	290	10.10

kg/ha) followed by BRRI dhan31 (3769 kg/ha), BRRI dhan53 (3751 kg/ha), BRRI hybriddhan4 (3696 kg/ha), BRRI dhan49 (3357 kg/ha), BRRI dhan56 (3484 kg/ha), BRRI dhan57 (3364 kg/ha), BRRI dhan33 (3270 kg/ha) and BRRI dhan62 (3138 kg/ha).

The short, medium and long growth duration varieties were harvested during 3rd week of October, 1st week of November and 3rd week of November respectively. Figure 3 shows the decadal rainfall during the growth duration (August-November). It has indicated slight water stress in 1st decade of October and severe water stress after the 1st decade of October. As the short growth duration varieties reached at their maturity stage before severe stress, therefore yield decrease was less. The medium growth duration varieties were also reached at their ripening phase before the stress. The longer growth duration varieties have experienced drought stress at the later part of their reproductive and the whole ripening phase.

Table 4 also shows the relative yield loss due to drought stress in different varieties. Among the short duration varieties, yield loss was the lowest in BRRI dhan56 (3.25%) followed by BRRI dhan57 (4.96%) and BRRI dhan62 (5.96%). Growth duration of BRRI dhan56 is also the highest in the group. Therefore, BRRI dhan56 is more drought tolerant compared to the two other varieties.

Among the medium duration varieties, yield loss was the lowest in BRRI dhan53 (10.33%) followed by BRRI hybriddhan4 (10.80%) and BRRI dhan33 (12.75%). Growth duration of BRRI dhan53 is equal to the other varieties in the group. Therefore, BRRI dhan53 is more drought tolerant compared to the two other varieties. Among the long duration varieties, yield loss was the lowest in BRRI dhan31 (14.00%) followed by BRRI dhan49 (20.16%) and BRRI dhan54 (25.18%). Growth duration of BRRI dhan31 is also slightly lower than BRRI dhan54 and equals to BRRI dhan49. Therefore, BRRI dhan31 is more drought tolerant compared to the two other varieties.

The highest yield reduction was found for BRRI dhan54 (25.2%) followed by BRRI dhan49 (20.2%), BRRI dhan31 (14.8%), BRRI dhan33 (11.0%), BR 25 (14.6%), BRRI dhan39 (12.7%) and BR 11 (12.5%). Yield reduction was the lowest for BRRI dhan31 (1.7%) followed by BRRI dhan30 (3.2%), BRRI dhan49 (4.9%), BRRI dhan33 (7.2%) and BRRI dhan40 (7.6%), respectively.

Table 4. Growth duration, and yield of different varieties under supplementary irrigated (T_1), rainwater conserved (T_2) and rainfed (T_3) condition with relative yield reduction due to drought stress in T. Aman season 2015 at BRRI farm, Gazipur.

Group	Variety	Seedling age (day)	Growth duration (day)	Yield (kg/ha) T_1	Yield (kg/ha) T_2	Yield (kg/ha) T_3	Yield loss (%)
			1				
	BRRI dhan56	16	102	3600.9	3511.8	3483.9	3.25
Group	BRRI dhan57	16	100	3539.3	3409.2	3363.8	4.96
	BRRI dhan62	16	99	3337.1	3228.7	3138.2	5.96
			2				
	BRRI dhan33	20	115	3748.0	3385.5	3270.0	12.75
Group	BRRI dhan53	20	113	4182.8	3961.4	3750.9	10.33
	BRRI hybriddhan4	20	115	4142.9	3845.7	3696.0	10.79
			3				
	BRRI dhan 31	24	134	4370.3	3976.3	3758.5	14.00
Group	BRRI dhan49	24	134	4204.7	3682.3	3357.1	20.16
	BRRI dhan54	24	140	4925.1	4083.2	3685.0	25.18

Date of transplanting: 28 Jul 15.

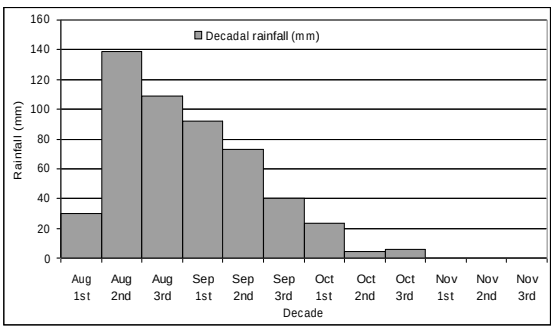

Fig. 3. Decadal rainfall and pan evaporation (in mm) during the T. Aman season 2015 at BRRI farm, Gazipur.

Considering the growth duration, rainfall and yield performances, BRRI dhan31, BRRI dhan53 and BRRI dhan56 were found more drought stress tolerant among the long, medium and short duration varieties respectively.

Rain water harvesting from roof top of BRRI campus, Gazipur. The experiment was conducted on the roof of Irrigation and Water Management Division at BRRI, Gazipur, during 2014-15. The area of the rooftop was taken 7*7 m^2. A rain gauge was placed to measure the daily rain fall. A PVC pipe was used to carry the rain water to storage tank from the roof. In the rainy day the total flow of volume water was recorded by the flow meter. Total rainfall and volume of runoff water was recorded.

Total 791.92 mm rainfall was recorded from August 2015 to June 2016, which produced 20.25m^3 runoff from the catchment area of 49 m^2. The highest monthly total 339.84 mm rainfall was occurred in May, which produced 9.6158 m^3 runoff. Result shows that the catchment area has a runoff coefficient of 0.48**.** Runoff volume produced from the catchment depend not only the roughness of the catchment but also the amount of rainfall. Figure 4 shows that rainfall less than 20 mm produced about 30% runoff and gradually increased on ward. More than 70 percent runoff was observed from a rainfall greater than 100 mm. Figure 5 thows total rainfall and runoff volume in the catchment area of rooftop at BRRI campus.

The catchment area has a runoff coefficient of 0.48**.** Runoff volume produced from the catchment depend not only the roughness of the catchment but also the amount of rainfall.

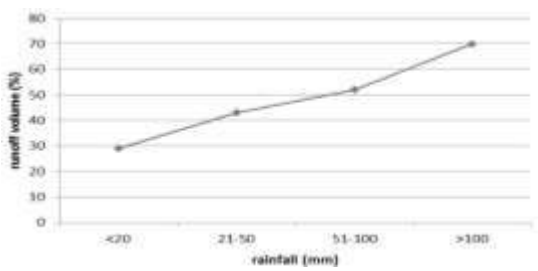

Fig. 4. Rooftop runoff from rainfall at BRRI campus during 2015-2016.

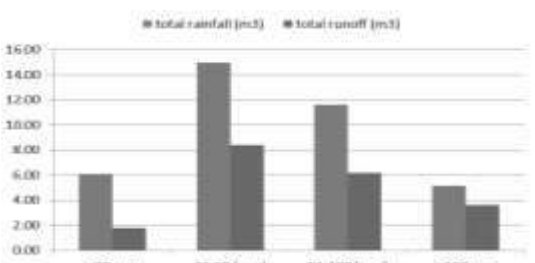

Fig. 5. Total rainfall and runoff volume in the catchment area of rooftop at BRRI campus during 2015-2016.

LAND AND WATER RESOURCES USE FOR SUSTAINABLE CROP PRODUCTION

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

Water salinity was measured in Barisal, Jhalokhati, Pirojpur, Patuakhali and Barguna districts from December to May. Three major river systems of the area: Buriswar, Biskhali and Boleswar were taken under the study.

Salinity of river water was measured in 21 locations. There were six locations in Buriswar, seven locations in Biskhali and eight locations in Boleswar river systems). Table 5 shows the salinity data on different dates at different locations. The general trend was a decreasing salinity level towards the upstream in all the rivers. The temporal trend was a decreasing trend after March. On 19-20th December 15, the highest salinity was found 0.42 dS/m at Haringhata (Baleswar river near Padma Bazar of Patharghata) followed by 0.38 dS/m at Nissanbaria kheyaghat (Biskhali river) and 0.21 at Golbunia Bazar (Buriswar river). This indicates that at this time water in all the rivers remain suitable for irrigation. On 29-30th March 2016, the highest salinity was found 15.93 dS/m at Padma Bazar (Boleswar river) followed by 9.40 dS/m at Baliatoli (Buriswar river) and 6.53 dS/m at Nissanbaria kheyaghat (Biskhali river). Through a particular latitude, salinity level was highest in the Boleswar river followed by Biskhali river and Buriswar river.

The highest salinity at Golbunia Bazar, Kakchira Ferryghat and Telikhali Launchghat, Bhandaria were 0.93 dS/m, 0.97 dS/m and 0.98 dS/m on 29th March, 30th March and 30th March 2016 respectively. This indicates that water at the upstream part of three rivers are suitable for irrigation throughout the dryseason. Therefore, there is potential for growing Rabi crops in the downstream where salinity remains below 1 dS/m before March. To investigate the potential measurement should be taken in January and February.

A considerable part of the upstream Buriswar, Biskhali and Boleswar river was suitable for irrigation throughout the dry season. The adjacent area of the rivers could be used for irrigated crop production.

RENEWABLE ENERGY FOR IRRIGATION

Effectiveness of solar pump for irrigated rice

A submersible solar pump (1.5 hp capacity) was installed at BRRI headquarters for testing discharge output and irrigated area coverage. Eight solar panels (size: 1×1.5 m^2) have been connected together in arrays, which produced 1600 watt DC energy. A 1.1 KW AC 3 phase submersible pump were purchased and connected with pump controller using cables. A pump controller converts DC current from the solar array into AC current to drive the pump. Manual and auto tracking both can be used in solar system. Manual system produced less energy than auto tracking. To obtain maximum output of energy, the panels were setup to face the sun as it could move across the sky and increased the output of discharge.

Irrigation of Boro rice. The solar pump was used for irrigation of Boro rice in different treatments during 2015-16 seasons in the experimental field of BRRI headquarters. The treatments were 3 cm depth of irrigation at saturation level and 3 cm depth of irrigation in AWD system. The rice variety was BRRI dhan63. The soil type was clay loam. BRRI dhan63 was transplanted on 29 January 2016 and harvested on 1 May 2016.

Table 5. Water salinity in the major rivers of Barisal division at different locations during dry season 2015-16.

Location	River name	Latitude	Longitude	EC (dS/m)				
				19-20 Dec 15	29-30 Mar 16	19-20 Apr 16	23-24 Apr 16	18-19 May 16
Dopdopia bridge, Barisal	Khoirabad	22.65	90.36	0.15	0.24	0.23	0.21	0.20
Lebukhali ferry ghat, Barisal	Khoirabad	22.47	90.34		0.27	0.31	0.30	0.23
Mohiskata bazar, Amragacia, Barisal	Buriswar	22.42	90.25		0.32	0.37	0.45	0.25
Subitkhali, Potuakhali	Buriswar	22.37	90.22		0.38	0.43	0.45	0.20
Fuljhuri Bazar, Borguna	Bishkhali	22.21	90.07	0.18	0.35		0.41	0.35
Boroitola Ferryghat, Barguna	Bishkhali	22.15	90.07		0.65	0.31	0.42	0.25

Table 5. Continued.

Location	River name	Latitude	Longitude	EC (dS/m)				
				19-20 Dec 15	29-30 Mar 16	19-20 Apr 16	23-24 Apr 16	18-19 May 16
Nishanbaria kheyaghat, Borguna	Bishkhali	22.04	89.98	0.38	6.53	0.74	1.95	0.85
Baliatoli, Borguna	Buriswar	21.99	90.06	0.22	9.40	0.42	3.90	1.51
Golbunia Bazar, Borguna	Buriswar	22.11	90.14	0.21	0.93		0.41	0.24
Kakchira Ferryghat, Patharghata	Bishkhali	22.16	90.06		0.97	0.32	0.46	0.24
Rupdhonhat, Patharghata	Bishkhali	22.13	90.02		1.19		0.47	0.32
Kalmegha Bazar, Patharghata	Bishkhali	22.10	90.01		1.22	0.41	0.95	0.24
Pathorghata hat	Bishkhali	22.03	89.97	0.38	3.45	1.37	2.30	0.34
Padma Bazar	Boleswar	22.01	89.93	0.42	15.93	9.63	10.19	3.62
Charduanihat, Patharghata	Boleswar	22.12	89.91		4.78	3.84	3.42	1.86
Khetachira, Mothbaria	Boleswar	22.16	89.91		4.10	3.64	1.95	1.19
Hogolpati hat, Mothbaria	Boleswar	22.24	89.88		3.14	2.04	1.32	1.32
Boro Machua, Mothbaria	Boleswar	22.31	89.88		2.82	1.61	1.23	1.35
Choto Machua, Mothbaria	Boleswar	22.38	89.91		2.60	0.96	1.06	0.89
Telikhali Launchghat, Vandaria	Kocha	22.42	89.97		0.98	0.62	0.687	0.53
Charkhali ferryghat, Vandaria	Kocha	22.49	89.99		0.56	0.31	0.31	0.29

Performance of solar pump. In September 2015, pump discharge was measured in liter per hour and m^3 per day. It was observed that discharge varied with the solar radiation at different times of the day. Discharge rate was monitored in 27 September 2015 from dawn to dusk.

Figure 6 shows that discharge rate rose with the increase of solar radiation and it went to peak in the noon (12.00 pm) and after noon discharge rate declined gradually as radiation was decreasing. Maximum discharge was found at 10200 lit/hr (170 lit/min) at 12.00 pm when solar radiation recorded at 902 w/m^2 and the average discharge rate was 107 lit/min.

Figure 7 shows daily discharge of the pump in April 2016. Due to cloudy sky sometimes the discharge rate was very low. The highest discharge was recorded at 59.37 m^3 (59370 lit) and lowest at 24.88 m^3 (24.880 lit).

In February 2016, average discharge and maximum rate was at 39 m^3 (39,000 lit) and 48 m^3 (48,000), respectively (Fig. 8). It was comparatively lower than that of other months because of short day length and sometimes foggy day. From March to April, the discharge rate increased successively during this period. Average and maximum discharge was also higher. From February to May 2016 discharge was found lower than that of 2015 due to auto tracker was not in operation

Irrigation of Boro rice using solar pump. Irrigation water was applied in Boro field through hose pipe. It was maintained 3 cm depth of irrigation and Alternate Wetting and Drying (AWD) method was adopted for determining efficient irrigation schedule as well as maximum irrigation coverage.

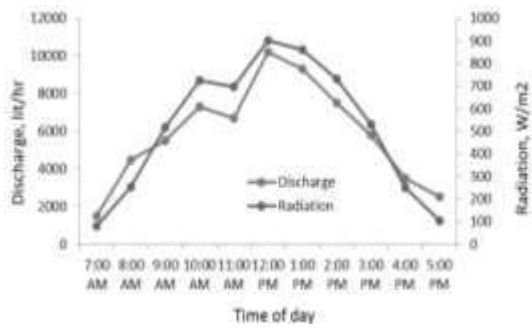

Fig. 6. Variation of discharge of solar pump with solar radiation at different time of day in Gazipur.

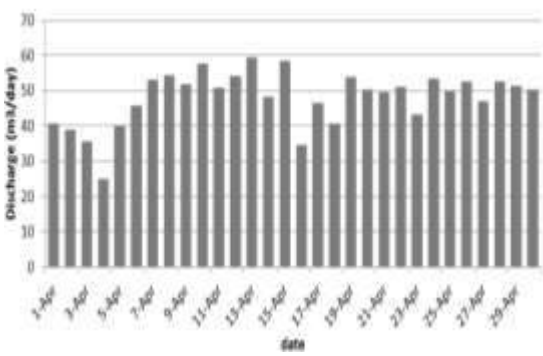

Fig. 7. Discharge of solar pump during April 2016 at BRRI farm, Gazipur.

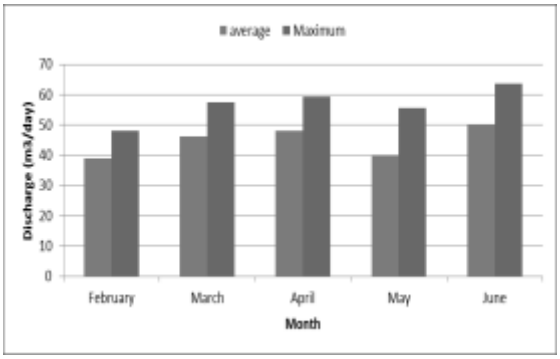

Fig. 8. Average and maximum discharge of solar pump in different months.

Considering, water requirement (S and P and ET) per day was 1 cm. Hence, three days were needed for disappearing 3 cm depth of standing water and moreover, two days were needed for lowering water level at 15 cm depth below soil surface. So, once applied irrigation at 3 cm depth then next irrigation was provided after five days. BRRI dhan63 gave lower yield (5 t/ha) than potential (6 t/ha) because of the land was reclaimed recently. During the season, the applied irrigation water was 660 mm and total rainfall was 330.5 mm.

A comparative study has been done to determine irrigation coverage with respect to different depths of irrigation between actual and simulated data. During Boro season, the average discharge of 1.5 hp solar pump was 43.6 m^3 per day. In this study, simulated irrigated areas for different depths of irrigation except 3 cm depth in AWD practice were calculated based on the average discharge.

Plant Physiology Division

SUMMARY

A total of 236 rice genotypes from different sources i.e. germplasm of BRRI Genebank, advanced breeding lines, anther cultured lines, green super rice (GSR) and *International Network* for Genetic Evaluation of Rice (INGER) materials were screened for seedling stage salinity tolerance of which 41 genotypes were selected as tolerant to moderately tolerant. Five advanced breeding lines and BRRI hybrid dhan4 were characterized for reproductive stage salinity tolerance during T. Aman season. Three lines IR77092-2R-B-10, IR73055-8-1-1-3-1 and IR78761-B-SATB1-68-6 were selected on the basis of their yield reduction (<50%) at 8 dS/m salinity stress. One hundred rice germplasm of BRRI Genebank were screened for complete submergence tolerance. All the germplasm had 100% survival, but none of them was selected for complete submergence tolerance as they were elongating deepwater type. Phenological development and recovery period of two previously selected submergence tolerant rice germplasm BRRI acc. no. 1838 and BRRI acc. no. 4096, BRRI dhan51, BRRI dhan52, BINA dhan11 and FR13A were studied, where all two tested rice germplasm and BINA dhan11 showed 80% survival after 18 days complete submergence. Fifty-three advanced lines were screened for medium stagnation tolerance but none of them was suitable for medium water stagnant condition. Some 173 germplasm were screened for drought tolerance at reproductive stage of which 36 genotypes were selected. Deep rooting ability of 30 advanced breeding lines and eight Aus rice genotypes were tested from where 11 advanced lines and three Aus rice genotypes were selected. Some 128 rice genotypes were evaluated for heat tolerance of which 41 BRRI germplasm, PSBRC82, BRRI dhan62 and five IRRI materials were selected.

A marker assisted backcrossing (MABC) programme is on-going to introgress spikelet fertility QTL (*qSF4.1*) into BRRI dhan28 and BRRI dhan29 from heat tolerant donor N22. After selection through R4M30 and cleaved amplified polymorphic sequence (CAPS) marker, 78 progenies were selected and advanced to BC_3F_2. Some 205 rice genotypes from BRRI Genebank germplasm and Biotechnology Division were screened for cold tolerance and 63 genotypes were selected as moderately tolerant. One hundred nine advanced rice genotypes and 21 IRRI materials were evaluated for reproductive stage cold tolerance at natural condition of which 13 advanced genotypes and four IRRI materials were selected. Twenty-six rice genotypes were evaluated for reproductive stage cold tolerance of which Bhutan, IR8222-F11-173, HbjBVI and Jinbubyeo were identified as tolerant. Twenty-six rice genotypes of IRTON-IRRI were evaluated in Rangpur of which IR83222-F11-15, IR83222-F11-156, IR83249-F9-26, YR14323-69-2-3-2-1 and IR12K268 were selected as moderately cold tolerant. Healthy seedling raising technique was demonstrated using polythene covered seedbed in Rangpur areas during Boro season and farmers showed their interest to adopt this technology. Photo-sensitive response of three rice varieties and five advanced lines were tested. Rice varieties BRRI dhan46, BRRI dhan44 and BRRI dhan66 were found as strongly, moderately and weakly photoperiod sensitive respectively, whereas advanced lines BR7941-119-1-2-1, BR7441-30-1-1-1, BR7941-116-1-2-1 and BR7941-41-2-2-4 showed moderately photoperiod sensitive. Six rice varieties BR11, BR22, BR23, BRRI dhan44, BRRI dhan46 and BRRI dhan54 were evaluated for delayed planting in T. Aman season. BRRI dhan54 had significantly less sterility with delayed planting that resulted in higher yield than the other varieties. Contribution of primary tiller to grain yield was significantly higher in BRRI dhan29 than BRRI dhan28 which provided higher grain yield. When apical dominance was broken, five germplasm i.e. Pukhi, Surja Mukhi, Kala Manic, Sukhti and Juma had significantly higher yield than conventional planting. Late sowing resulted in shorter growth duration and lower dry matter accumulation which ultimately caused lower grain yield. Growth duration and yield of Boro varieties were reduced by around 20 days and 20-30% respectively by one month delay of sowing time from 30 November to 30 December. A total of 202 germplasm from BRRI gene bank germplasm, six BRRI varieties along with four checks i.e. IR72, N22, Dular and Kasalath was tested to identify CO_2-responsive genotypes from Bangladeshi rice germplasm of which 10 germplasm were selected.

SALINITY TOLERANCE

Screening of rice genotypes for salinity tolerance at seedling stage

Rice genotypes from different sources i.e. advanced breeding lines, GSR and INGER materials, anther cultured lines were screened under 12 dS/m salinity stress to identify salt tolerant genotypes at seedling stage. Screening was done according to Gregorio *et al.*, 1997.

Advanced breeding lines. Eight rice genotypes along with IR58443-6B-10-3 and IR154 as standard tolerant and sensitive check respectively were screened. Three genotypes IR78761-B-SATB1-68-24, BRRI dhan53 and IR77092-B-2R-B-10 showed visual score 4-5 that is tolerant to moderately tolerant. The survivability percentage of these genotypes varied from 66 to 70%.

GSR materials. Three rice genotypes along with standard tolerant IR58443-6B-10-3 and sensitive check IR154 were screened, but none of the genotypes were found tolerant at high salinity stress.

INGER materials. Fifty six genotypes along with standard tolerant IR58443-6B-10-3 and sensitive checks IR154 and IR29 were screened. Among them, only 21 genotypes IR13T106, IR14T102, IR14T104, IR14T105, IR14T109, IR14T128, IR13T141, IR12T195, IR11T171, IR11T189, IR11T197, IR11T205, A-69-1, CSR 28, CSR-90IR-2, IR55179-3B-11-3, IR58443-6B-10-3, IR66946-3R-178-1-1, Nona bokra, Pokkali, BRRI dhan53 showed visual score 3 to 5 that is tolerant to moderately tolerant at high salinity stress. The survivability percentage of these tolerant genotypes varied from 54 to 90%.

Anther cultured lines for T. Aman season. Seven genotypes along with tolerant checks IR58443-6B-10-3, FL478 and susceptible check IR154 were screened, and identified 3 genotypes BR8018-AC2-2-2-1, BR8019-AC9-3-3-1and BR8032-AC4-1-2-2 which showed visual score 6. Survivability percentage of these genotypes varied from 55 to 58%.

Anther cultured lines for Boro season. Eight genotypes along with tolerant and susceptible check IR58443-6B-10-3 and IR154 respectively were screened and selected 3 moderately tolerant genotypes BR(BIO)9777-26-4-1, BR(BIO)9777-79-3-4 and BR(Bio)9777-113-12-5 having visual score 5. Survivability percentage of these genotypes varied from 52 to 100%

BRRI gene bank Germplasm. Two hundred germplasm along with standard tolerant Pokkali and sensitive check IR29 were screened of which 25 germplasm were found moderately tolerant (SES score 5.0 to 5.5)

Characterization and evaluation of some rice genotypes for salinity tolerance at reproductive stage

Two sets of experiment were conducted according to Gregorio *et al.*, 1997 with some modification for this experiment. In the 1st set, two advanced breeding lines (IR77092-2R-B-10, BR9377-9-21-3B) and two varieties (BRRI hybrid dhan4 and BRRI dhan41) along with IR58443-6B-10-3 and IR29 as tolerant and susceptible checks respectively were evaluated under varying levels of salinity during T. Aman season. Whereas, in the 2nd set, three advanced breeding lines (IR73055-8-1-1-3-1, IR78761-B-SATB1-68-6, IR78761-B-SATB1-28-3-24) along with BRRI dhan53 and IR58443-6B-10-3 as tolerant and IR154 as susceptible checks were considered. Thirty-six-day after sowing, all rice genotypes were exposed to three levels of salinity stress i.e. 4, 8 and 12dS/m which were made by adding NaCl in the bucket. One set of plants without adding salt was used as control.

At normal condition, grain yield of BRRI dhan41 and IR58443-6B-10-3 were higher than all other tested lines in the 1st set (Table 1), whereas it was the highest for IR78761-B-SATB1-28-3-24 in the 2nd set (Table 2). At 4 dS/m salinity level, yield reduction was less than 50 percent of all the tested genotypes except sensitive check IR29 (66.07%) in the 1st set (Table 1) and IR154 (55.1%) in the 2nd set (Table 1). However, yield was not reduced in BRRI dhan53 at 4 dS/m salinity level (Table 2). But with the increase of salinity to 8 dS/m yield was reduced remarkably. At this stress, yield reduction of IR77092-2R-B-10 in 1st set; BRRI dhan53, IR73055-8-1-1-3-1 and IR78761-B-SATB1-68-6 in 2nd set was 43.8, 39.5, 46 and 50.7% respectively (Tables 1 and 2) indicating their salt tolerance ability. At 8 dS/m the lowest yield reduction in both two sets was recorded in tolerant check IR58443-6B-10-3 (Tables 1 and 2). Grain yield of all rice genotypes decreased

Table 1. Grain yield of some rice genotypes as affected by salinity stress.

Genotype	Salinity stress (dS/m)						
	0	4		8		12	
	Grain yield (g/hill)	Grain yield (g/hill)	Reduction (%)	Grain yield (g/hill)	Reduction (%)	Grain yield (g/hill)	Reduction (%)
IR77092-2R-B-10	8.9	5.6	37.07	5	43.8	1.1	87.6
BR9377-9-21-3B	12.2	9.9	18.8	0.42	96.5	-	-
BRRI dhan41	15.1	10.9	27.8	0.36	97.6	-	-
BRRI hybrid dhan4	9.4	5.4	42.5	3.5	62.7	2.2	76.5
IR58443-6B-10-3	12.8	11.9	7.03	8.03	37.2	2.7	78.9
IR29	5.6	1.9	66.07	0.58	89.6	0	100

$LSD_{0.05}$ for genotype (G), salinity stress (S) and G×S are 1.6, 1.3 and 3.3 respectively.

Table 2. Grain yield of some rice genotypes as affected by salinity stress.

Genotype	Salinity stress (dS/m)						
	0	4		8		2	
	Grain yield (g/hill)	Grain yield (g/hill)	Reduction (%)	Grain yield (g/hill)	Reduction (%)	Grain yield (g/hill)	Reduction (%)
IR73055-8-1-1-3-1	11.3	9.2	18.5	6.1	46	1.1	90.2
IR78761-B-SATB1-68-6	13.2	10.7	18.9	6.5	50.7	1.7	87.1
IR78761-B-SATB1-28-3-24	18.3	12.8	30	4.14	77.3	0.2	98.9
BRRI dhan53	6.7	6.7	0	4	39.5	0.3	95.5
IR58443-6B-10-3	14.5	17.3	+19.3	10.6	26.8	2.4	83.4
IR154	12.7	5.7	55.1	2.7	78.7	0	100

$LSD_{0.05}$ for genotype (G), salinity stress (S) and G×S are 1.3, 1.09, 2.6 respectively.

greatly (76-100%) at 12 dS/m salinity level (Tables 1 and 2). So salinity level at 8 dS/m could be the discrimination level of tolerant genotypes in the study. BRRI dhan53 performed better up to 8 dS/m salinity stress with low yield potential. Considering yield potential and tolerance ability at different salinity stresses IR77092-2R-B-10, IR73055-8-1-1-3-1 and IR78761-B-SATB1-68-6 could be used for further breeding programme.

Characterization of anther cultured lines for salinity tolerance at reproductive stage. An experiment was conducted during Boro season to find out the yielding ability of some anther cultured lines with other physiological traits and to determine the tolerance level in varying salinity level at reproductive stage. Four lines BR(BIO)9777-26-4-1, BR(Bio)9777-72-12-2, BR(BIO)9777-79-3-4 and BR7084-310-AC2-7 along with IR58443-6B-10-3 and. IR29 as tolerant and susceptible check were considered for this study. Salt stress was applied 60 days after sowing. Stress was made by adding salt e.i. NaCl in the bucket at 8 dS/m. One set of plants were used as control. Interaction between rice genotypes and salinity showed significant effect on grain yield. Grain yield varied significantly with rice genotypes and salinity stress. Irrespective of genotype grain yield was lower at 8 dS/m salinity stress than control condition. The reduction percentage of grain yield over control was above 50% for all the genotypes except tolerant check IR58443-6B-10-3 (48%). Considering the yield related traits and tolerance ability none of the genotypes could be selected for reproductive stage at 8 dS/m salinity stress.

SUBMERGENCE TOLERANCE

Screening of rice germplasm against complete submergence

Some 100 germplasm from BRRI gene bank along with resistant check FR13A and susceptible check BR5 were tested to identify tolerant germplasm at the seedling stage under complete submergence condition. Fourteen-day-old seedlings were grown in line at submergence tank. Two weeks after transplanting, the plants were completely submerged by tap water and retained 70 cm water depth from the base of the plant for 14 days. All

the germplasm were elongating type and could not be selected for submergence tolerance, rather they might be suitable for deepwater rice.

Observation of phenological development and yield of rice varieties at different submergence condition

An experiment was conducted to study the phenological development and recovery period of rice genotpypes under complete submergence condition. Fourteen-day-old seedlings of five submergence tolerant rice genotypes BRRI acc. no. 1838, BRRI acc. no. 4096, BRRI dhan51, BRRI dhan52, BINA dhan11 along with resistant check FR13A and susceptible check BR5 were transplanted in three submergence tanks. Two weeks after transplanting, the plants were completely submerged by tap water and retained 70 cm water depth from the base of the plant for 12 ,18 and 24 days in tank-1, tank-2 and tank-3, respectively. Another one set was grown in normal condition. After 12 days of complete submergence survivability of BRRI acc. no. 1838, BRRI acc. no. 4096, BINA dhan11 and tolerant check FR13A was 100%, while it was 98.6, 94.4 and 0 % for BRRI dhan51, BRRI dhan52 and BR5 respectively. Furthermore, after 18 days of complete submergence survivability of acc. no. 1838, acc. no. 4096 and BINA dhan11 was more than 80% and it was similar with FR13A. Survivability of BRRI dhan52 (75%) was significantly less than FR13A (94%). Moreover, BRRI dhan51 showed susceptibility at 18 days of complete submergence. On the other hand, none of the genotypes survived when completely submerged for 24 days. Days to panicle initiation, flowering and growth duration did not differ significantly between 12 days completely submerged and normal plant except acc. no. 4096, while it was increased after 18 days of submergence. BRRI acc. no. 1838 had the shortest growth duration with 3.90 t/ha grain yield. Despite of lower survivability rate, BRRI dhan52 out yielded all other rice genotypes when submerged for 12 days. However, grain yield of BRRI acc. no. 1838 and BINA dhan11 had higher when plants were completely submerged for 18 days.

Screening of advanced breeding lines against medium water stagnation

Fifty-three advanced breeding materials along with five check variety BRRI dhan52, IR119, BRRI dhan44, BRRI dhan49 and BRRI dhan51 were tested under 60 cm (gradually increase) water stress up to flowering to identify medium stagnation tolerant rice genotype. None of the genotype was suitable for medium water stagnant condition.

DROUGHT TOLERANCE

Screening of rice germplasm for drought tolerance at reproductive phase, T. Aman 2015

Some 173 germplasm along with check variety BRRI dhan56 were evaluated during T. Aman season 2015 at BRRI farm, Gazipur following field-managed screening protocol (IRRI, 2008). Drought stress was initiated four weeks after transplanting and field were drained properly for not allowing any standing water until maturity. The experiment was laid out in Alpha lattice design with two replications. Out of 173 germplasm, 36 genotypes produced grain yield more than check variety BRRI dhan56 having the sterility percentage below 50%.

Screening for deep rooting ability of some advanced breeding lines

Sprouted seed of eight Aus rice genotypes, nine and 21 advanced breeding lines respectively of T. Aman and Boro were tested with a local check variety Morichboti to identify genotypes having deep rooting ability following BRRI protocol (2006).

Aus rice genotypes. Among the tested breeding lines the highest root length was found in BR7992-2B-5-2 (67 cm) followed by BR7383-2B-23 (65.6 cm) and BR7698-2B-1-9-2 (65.3), which was comparable with Morichboti (74 cm). Genotype BR7698-2B-1-9-2 (2104.9 cm) produced significantly higher cumulative root length (CRL) than all other genotypes including BRRI dhan65 (1831.1 cm) and Morichboti (1788.6 cm). Moreover, the number of root below 30 cm depth was also recorded higher in the genotypes BR7698-2B-1-9-2, BR7992-2B-5-2 and BR7383-2B-23

than Morichboti. Among the tested genotypes BR7698-2B-1-9-2 produced the highest amount of root followed by BR7383-2B-23 and BR7992-2B-5-2. The check variety Morichboti produced 185 mg/g of shoot. Considering root dry weight, CRL and root shoot ratio and number of root below 30 cm depth genotype BR7698-2B-1-9-2, BR7992-2B-5-2 and BR7383-2B-23 performed well and could be used for further evaluation.

Advanced breeding lines (T. Aman). Morichboti had the highest root length (70 cm) followed by BR7182-2B-1-HR4 (61cm), BRRI dhan41 (61cm) and BR6855-3B-12 (60.6 cm). Genotype IR84788-40-3-3-1-1 (1945 cm) produced the highest cumulative root length (CRL) which was statistically similar with BR6855-3B-12 (1918.8 cm). Root number, root dry weight and root shoot ratio were higher in IR84788-40-3-3-1-1, BR6855-3B-12 than Morichboti. Moreover, below 40 cm depth CRL, dry weight, root number and root shoot ratio was also higher for BR6855-3B-12, IR84788-40-3-3-1-1, IR90228-1-3-3-3-2 and BR7182-2B-1-HR4, which are comparable with Morichboti. Considering root length, root dry weight, CRL and root shoot ratio and number of root genotypes IR84788-40-3-3-1-1, IR90228-1-3-3-3-2, BR6855-3B-12 and BR7182-2B-1-HR4 performed well and could be used for further breeding programme.

Advanced breeding lines (Boro). The highest root length was found in Morichboti followed by IR95781-15-1-1-4, IR93856-104-1-1-4, IR93806-19-4-3-1, IR92545-24-1-1-2 and IR92545-42-2-2-1. Cumulative root length (CRL) was maximum in IR93806-19-4-3-1, which was statistically similar to IR93856-104-1-1-4, IR92545-42-2-2-1, IR94224-17-1-3-3 and Morichboti. Cumulative root length below 30 cm was maximum in Morichboti followed by IR93806-19-4-3-1, IR92545-42-2-2-1 and IR93827-29-1-1-2. Considering root length, root dry weight, CRL and deep root shoot ratio genotype IR94224-17-1-3-3, IR95781-15-1-1-4, MTU1010, IR93827-29-1-1-2, IR93856-104-1-1-4, IR93806-19-4-3-1, IR93810-17-1-4-1, IR92545-24-1-1-2, IR92545-42-2-2-1 performed well and could be used for further evaluation.

HEAT TOLERANCE

Evaluation of rice genotypes for development of heat tolerant rice

An experiment was conducted to identify new sources of heat tolerance at reproductive stage. About 128 genotypes including BRRI gene bank accessions and breeding lines were considered for this study. There were three hills per pot. Six pots were maintained for each genotype. All pots were placed in natural condition until heading with BRRI recommended management practices. During heading three pots from each genotype were introduced into high temperature (35 ± 3^0C) and high humidity (75±5%) in controlled glass house for seven days. Pots were then moved to natural condition and kept until maturity. Three pots of each genotype were kept in natural condition as control treatment. At harvest floret fertility and physiological traits for the plants were examined.

Among the landraces acc. nos. 152, 183, 184, 185, 187, 267, 272, 571, 572, 574, 808, 811, 812, 813, 814, 815, 817, 1203. 1205, 1208, 1210, 1317, 1318, 1321, 1549, 1626, 1629, 1630, 1643, 1680, 1681, 1684, 1689, 1692 showed 41 to 60% spikelet fertility under heat stress condition and got score 5 and acc. nos. 563, 568, 816, 1212, 1532, 1546, 1688 showed 61 to 80% fertility and scored 3. Among the tested breeding lines seven materials scored 5. Moreover, BRRI dhan62 and an exotic rice variety PSBRC 82 got score 5. Among the eight IRRI breeding lines four materials scored 3 and one scored 5.

Progress of the development of heat tolerant BRRI dhan28 and BRRI dhan29 by introgressing spikelet fertility QTLs *(qSF4.1)* through marker-assisted selection

A study was undertaken for improving heat tolerance of BRRI dhan28 and BRRI dhan29 during flowering by introgressing spikelet fertility QTL *(qSF4.1)* from N22 (IRGC19379). An InDel marker (R4M30) nearer to the spikelet fertility QTL *(qSF4.1)* was used to select progenies carrying the QTL of the backcross populations. Then, a CAPS marker used to confirm the presence of the QTL (*qSF4.1*) into the selected progenies. Finally, based on the phenotypic similarity with reference to the parents were selected. At 3rd

backcross generation, 113 progenies (23 from BRRI dhan28 and 90 from BRRI dhan29) were planted into field. After selection through R4M30 and CAPS, a total of 78 progenies (17 from BRRI dhan28 and 61 from BRRI dhan29) were selected and advanced to BC_3F_2. Phenotypic selection and fixation of the QTL loci will be carried out on the next Aus season.

COLD TOLERANCE

Screening of rice genotypes for cold tolerance at seedling stage

Some 204 rice germplasm collected from BRRI gene bank and one breeding lines from Biotechnology Division of BRRI along with six check varieties namely BR18, BRRI dhan28, BRRI dhan36, BRRI dhan58, Bhutan and HbjB-VI were tested for seedling stage cold tolerance in cold water tanks at artificial condition. Among the tested germplasm, none was found tolerant, while only 63 germplasm showed average visual score (SES) 5.0 to 5.5 that is classified as moderately tolerant. However, other genotypes showed visual score 6 to 9 that is susceptible to highly susceptible. The selected accessions were: 935, 936, 940, 1014, 1015, 1030, 1031, 1032, 1035, 1036, 1037, 1040, 1042, 1043, 1049, 1050, 1069, 1092, 1097, 1098, 1104, 1124, 1152, 1155, 1159, 1163, 1164, 1165, 1173, 1182, 1183, 1196, 1197, 1199, 1200, 1205, 1213, 1215, 1226, 1236, 1237, 1239, 1250, 1257, 1271, 1277, 1281, 1469, 1472, 1473, 1474, 1703, 1705, 1708, 1710, 1711, 1712, 1714, 1715, 1793, 1794, 1795, 1796.

Evaluation of advanced breeding lines for reproductive stage cold tolerance

One hundred nine advanced rice genotypes along with BRRI dhan28 and BRRI dhan36 as checks were evaluated for reproductive stage cold tolerance under natural condition in BRRI farm, Gazipur during Boro 2015-16 season. Thirty-day-old seedlings were transplanted on 22 November 2015. Considering plant height, growth duration, last internode length, panicle exersion, phenotypic acceptance, grain size and yield, 13 genotypes (BR8909-B-12-2-CS1-4-CS2-P6-1, BR8562-28-3-1-3-CS1-1-CS2-P3-2, BR8562-28-3-1-3-CS1-1-CS2-P3-4, BR8909-B-12-2-CS1-4-CS2-P5-5, BR8909-B-12-2-CS1-4-CS2-P5-6, BR8909-B-12-2-CS1-5-CS2-P1-3, BR8909-B-12-2-CS1-5-CS2-P1-4, BR8909-B-12-2-CS1-5-CS2-P1-4, BR8562-28-3-1-3-CS1-2-CS2-P2-1, BR8562-28-3-1-3-CS1-2-CS2-P2-3, BR8907-B-1-2-CS1-4-CS2-P6-4, BR8907-B-1-2-CS1-4-CS2-P2-2, BR8907-B-1-2-CS1-4-CS2-P3-2) were selected.

Evaluation of some rice genotypes for reproductive stage cold tolerance

Two sets of experiments were conducted using BRRI developed 15 advanced breeding lines and some other rice genotypes- Bhutan, Jinbubyeo, IRGC68815, IRGC7714, IRGC117270, IR8222-F11-173 along with HbjB-IV, HbjB-VI, BRRI dhan28, BRRI dhan36 and BRRI dhan58 for evaluation of reproductive stage cold tolerance under artificial condition. Twenty-day-old seedlings were transplanted in pots. Three pots of each genotype at meiotic stage were introduced into a growth chamber at 17°C for 10 days. Other three pots of same genotype were kept at natural condition as control. After cold treatment, growth duration and sterility were increased, whereas plant height, last internode length, panicle length, panicle exertion and field grain per panicle were reduced in all rice genotypes except IR8222-F11-173, Bhutan, HbjB-VI and Jinbubyeo, which were less affected. Rice genotypes Bhutan and IR8222-F11-173 showed better performance in relation to cold tolerance than the others (Tables 3 and 4).

Characterization and evaluation of some cold tolerant rice genotypes for whole growth periods under natural condition

Twenty-one rice genotypes were characterized and evaluated for cold tolerance along with BRRI dhan28 and BRRI dhan36 as check in BRRI farm, Gazipur during Boro 2015-16 season. There were two seeding dates i.e. 15 October and 15 November 2015. Physiological parameters i.e. plant height, panicle length, last internode length, last leaf sheath length, flag leaf length, growth duration, panicle exertion, sterility, yield and yield components were measured and recorded. Fifteen October seeded rice plants were compared with optimum seeding time i.e. 15 November. The experiment was laid out in RCB design with three replications. Plant height, panicle length, last internode length, last leaf sheath length, flag leaf length, panicle exertion and yield were reduced, while growth duration and sterility were increased

Table 3. Physiological parameters of some rice genotypes after coldtreatment (1st set).

Genotypes	Growth duration increased (day)	Plant height reduced (cm)	Last internode length reduced (cm)	Pan length reduced (cm)	Pan degeneration increased (%)	Field grain/panicle (no.)	Sterility (%)
HbjB-VI	7	9.48	13.56	6.02	6.96	37.37	41.14
HbjB-IV	7	19.23	12.43	3.2	16.0	10.83	87.88
Jinbubyeo	7	16.81	7.08	1.75	7.23	18.66	62.92
IRGC68815	7	29.07	4.69	2.5	15.89	10.50	86.51
IRGC77142	9	19	7.66	4.01	14.21	14.46	72.58
IRGC117270	8	9.91	4.93	2.77	12.01	8.38	84.56
Bhutan	4	0.61	0.17	0.9	4.20	31.11	54.15
BRRI dhan28	10	22.03	8.72	5.37	22.74	20.53	77.18
BRRI dhan36	8	11.47	2.67	5.28	18.86	9.61	77.09
BRRI dhan58	11	24.89	8.77	6.42	42.42	0	100
LSD@ 5%	1.72	7.44	3.87	2.21	10.16	12.76	12.93

Table 4. Physiological parameters of some rice genotypes after cold treatment (2nd set).

Genotypes	Growth duration increased (day)	Plant height reduced (cm)	LIL reduced (cm)	Pan length reduced (cm)	Field grain/panicle (no.)	Sterility (%)
IR8222-F11-173	4.75	1.53	2.3	0.23	35.13	60.39
BR8910-B-6-3-CS1-6-CS2-P11-1	6.66	22.17	6.91	3.72	26.12	69.85
BR8910-B-6-3-CS1-5-CS2-P3-1	6.67	13.5	7.71	1.05	47.3	58.53
BR8910-B-6-3-CS1-5-CS2-P3-3	7.67	17.24	10.35	3.18	33.1	73.78
BR8910-B-6-3-CS1-5-CS2-P3-4	6.9	12.75	9.41	1.59	34.41	68.71
BR8910-B-6-3-CS1-5-CS2-P3-7	7.67	19.37	11.37	3.32	14.26	84.74
BR8909-B-12-2-CS1-4-CS2-P6-5	8.92	19.39	12.44	4.42	6.41	93.36
BR8909-B-12-2-CS1-4-CS2-P6-6	7.25	14.43	9.73	3.53	21.22	77.2
BR8909-B-12-2-CS1-4-CS2-P1-6	7.67	10.16	7.94	3.96	22.2	73.58
BR8909-B-12-2-CS1-4-CS2-P2-1	6.33	12.2	9.76	5.17	15.66	83.88
BR8909-B-12-2-CS1-4-CS2-P2-3	6.01	18.61	10.69	4.39	15.62	81.29
BR8909-B-12-2-CS1-4-CS2-P2-4	5.9	23.16	10.23	7.56	17.91	82.80
BR8909-B-12-2-CS1-4-CS2-P5-2	7.34	16.76	10.24	7.87	30.91	65.64
BR8909-B-12-2-CS1-4-CS2-P5-3	6.44	17.04	8.67	4.36	17.83	81.45
BR8909-B-12-2-CS1-4-CS2-P5-4	7.66	27.22	6.7	7.55	14.75	80.05
BR8909-B-12-2-CS1-5-CS2-P1-6	6.12	18.32	9.46	6.11	7.33	94.17
HbjB-VI	3.67	0.23	6.47	3.55	29.82	69.73
Bhutan	4.66	2.30	5.39	0.57	52.03	38.74
BRRI dhan28	8.33	21.39	9.27	4.84	26.27	76.21
LSD@ 5%	1.85	5.89	2.27	1.73	13.32	11.49

when cold susceptible rice genotypes were sown on 15 October. Above parameters were affected less in tolerant genotypes. Considering above mentioned parameters, IR87322-65-2, IR10K150, MILYANG240 and IR83222-F11-85 were selected as cold tolerant at reproductive phase which could be used as donor parents.

International temperate rice observational nursery (IRTON, 2015)

Twenty-six rice genotypes of IRTON-IRRI along with BRRI dhan28 and BRRI dhan36 as cheecks 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 RCB design with three replications. Among the tested genotypes five genotypes (IR83222-F11-15, IR83222-F11-156, IR83249-F9-26, YR14323-69-2-3-2-1 and IR12K268) were selected as moderately tolerant to cold with other good agronomic characteristics specially yield. Rice genotypes IR83222-F11-156 showed the best performance in relation to cold tolerance and yield.

Demonstration of nursery management by polythene covering technique for seedling raising in Boro season

Healthy Boro seedling raising by polythene covering technique was demonstrated for rapid dissemination of the technology with the help of IAPP fund at the cold prone Rangpur, Lalmonirhat, Kurigram and Nilphamari districts of Bangladesh during Boro 2015-16. Based on the result it was revealed that the polythene covering seedbed techniques had lower seedling mortality at seedbed, higher seedling dry matter and longer seedling height, which provided healthy seedling raising at low temperature condition. Therefore, the polythene covering seedbed technology can be recommended for massive diffusion through extension service providers like DAE in cold prone northern region of Bangladesh.

GROWTH STUDIES

Photo-sensitivity test of some advanced breeding lines and BRRI released modern T. Aman varieties

An experiment was conducted in the net house of Plant Physiology Division during T. Aman season 2015 to know the photo-sensitive response of three varieties and five advanced lines. Rice variety BR11 and Nizersail were used as checks for this study. Data on basic vegetative phase (BVP), photoperiod sensitive phase (PSP) and relative photoperiod sensitivity (RPS) were determined. The PSP or the eliminable phase is the growth stage indicative of the rice plant's sensitivity to photoperiod. In photoperiod-sensitive cultivars, the PSP determines the rice plant's sensitivity. The PSP of BRRI dhan44, BRRI dhan66 was 56 and 45 days, while RPS was 35 and 29% respectively (Table 5). Among the breeding lines the four entries showed a low response or a slight delay in flowering with an increase in photoperiod. Another breeding line (BR7358-56-2-2-1-HR7) showed higher response to photosensitivity. The PSP of BRRI dhan46 was 156 days and identified to have the degree of photoperiod sensitivity as high as Nizersail (Table 5). On the basis of PSP and RPS BRRI dhan66 is weakly photoperiod-sensitive, BR7941-119-1-2-1, BR7441-30-1-1-1, BR7941-116-1-2-1, BR7941-41-2-2-4, BRRI dhan44 are moderately photoperiod-sensitive and BRRI dhan46 is strongly photoperiod-sensitive.

Evaluation of BRRI photosensitive varieties suitable for delay planting

An experiment was conducted at BRRI farm, Gazipur to study the effect of delay planting on BRRI developed six photosensitive varieties (BR11, BR22, BR23, BRRI dhan44, BRRI dhan46, BRRI dhan54). Spouted seeds of those varieties were sown in seedbed. There were three seeding dates at seven days interval from 7 to 21 August 2015. Thirty-day-old seedlings were transplanted at 20×20 cm spacing. BRRI recommended management practices were followed. Duration from seed sowing to panicle initiation, flowering and maturity differed significantly with sowing times and rice genotypes. When seeds were sown on 7 August, days to PI, days to flowering and growth duration were increased as because of critical day length came later. Whereas, duration of panicle initiation and flowering of all varieties were decreased in 14 August seeded plants than 7 August. However, those durations were increased in 21 August seeded plant except four varieties of which BRRI dhan54 and BR22 required less time. When the seeds of weakly sensitive varieties were sown on 21 August, days to PI, days to flowering and growth duration delayed due to low tempatature at developmental stage (Table 6). With the delay of sowing time from 7 August to 21 August grain yield was reduced significantly in weakly sensitive varieties and it was maximum (54%) in BR11. Cold induced sterility might be the main cause of yield losses due to delayed planting. Yield reduction was neglagible for BRRI dhan54 (1.88%), but moderate for BRRI dhan44 (37.1%). However, it was lower for BR22, BR23 and BRRI dhan46 which were 13.79, 16.39 and 21% respectively (Fig. 1).

Physiological dissection of growth behaviour and allied high yielding traits of three best varieties in the Boro season

An experiment was conducted to study the physiological parameters contributing to yield of two most popular rice varieties viz BRRI dhan28 and BRRI dhan29. Seedlings were transplanted at five leaves stage with the spacing of 20×20 cm. BRRI recommended fertilizer and cultural practices were followed with RCB design that was replicated thrice. The data were analyzed by using

Table 5. BVP, PSP and RPS of some breeding lines and BRRI released T. Aman varieties.

Variety	BVP	PSP	RPS (%)	Remark
Nizersail	14 (±0.470)	158 (±0.64)	100	Check
BR11	34 (±0.513)	54 (±1.16)	34	Check
BR7941-119-1-2-1	33 (±0.868)	74 (±1.96)	47	moderately photosensitive
BR7441-30-1-1-1	31 (±0.914)	69 (±1.64)	43	moderately photosensitive
BR7941-116-1-2-1	32 (±1.01)	73 (±2.10)	46	moderately photosensitive
BR7941-41-2-2-4	39 (±0.77)	68 (±1.99)	43	moderately photosensitive
BR7358-56-2-2-1-HR7	11 (±0.41)	127 (±0.43)	81	Strongly photosensitive
BRRI dhan44	35 (±1.32)	56 (±0.96)	35	moderately photosensitive
BRRI dhan46	5 (±0.466)	156 (±0.63)	99	strongly photosensitive
BRRI dhan66	15 (±0.549)	45 (±1.64)	29	weakly photosensitive

Figures in the parentheses denote standard error.

Table 6. Days to PI, flowering and growth duration six rice varieties as affected by delayed sowing.

Variety	Day to PI			Day to flowering			Growth duration (day)		
	7 Aug	14 Aug	21 Aug	7 Aug	14 Aug	21 Aug	7 Aug	14 Aug	21 Aug
BR11	76	75	80	109	107	109	140	138	140
BR22	65	61	58	92	89	86	120	121	116
BR23	69	64	63	98	93	93	120	122	125
BRRI dhan44	67	63	72	92	91	101	118	121	133
BRRI dhan46	67	63	67	92	90	93	121	117	123
BRRI dhan54	62	57	55	83	79	77	107	102	100
5% LSD		1.8			1.7			1.6	

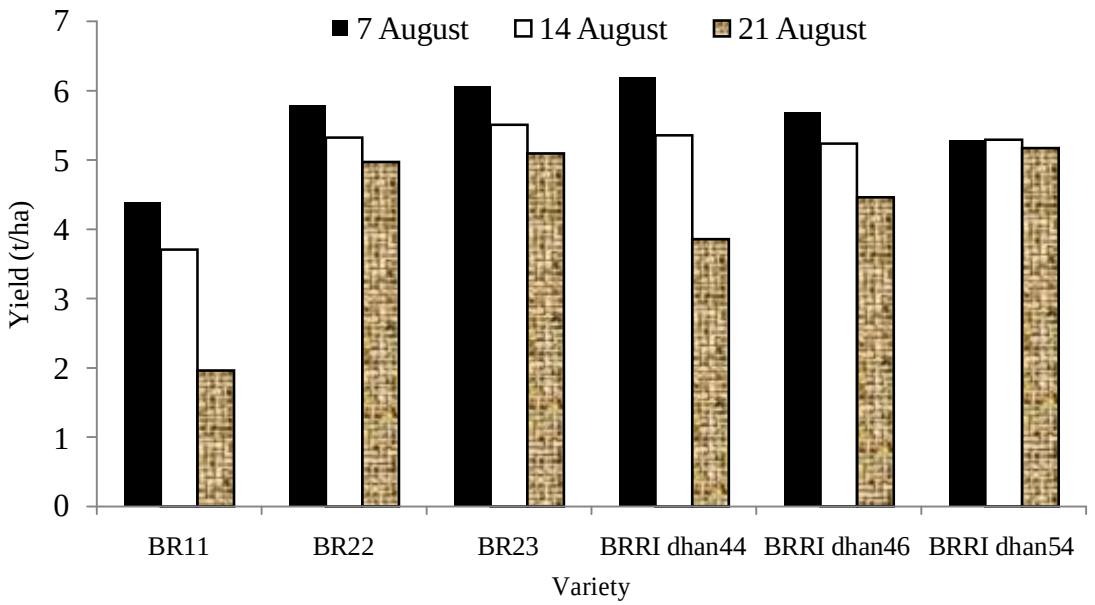

Fig. 1. Grain yield of rice varieties as affected by different sowing times.

CropStat7.2. Primary tiller contributed most for grain yield production in all the varieties. Panicle of secondary tiller had the highest percentage of spikelet sterility. Panicle length, LAI and photosynthesis rate did not differ significantly among the varieties. Grain yield was significantly higher in BRRI dhan29 (6.47 t/ha) than BRRI dhan28. Contribution of primary tiller to grain yield was recorded 50.78 and 57.13 % in BRRI dhan28 and BRRI dhan29 respectively.

Entomology Division

SUMMARY

Overall insect pest incidence was low in the reporting year. Weekly survey results of BRRI farm, Gazipur reveal that green leafhopper (GLH), white leafhopper (WLH) and yellow stem borer (YSB) were the most abundant pests. Spider, damselfly (dam. fly), lady bird beetle (LBB) and carabid beetle (CDB) were the dominant natural enemies.

GLH, brown planthopper (BPH), YSB, white backed planthopper (WBPH), WLH and rice leaf folder (RLF) were dominant pests and green mirid bug (GMB), spider and CDB were the dominant natural enemies in light trap.

RPH (BPH, WBPH and SBPH) and natural enemy (GMB and spider) were more active in the Boro seedbed. The highest number of insect was caught at 2.44 m height traps than the other one. Seasonal prediction of RPH outbreaks were made and applied to manage RPH in appropriate time.

Natural enemy population varied among the different surveyed rice landscapes in Barisal region.The highest natural enemies and the lowest number of insect pests were observed in the rice field nearby nectar-rich flowering plants. However, least natural enemies and parasitism were found in rice field where four times (continuous/ prophylactic) insecticides were applied. Moreover, there was no yield reduction observed in rice field surrounded by flowering plants compared with insecticide application.

Yield loss occurred in rice leaf folder infested hills compared to control hills in BR3 variety and it was estimated 12.31%. For YSB, highest yield loss occurred in BRRI dhan52 (31.97%), followed by BR11 (15.37%) and BRRI dhan34 (8.74%). For gall midge, the highest yield loss occurred in BRRI dhan52 (24.43%) followed by BRRI dhan49 (13.68%).

Out of 38 commercial formulations of insecticides tested, 24 insecticides were found effective against BPH and none was effective against YSB.

Continuous use of insecticide had no effect on rice yield when insect infestation was below the ETL. So, farmers should avoid continuous or indiscriminate use of insecticide, which ultimately saves production cost and protect environment from insecticidal pollution.

Out of 129 rice entries, 30 were found moderately resistant against BPH and out of 91, 29 were selected as moderately resistant against WBPH. Two germplasms showed resistant and 2 moderately resistant reactions to GM at glasshouse condition.

The highest numbers of regurgitated pellets of owl were collected from 10 feet height watching tower than the other heights. The highest number of pellets was collected in June followed by December and May and least number of pellets was recorded in February. Identified pellets confirmed predation on rat.

SURVEY AND MONITORING OF RICE ARTHROPODS

Pest and natural enemy monitoring at BRRI farm

Incidence of rice insect pests and their natural enemies along with their damage intensities was monitored weekly at BRRI farm, Gazipur. Data collected from five different habitats (seed bed, grass fallow, upland and irrigated rice, rice-ratoon) in Aus, T. Aman and Boro seasons 2015-16. Overall insect pest incidence was low in the reporting year. Higher incidences of insect pests were found in Aus and T. Aman seasons than the Boro season (Tables 1, 2 and 3). GLH, WLH and yellow stem borer (YSB) were the most abundant pests and found in all the three seasons. The highest population of GLH was found in the upland rice of Aus season, transplanted rice of T. Aman season and seed bed of Boro season. Higher numbers of natural enemies were found in the Aus season than Boro and T. Aman seasons. Spider (SPD), damsel fly (Dam. fly), LBB and CDB were the dominant predators (Tables 1, 2 and 3) in all the habitats of the seasons except in a few cases.

Pest and natural enemy incidence in light trap

Rice insect pests and their natural enemies were monitored by using light traps during July 2015 to June 2016 at BRRI farms in Gazipur, Barisal, Rajshahi, Rangpur, Comilla and Sonagazi. The incidence of insect pests was higher at Gazipur than the other regional stations. The total number of insect pests was the highest at Gazipur followed by BRRI RS, Rajshahi, Barisal, Rangpur,

Table 1. Incidence of insect pests and natural enemies in rice and non-rice habitats (determined by sweep net), Aus 2015, BRRI farm, Gazipur.

Arthropod	Seed bed	Ratoon	Grass fallow	Irrigated rice	Upland rice
			Insect pests (no./week/100 CS)		
YSB	0.50	0.00	0.37	0.75	0.25
GLH	1.5	0.625	2.87	2.65	5.62
WLH	1.12	1.375	1.87	1.12	2.12
RH	00	00	0.125	00	00
RB	00	0.5	00	1.62	0.62
LHC	5.25	1.87	0.17	0.87	0.12
SC	00	00	0.25	0.5	0.49
LF	00	0.28	0.125	0.5	00
Total	8.37	4.65	5.78	8.01	9.22
			Natural enemies (no./week/100 CS)		
LBB	0.5	0.5	0.62	2.87	1.5
SPD	1.62	1.62	4.12	6.25	3.37
CDB	2.37	0.5	0.00	7.87	3.25
Dam. Fly	1.37	1.00	4.25	4.12	3.0
TB	0	0	0.125	0	0
Ear wig	0	0	0	0	0.37
Total	5.86	3.62	9.11	21.11	11.49

Table 2. Incidence of insect pests and natural enemies in rice and non-rice habitats (determined by sweep net), T. Aman 2015, BRRI farm, Gazipur.

Arthropod	Seed-bed	Ratoon	Grass fallow	Transplanted rice
		Insect pests (no./week/100 CS)		
YSB	0.125	0.32	0.187	1.06
GLH	4.68	0.625	3.18	9.81
WLH	00	0.50	3.31	1.50
LHC	0.37	0.31	00	0.187
RLF	0.125	00	0.44	1.50
RH	00	0	0.187	0.187
RB	00	0.31	0.625	0.43
Total	5.3	2.06	7.93	14.67
		Natural enemies (no./week/100 CS)		
LBB	0.93	3.125	1.50	1.81
SPD	2.62	1.875	3.68	4.2
CDB	1.25	0.81	0.25	0.31
Dam. Fly	1.875	0.50	1.375	1.94
TB	0.125	0.31	0.37	0.125
Total	6.8	6.62	7.17	8.38

Table 3. Incidence of insect pests and natural enemies in rice and non-rice habitats (determined by sweep net), Boro 2016, BRRI farm, Gazipur.

Arthropod	Seed-bed	Ratoon	Grass fallow	Irrigated rice
		Insect pests (no./week/100 CS)		
YSB	0.05	00	0.16	0.17
GLH	2.47	0.47	0.47	0.23
WLH	1.14	0.05	0.05	0.53
RB	0.05	0.17	0	0.05
RH	00	00	0.16	0.23
MC	00	0.05	0.05	0.05
LHC	0.29	00	0.11	0
Total	4.0	0.74	1.0	1.26
		Natural enemies (no./week/100 CS)		
LBB	1.47	0.94	8.17	1.29
SPD	1.53	0.76	4.05	3.41
CDB	0.35	0.17	0.47	0.35
Dam. Fly	0.47	0.29	2.0	1.88
TB	00	00	0.05	0.17
Total	3.82	2.16	14.74	7.1

CS= Complete sweep i.e. left to right and right to left stroke of sweep net.

Sonagazi, Habiganj and Comilla. The abundance of GLH, BPH, YSB, WBPH, and WLH, were observed (Fig. 1) in all locations. The highest population of GLH was recorded at Rajshahi during the reporting year followed by Gazipur and Barisal (Fig.1). The highest number of BPH was observed during the month of October at Gazipur. An additional peak was also observed in May 2016 at the Gazipur and Rangpur locations. The highest peak of YSB was observed at Barisal in October and February. WBPH peak was the highest at Gazipur in October. WLH had three peaks in Rajshahi in October, November 2015 and May 2016 (Fig. 1). The highest number of natural enemies were recorded at Gazipur followed by Rajshahi Barisal, Sonagazi, Habiganj and Comilla (Fig. 1). GMB population was noticeably higher at Gazipur than that of Comilla and Rajshahi, and its peak abundance was recorded in October to November 2015. STPD also was the dominant predator in October to November 2015 at Gazipur and Rajshahi. CDB population from Rajshahi showed peaks in October to November 2015 and Gazipur in May to June 2016 (Fig. 1).

Construction of epidemiology information inter-change system for migratory disease and insect pests in Asia region

Monitoring of planthoppers in light trap. Yearly incidence of plant hoppers differed among the light trap locations. The highest number of winged adults of BPH and WBPH were trapped in Gazipur light trap followed by the catches of Sagordi farm, Barisal; Dobila and Washin under Tarash upazila. At Dobila, BPH and WBPH population build-up started from the 1st week of October and peak incidence occurred during 4th week of October and again in 3rd week of April to the middle of May 2016. The number of WBPH was higher than BPH and its peak was in 3rd week of November 2015 and 2nd week of May 2016. Similar results were obtained from Washin. Among the natural enemies, GMB population was almost two times higher in BRRI HQ, Gazipur than Sagordi farm, Barisal; indicating their density dependence with rice planthopper (BPH and WBPH) population build-up.

Monitoring of planthoppers with yellow sticky trap (YST). Monitoring by YST during T. Aman 2015 indicates that the rice planthopper incidence started from 3rd week of September 2015. Peak incidence was found on 4 November in most locations. Among the natural enemies, GMB population was higher in Kasta on November 11 catches. Spider population was almost similar during the observation period (from September. to November 2015) in all the locations.

In Boro 2016, BPH and WBPH population tended to increase at Dobila, Hamkuria and Washin from the 4th week of March and the peak population was in the 3rd week of April.

Monitoring of planthoppers with aerial YST. RPH (BPH, WBPH and SBPH) and natural enemy (GMB and spider) were more active in the Boro rice seedbed, and higher number of insects was caught at 2.44 m height traps indicating that aerial movement of RPH occured in space and it was again higher in Dobila followed by Hamkuria and Washin.

RPH forecasting and management. Farmers in Sirajganj project area had been informed earlier about the incidence of RPH. Data was uploaded in AMVIS website and information on outbreaks of RPH shared among the member countries in Asia through the internet platform of AMIVS, which is helpful in prediction of possible outbreaks of RPH among member countries.

Survey of insect pests in rice landscapes

The insect pest and natural enemy (NE) population dynamics in rice landscape were assessed at maximum tillering stage of rice crop during Boro 2016 at Rotab of Jhalokati, Kaliarghob and Paramandasha of Barisal Districts. The number of insect pest population was low and had no effect on rice crop. The investigated field did not show any visual field damage due to insect pests. But the number of NE population varied among the surveyed landscape area. Landscape located in Rotab showed higher population than that of the other two locations. Population of spider, GMB, CDB and STPD were significantly varied among three locations both in rice plot and rice bund. Spider population was higher in rice field than rice bund in two locations including Rotab and Kaliarghob but higher population was found in rice bund than field in Paramandasha landscape. (P=0.001). The spider population found in rice bund also depended on the width of rice bund and population increased with the increase of bunds' width.

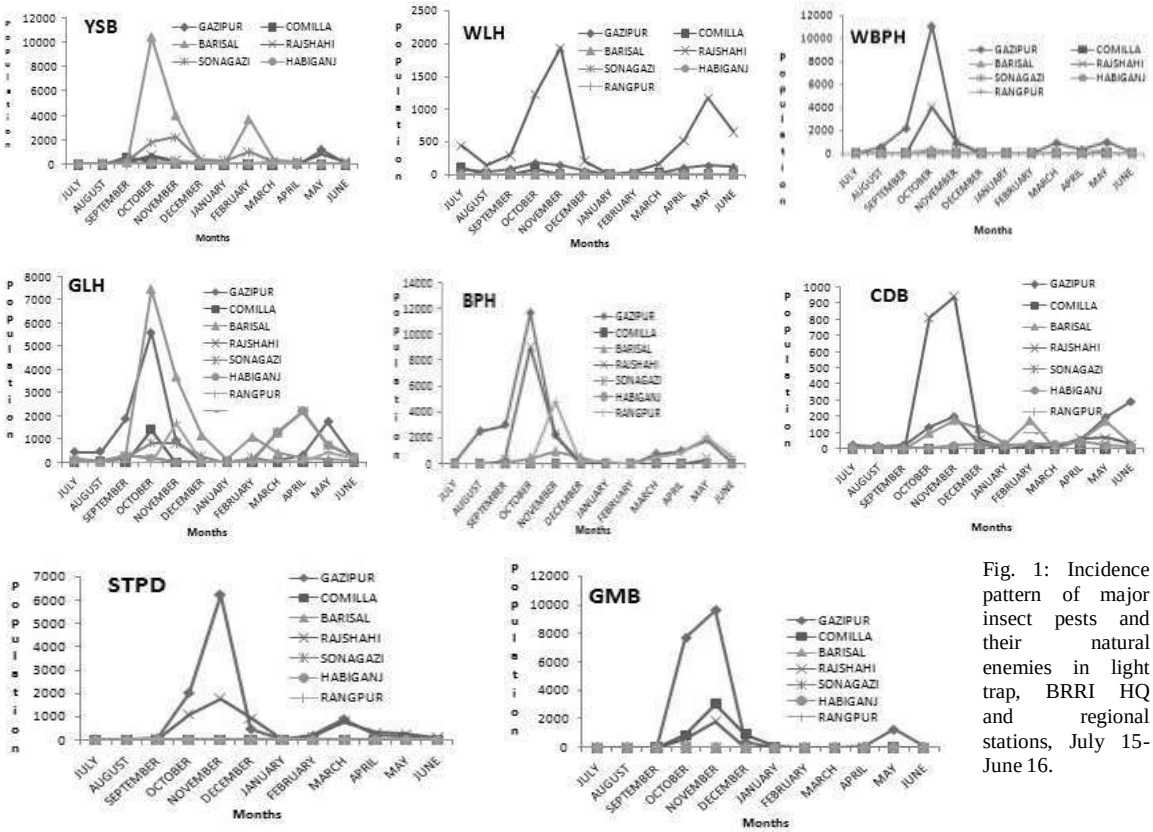

Fig. 1: Incidence pattern of major insect pests and their natural enemies in light trap, BRRI HQ and regional stations, July 15-June 16.

Population of GMB, CDB and STPD were also significantly different in three rice landscapes. The CDB population found in rice bund also depended on the width of rice bund and population increased with the increase of bunds' width. The STPD population varied significantly between rice field and rice bund in Rotab ($df = 9$, $p < 0.05$) but there was no significant difference between rice field and rice bund in other two locations ($p > 0.05$). The STPD population, found in rice bund, did not depended on the width of rice bund.

STUDIES ON RICE INSECT PEST AND NATURAL ENEMY BIO-ECOLOGY

Conservation of natural enemies through ecological engineering approaches

The experiment was conducted in BRRI, Gazipur research field divided with three blocks. Nectar-rich flowering plants (marigold, cosmos and sunflower) were planted on bunds of rice plot. Twenty complete sweeps were taken from all the plots at every 15 days interval up to flowering. Insect pest and natural enemies were counted from different blocks by sweepnet catches and recorded separately from different treatments i.e., T_1= One meter away from the flowering plants of rice bunds, T_2= Prophylactic insecticide use and T_3= Control. Egg bait traps were used to detect the activity of parasites in rice field. In T. Aman 2015, the highest number of GH (grasshopper) and leaf folder were found in T_1 but the incidence was below the ETL. The highest number of spider was found in T_1. In T_2, insecticide was used four times but yield was similar to that of T_1 and T_3. No yield reduction was observed in rice field surrounded by flowering plants. In Boro 2015, the highest number of GH and YSB were found in T_3. But the incidence was below the economic threshold level (ETL). In case of natural enemies, the highest number of spider and green GMB were found in T_1. In T_2, insecticide was used four times (carbofuran 5G@ 10.0 kg/ha) but yield was similar

to that of T_1 where nectar- rich flowering plants were grown in bunds surrounding rice crops. Moreover the lowest parasitism of BPH egg was found where insecticide was continuously used.

The similar type experiments were conducted with BRRI dhan52 during T. Aman 2015 and BRRI dhan63 during Boro 2015-16 season at BRRI RS, Rajshahi. Nectar-rich flowering plants (Cosmos in T. Aman and marigold in Boro) were planted on bunds of each plot. Insect pests and natural enemies counted from the plots one and four meter away from the flowering plants treated as T_1 and T_2 respectively. Prophylactic insecticide (Carbofuran 5G @ 10.0 kg/ha) was used at 15 days interval (four times) in the 2nd plot after 1st top dressing of urea and treated as T_3. Normal cultivation was done in the plot with no insecticide and no flowering plants and treated as T_4. Parasitism of YSB eggs determined through retrieval method.

During T. Aman 2015 season, highest number of GLH, YSB, RB, and rice leaf roller (RLR) were found in T_4 (13.25, 3.25, 2.00 and 5.25 per 20 complete sweep respectively). In Boro 2015-16, the highest number of GH, WLH and rice bug (RB) were found in T_1 (6.00, 3.00 and 3.67 per 20 complete sweeps respectively). In case of natural enemies the highest number of SPD, LBB, CDB, STB, Damsel fly and dragon fly (12.5, 11.5, 1.5, 2.75, 9.25 and 0.75 respectively per 20 complete sweep) were found in T_1. In T_3 , insecticide was used four times as a result, more or less, all natural enemies found lowest during sweeping indicating the detrimental effect of insecticide on natural enemies. Insecticide used four times in T_3 but yield was similar to that of T_1 and T_2 where nectar- rich flowering plants were grown in bunds surrounding rice crops. Lower yield was observed in T_4 where no insectiside applied and no flowering plants grown in rice bunds. Moreover, the lowest parasitism on YSB eggs occurred by *Trichogramma chilonis* where insectiside was continuously used.

Incase of natural enemies the highest number of spider, dam. fly, LBB and CDB (21.25, 4.50, 15.75 and 2.00 respectively per 20 complete sweep) were found in T_1. In T_3 insecticide was used four times (carbofuran 5G@ 10.0kg/ha) but yield was similar to that of T_1 and T_2, where nectar-rich flowering plants were grown one and four meter away from rice bunds respectively surrounding rice crops. The lower yield was observed in T_4 where no insectiside applied and no flowering plants grown in rice bunds

The highest natural enemies, percent parasitism by *Trichogramma chilonis* on YSB eggs were observed in rice field nearby nectar-rich flowering plants. In all experiments least natural enemies and parasitism were found in rice field where four times (continuous/ prophylactic) insecticides were applied. 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.

INTEGRATED PEST MANAGEMENT

Validation of BRRI recommended practices for the management of major insect pests of rice

Six experiments were conducted in farmer's fields at Barisal, Rangpur and pirojpur districts. Two experiments for Barisal in T. Aman 2015 and Boro 2015-16 seasons and three experiments for Rangpur in Aus 2015, T. Aman 2015 and Boro 2015-16 seasons, and one experiment for Pirojpur in Boro 2015 season were conducted. One portion of each farmer's field was remained under the respective farmers' supervision without any intervention treated as T_3 in Barisal region and same treatment was named as treatment T_4 in Rajshahi region. The other portion was managed with three treatment combinations i.e., T_1= Prophylactic use of insecticide, T_2: Perching+ Sweeping+ Need based insecticide application in two locations.

The insect infestation was below the ETL at all experimental plots in all locations and seasons. So, no significant differences were observed for insect infestation among the treatments. During Aman season in Barisal, when rice field was infested by rice hispa, insecticide was applied to control the insect. One application was quite enough to control rice hispa in researcher managed experimental plot during T. Aman season. The infested field was fully recovered and harvested good yield compared to other plots. Thus other plots were also infested

by rice hispa and farmers applied 2-3 times insecticides to control. This result indicates that need based application of insecticides reduces production cost. Moreover, use of chemical pesticides will be reduced from rice field that saves environmental degradation from chemical pesticide.

Though definite trend was not found, it is clear that lower number of different natural enemies were found in insecticide treated plots including farmers practiced plots compared to other treatments in all the locations. Farmers also applied insecticide three times or more. Thus it was indicated that continuous use of insecticide had the detrimental effect on the population of natural enemies. Treatment2 and T_3 refrained from insecticide use at the early crop stages (30-40 DAT). As a result SPD and LBB populations were found highest in T_2 and T_3 respectively during hill counting and sweeping, which might reduce pest population below the ETL. So, indiscriminate use of insecticide should be avoided at the early crop stage (30-40 DAT) to conserve natural enemy in the rice field.

In T_2 field of Pirojpur, only perching and sweeping were done fortnightly or when necessary and no insecticide was used but no yield reduction was observed. Insecticide Virtako 40WG, (75 g/ha) was applied four times in Prophylactic insecticide used plot (T_1) but no yield advantage was observed. Therefore, it was concluded that continuous use of insecticide had no effect on rice yield when insect infestation was below the ETL. So, farmers should avoid continuous or indiscriminate use of insecticide, which ultimately saves production cost and saves the environment from insecticidal pollution.

CROP LOSS ASSESSMENT

Estimation of yield loss due to major insect pest of BRRI released variety

Field trial was established in T. Aman 2015 season for leaffolder with BR3 at BRRI Gazipur, for yellow stem borer (YSB) with BR11, BRRI dhan34 and BRRI dhan52; for gall midge (GM) with BRRI dhan49 and BRRI dhan52 at BRRI Rajshahi. Insecticide was not applied to maximize natural pest infestation in order to realize the highest yield loss. No significant differences were observed in case of tiller and panicle per hill in all the varieties. Yield loss occurred in rice leaf folder infested hills compared to control hills in BR3 variety and it was estimated 12.31% (Fig. 2).

For YSB, highest yield loss occurred in BRRI dhan52 (31.97%), where 20.29% deadheart was observed (ranged 7.14 to 33.33%) followed by BR11 (15.37%) where 14.66% deadheart appeared (ranged 7.0 to 30.0%). The lowest yield loss occurred in BRRI dhan34 where 7.1% deadheart was observed. For gall midge, the highest yield loss occurred in BRRI dhan52 (24.43%) where 16.62% onion shoot was observed (ranged 5.0 to 36.84%) followed by BRRI dhan49 (13.68%) where 14.15% onion shoot appeared (ranged 4.0 to 33.33%).

EVALUATION OF CHEMICALS AND BOTANICALS AGAINST RICE INSECT PESTS

Test of different candidate insecticides against major insect pests of rice

A total of 38 commercial formulations of insecticides, received through the plant protection wing of DAE, were evaluated against brown planthopper (BPH) and yellow stemborer (YSB). Twenty-four insecticides were found effective against BPH and none was found effective against YSB.

HOST PLANT RESISTANCE

Screening of elite breeding lines against major insect pests of rice

A total of 129 entries were tested under controlled conditions in green house against brown planthopper (BPH), 91 against white backed planthopper (WBPH) during the reporting period. Out of 129 entries, 30 were found moderately resistant against BPH. Among the 91 entries, 29 were selected as moderately resistant against WBPH.

Screening of elite breeding lines, germplasm and rice varieties against gall midge

Among tested 91 rice germplasms, BR8693-17-6-2-1 and Koha binni (Acc# 93/208) recorded as

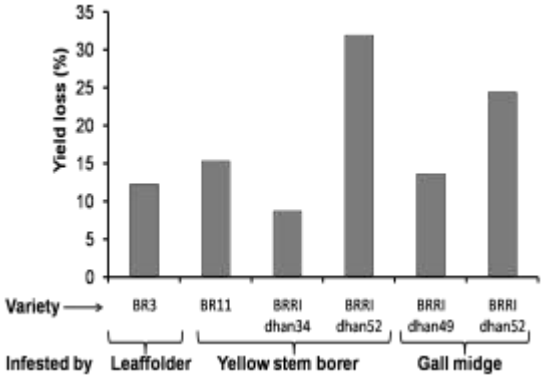

Fig. 2. Incidence pattern of major insect pests in light trap, BRRI HQ and regional stations, July 15- June 16.

resistant (0-1% OS), whereas Muktahar (Acc # 66/156), Safahar (Acc #10/368) and a cross combination 'BR11/BRRI dhan33 (10768)' showed moderately susceptible (MR) (11-20%OS) reaction to GM at glasshouse condition.

VERTEBRATE PEST MANAGEMENT

Study on the barn owl (*Tyto alba)* and their biology for sustainable rat management

Owl watching towers were established at 8, 10 and 12 feet heights in different locations of BRRI farm. Net is used to collect the owl regurgitated pellets for analysis. The highest number of regurgitated pellets was collected from 10 feet height watching tower than the other heights. The highest number of pellets was collected in June 2016 followed by December 2015 and May 2016 and least number of pellets was recorded in February 2016. This result indicates that 10 feet height is suitable for owl watching and preying in rice field rats. It is effective from dusk to dawn and can be used as perching device during day time. Regurgitated pellets confirmed the rat predation by owl.

Plant Pathology Division

SUMMARY

Tray seedling raising (TSR) technology was developed for controlling seedling blight disease. Healthy seedling can be transplanted within 26 days following mechanical or hand transplanting. Five fungicides were found to be effective against sheath blight under field conditions and recommended for registration. In T. Aman 2015 and Boro 2015-16 seasons, survey of rice diseases was conducted in different locations such as Kushtia, Comilla, Habiganj, Nilphamari, Rangpur, Rajshahi, Satkhira and Barisal. Bacterial blight, sheath blight, false smut and tungro were predominantly observed in T. Aman 2015 season. Conversely, in Boro 2015-16, bacterial blight, leaf and neck blast, brown spot and narrow brown spot were predominant along with sheath blight. Ufra infestation was noticed in Barisal region. Four races of *P. oryzae* such as U73-i7-k177-z-17-ta633; U73-i7-k177-z15-ta433; U73-i5-k177-z07-ta633 and U73-i7-k177-z15-ta433 were detected indicating high variability among rice blast fungi. NILs of IR49830 harbouring blast resistant genes *Pish*, *Pi9* and *Pita-2* and *Sub-1* were evaluated for yield potential and blast resistance. None of the lines was found to be high yielder compared to the check varieties. However, the test-lines showed resistance against natural rice blast incidence under tidal non-saline condition. Monogenic blast resistant genes *Pish*, *Pita-2*, *Pi9* and *Pi40* were attempted to be introgressed separately in the mega variety BRRI dhan28 and BRRI dhan29 during Boro 2015-16. A set of 13 rice genotypes were tested for resistance against rook knot nematode. One genotype (IR 97153-B-55) was found to be unaffected by root knot nematode and considered as potentially resistant. In T. Aman 2015, out of 67 INGER materials, only five showed moderately resistant reaction to BB. However, in Boro 2015-16, 19 INGER materials were found to be moderately resistant against BB. In T. Aman 2015, out of 75 breeding lines, four showed moderately resistant reaction against BB. In Boro 2015-16 season, 65 breeding lines developed by Plant Breeding Division and 11 breeding lines developed by Biotechnology Division were tested for their resistance against BB. Out of 65 breeding lines developed by Plant Breeding Division, 12 showed resistant reaction to BB. Among the 12 lines of Biotechnology Division, nine were moderately resistant to BB. In Boro 2016, a total of 101 rice germplasms were tested for resistance against BB. All the germplasms were found to be moderately to highly susceptible to BB. In Boro 2015-16, 24 selected INGER lines and two standard checks (BRRI dhan28 and BRRI dhan29) were evaluated. Among the INGER lines, the highest yield (8.05 t/ha) was recorded in IR10A231, which was statistically identical to the yield of BRRI dhan29 (8.95 t/ha). However, all the test-lines were susceptible to highly susceptible to BB. Three fixed lines resistant to BB were selected in Boro 2015-16. In another study, BRRI dhan28, BRRI dhan29 and a local improved variety were crossed with IRBB60 and IRBB65 to develop BB resistant variety. Pathogenicity results showed that a good number of progenies of BC_4F_1 or BC_5F_1 developed from the crosses were resistant to the most virulent BB isolate BXO9. Again, 100 resistant materials were selected from BC_3F_2 and BC_4F_2 generation. In T. Aman 2015 season, 63 INGER materials were screened against rice blast. Eight materials showed moderately resistant reaction to blast. Again, 48 advanced breeding lines were screened against rice blast pathogen. Of those, five lines showed moderate resistance to blast disease. Rice false smut disease severity was evaluated at different flowering times. On the main crop, the disease level was low in the crops flowering till mid October. Studies on seedling blight management suggested that polythene cover of seedlings at night and soil management with NPK respectively @ 2-3, 3-4 and 2-3 g/tray could be effective for raising good and healthy seedling. The results also indicated that standing water or flooded irrigation controlled the disease effectively irrespective of fungicide treated or untreated seeds. Validation studies on healthy seedling raising technique found no or minimum disease incidence with both the seed treatment and spraying seedling with fungicides (Azoxystrobin + Difeconazole) irrespective of tray or field condition in different locations. For controlling false smut disease, seedling treatment along with twice foliar spray of fungicides (Carbendazim and Propiconazole) resulted in the lowest incidence of infected tiller. In another study, five fungicides were tested for their efficacy against false smut disease. None of those were found to be effective. Efficacy of five

chemicals were tested against kresek. The lowest (16.33%) kresek incidence was recorded when inoculated seedlings were dipped in Copper Hydroxide (2% w/v) solution for 30 minutes. Out of 16 chemicals tested against BB in Boro 2015-16, five were found to be effective. Again, out of 23 fungicides, six (Pazodi 32.5 SC, Oxy Plus 32.5 SC, Navera, Bravo 75 WG, Seltima and Azonil) successfully controlled rice blast disease. Rovral, Seltima, Folicur and Nativo were found effective against grain spot. In another study, seven different fungicides were found effective against sheath blight. A total of 53 demonstrations were conducted under IAPP, PGB and Mujibnagar projects for blast, BB and sheath blight disease management and healthy seed production, where BRRI recommended practices performed better than farmer's practice in terms of disease suppression and/or yield increase. In a study conducted under PGB project, sheath blight disease was successfully controlled utilizing *Trichoderma harzianum* applied as compost. In another study conducted under PGB project, red eel worm was identified as *Chyronomus sp*. (Phylum: Arthropoda, Class: Insecta) and successfully managed by an insecticide. A total of 90 farmers and 108 SAAOs were trained under PGB and Mujibnagar projects.

TRANSFERABLE TECHNOLOGY

Tray seedling raising technology

Tray seedling raising (TSR) technology is an integrated approach for raising healthy seedling by controlling the seedling blight disease. In this method, seeds are treated with fungicide Pyraclostrobin or Azoxystrobin+Difeconazole (0.2-0.3% for 18-20 hours). Sprouted seeds were sown in tray containing soil and then covered with a thin layer of soil. Immediate after sowing and subsequent irrigation, a polythene cover was given on the trays continuously for 72 hours and then regularly from afternoon to the next morning. Irrigation was given for two to three times every day. Fertilization of NPK at 2-3, 3-4 and 2-3 g respectively mixed with the pulverized soil is important for growing good quality healthy seedling. However, spraying of a mixture solution of urea, MOP, theovit and $ZnSO_4$ respectively @ 1-2, 0.6, 0.2 and 0.2% could be an alternative for nutrient management. Instead of seed treatment, fungicide spraying in trays at three days after seeding was also effective for controlling seedling blight disease. Healthy seedling (3-4 leaf age, 12-13 cm long) raised following this method can be transplanted within 26 days for mechanical or hand transplanting.

Chemical control of sheath blight. A total of 23 fungicides were tested for their efficacy to control sheath blight disease of rice. Of those, five fungicides such as Avtar (Zineb 68% +Hexaconazole 4%), Mactivo 75WG (Tebuconazole 50%+Trifloystrobin 20%), Novera (Azoxytrobin 20%+ Cyproconazole), Bravo 75WG (Tebuconazole 50% +Trifloystrobin 25%) and Seltima (Pyraclostrobin 10%) were found to be effective and recommended for registration.

SURVEY AND MONITORING

Status of rice diseases in selected areas. In T. Aman 2015 season, survey was carried out in different locations to investigate the present status of different rice diseases in different climatic conditions. In Kushtia district, brown spot disease was prevalent (incidence: 10-40%) compared to bacterial blight (BB), sheath blight and false smut. Survey was also carried out in Habiganj district where incidence of sheath blight was the highest (incidence: 10-70%, severity: 7) followed by BB (incidence: 10-50%, severity: 1-5) and brown spot (incidence: 2-20%, severity: 1-3) on BRRI dhan28 and BRRI dhan29. Again, in Nilphamari, BB, sheath blight and tungro were observed. In Rangpur, BB, sheath blight, false smut, brown spot and leaf scald were observed. BB (incidence: 45.8, severity: 5.4) was found severe in Rangpur sadar; and sheath blight was also found severe in Rangpur sadar (incidence: 44.1%, severity: 4.7), Pirgacha (incidence: 32.2%, severity: 4.3) and Mithapukur (incidence: 32%, severity: 4). Leaf scald was observed in Rangpur sadar (incidence: 32.2%, severity: 4.3). In Boro 2015-16 season, in Habiganj district sheath blight (incidence: 10-50%, severity: 1-5) was the highest on BR11 and BRRI dhan49 compared to other diseases such as BB, neck blast, brown spot and narrow brown spot. Again in Comilla district, different rice diseases such as

blast, BB, sheath blight, brown spot and leaf scald were found in different rice varieties such as BRRI dhan28, BRRI dhan29, BRRI dhan58 and hybrids (SL8, Hira). On average, disease incidence of blast, bacterial blight, sheath blight, brown spot and leaf scald were 10-90, 20-90, 5-100, 20-100 and 1-15% respectively. In Rajshahi, disease incidence of BB, brown spot and sheath blight ranged from 0-100% with disease severity 0-9 for BB and 0-7 for brown spot. BB was prevalent on BRRI dhan28 and a local variety Zira. In Satkhira, BB, brown spot and sheath blight diseases were prevalent in all the upazilas. Both incidence and severity of these diseases were prominent. In Barisal, brown spot, blast and bacterial blight diseases were predominantly observed on BRRI dhan28, BRRI dhan29, Kajla, Ghoralal and hybrid hira in all the survey sites. In addition, sheath blight and ufra were sparsely observed in Babuganj and Ujirpur, respectively. In Babuganj, brown spot was the most prominent disease (incidence: 5-90%, severity: 1-7) followed by BB (incidence: 10-50%, severity: 1-5) and leaf blast (incidence: 5-30%, severity: 3-5). Sheath blight (incidence: 40%, severity: 3) was observed in only one field. Again, in Ujirpur, brown spot was the most prominent disease (incidence: 10-90%, severity: 1-3) followed by BB (incidence: 5-70%, severity: 1-7) and leaf blast (incidence: 10-50%, severity: 1-5). Severe ufra outbreak (incidence: 70%, severity: 1) was observed in one field.

POPULATION BIOLOGY

Identification of new blast races across the country. A total of 125 blast samples were collected from the field of IR64 cultivated in blast hub. Among them 110 samples already sent to JIRCAS, Japan for pathogenicity analysis and other 10 samples were tested in BRRI Plant Pathology laboratory. Among the 110 isolates, disease reactions of 20 isolates were evaluated on differential varieties. Blast disease incidence was very low in IR64 plot. Again, out of ten, five samples collected from BRRI dhan28 in last Boro season showed good reaction (>80% resistance frequency) against different MLs where four races such as U73-i7-k177-z-17-ta633; U73-i7-k177-z15-ta433; U73-i5-k177-z07-ta633 and U73-i7-k177-z15-ta433 were detected indicating high variability among *P. oryzae*.

Molecular characterization of bakanae causing fungi in Bangladesh. Bakanae infected samples were collected from Gazipur sadar, Habiganj and Comilla districts. A set of 45 isolates were isolated, purified and preserved. Molecular characterization will be started soon.

Pathotypic and genetic diversity of *Rhizoctonia solani* AG1-IA. More than 100 samples of sheath blight were collected from Rajshahi, Rangpur, Gazipur, Satkhira, Kushtia, Gopalganj and Comilla districts. The pathogen was isolated and purified following standard protocol from 20 samples. Isolation from rest of the samples will be conducted soon.

DISEASE RESISTANCE AND MOLECULAR STUDIES

Evaluation of blast resistant multiline varieties of IR49830 in tidal non-saline ecosystem of Barisal. An investigation was carried out with NILs of IR49830 harbouring blast resistant genes *Pish*, *Pi9* and *Pita-2* and *Sub-1* to develop suitable blast resistant rice variety for tidal non-saline ecosystem in Barisal. Fourty-one-day-old seedlings were transplanted in 12 m^2 plots on 9 August, 2015. Two improved varieties BR22 and BRRI dhan46 and two local varieties Sadamota and Dudkolom were used as standard checks. The crop was completely submerged (up to 110 cm) twice for 7 and 10 days at early vegetative stage. Blast disease incidence was measured by percent panicle infection during harvesting. None of the lines were selected for further study as yield potential of these lines was not significantly higher than the check varieties. However, these lines showed some degree of resistance against rice blast disease in tidal non saline condition and, therefore, may be used as donor parents in future breeding programme. No natural blast incidence was recorded in the multiline variety of IR49830, but very little disease incidence (1.4 to 3.2%) with a severity scale of 1 was recorded in the check materials.

Pyramiding of major blast resistant gene in susceptible rice variety/lines. Monogenic blast resistant genes *Pish*, *Pita 2*, *Pi9* and *Pi40* were introgressed separately in the mega variety BRRI dhan28 and BRRI dhan29 during Boro 2015-16.

Table 1. Backcross progenies of BRRI dhan28, BRRI dhan29 and BRRI dhan63 in T. Aman 2015 and Boro 2015-16.

Recurrent parent	Gene introgressed	Progeny	No. of seed
	T. Aman 2015		
IR64	*Pita2*	BC2F1	80
	Pi9	BC2F1	40
	Pi40	BC2F1	54
Nayonmoni	*Pish*	BC2F1	39
	Pita2	BC2F1	22
	Pi9	BC2F1	14
	Boro 2015-16		
BRRI dhan28	*Pi9*	BC1F1	15
	Pi40	F1	90
BRRI dhan29	*Pish*	BC1F1	71
	Pita2	BC1F1	134
	Pi9	BC1F1	34
	Pi40	BC1F1	4
	Pita2	BC2F1	65
	Pi9	BC2F1	8
	Pi40	BC2F1	10
BRRI dhan63	*Pi40*	F1	170
	Pita2	BC1F1	30

Further, BRRI dhan63 and Noyonmani was also considered as recurrent parent in which the above mentioned gene(s) were introgressed. Table 1 shows the results.

Screening for rice root knot (*Meloidogyne graminicola*) resistance (ADB project). A set of 13 rice genotypes (including one HYV check BR11) were tested for resistance against rook knot nematode. Thirty-day-old seedlings were transplanted in a root knot nursery (having at least 10 juvenile/cm^3 soil) at BRRI following RCB design with three replications. Among the 13 test-genotypes, one (IR97153-B-55) was found to be unaffected (no. of knot/hill=0) by root knot nematode and, therefore, considered as potentially resistant. Average number of knot per hill in other seven genotypes (IR97153-B-123, IR97153-B-112, IR97153-B-85, IR97152-B-100, IR97153-B-323, IR97153-B-114 and BR11) ranged from 3 to 7.33. Rest of the genotypes (IR97152-B-113, IR97152-B-61, IR97152-B-47, IR 97152-B-212, IR97152-B-89) were found with higher number of knots (13.33 to 26.00 root knots/hill).

Screening of INGER materials, advanced breeding lines and germplasm against bacterial blight disease (TRB project). A total of 68 INGER materials including a susceptible check (BRRI dhan28) were screened against BB (*Xanthomonas oryzae* pv. *oryzae*) pathogen during T. Aman 2015 and Boro 2015-16 seasons. Plants were inoculated with the most virulent isolate of the major race (BXO9) at maximum tillering stage following leaf clipping method. In T. Aman 2015, out of 67 materials, only five such as IRBB51, IRBB53, IRBB58, IRBB60 and IRBB65 showed moderately resistant (MR) (disease severity scale 3) against BB. Rest of the entries were moderately to highly susceptible. In Boro 2015-16, out of 67 INGER materials, 19 such as IRBB21, IRBB52, IRBB53, IRBB 54, IRBB58, IRBB59, IRBB60, IRBB61, IRBB62, IRBB63, IRBB64, IRBB65, IRBB66, IR 82786-43-3-2-1, IR07A166, IR10N375, IR10N396, IR11A108 and IR78101-68-1-1-2-2 showed moderately resistant (MR) reaction. Rest of the entries were moderately to highly susceptible. A total of 75 advanced breeding lines (including susceptible and resistant checks) were screened against bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) pathogen in T. Aman 2015 season. Again, in Boro 2015-16 season, 47 advanced breeding lines (including susceptible and resistant checks) were tested.

The experiment was conducted under field conditions using artificial inoculation. Plants were inoculated with the most virulent isolate of the major race (BXO9) at maximum tillering stage following leaf clipping method. Out of 75 materials including checks, none of the materials showed resistant reaction whereas four materials (B10533F-KN-12-2, IR733885-1-4-3-2-1, BR77968-12-1-1-2 and BR82-9-12-1-2-1-1) showed moderately resistant reaction to BB. In Boro 2015-16 season, out of 47 materials including checks, only one material (IR 85849-33-1-2-1-2-2) showed moderately susceptible reaction against BB. In Boro 2015-16 season, a total of 65 breeding lines (including the susceptible and resistant checks) developed by Plant Breeding Division and 11 breeding lines (including the susceptible and resistant checks) developed by Biotechnology Division were tested for their resistance against bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) pathogen. Plants were inoculated with the most virulent isolate of the major race (BXo9) at maximum tillering stage following leaf clipping method. Out of 65 breeding lines developed by Plant Breeding Division, 12 showed resistant (R) reaction (disease severity 1) against BB (Table 1).

Again, seven entries showed moderately resistant (MR) reaction. And the rests were moderately to highly susceptible. Among the 12 lines of Biotechnology Division, nine showed moderately resistant reaction to BB. One entry (IRBB 60) was highly resistant and the rests were susceptible. In Boro 2016 season, a total of 101 rice germplasm supplied by GRS division and one susceptible (BRRI dhan28) and resistant (IRBB 65) check were screened against bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) pathogen using artificial inoculation. Plants were inoculated with the most virulent isolate of the major race (BXO9) at maximum tillering stage following leaf clipping method. All the test-genotypes were found to be moderately to highly susceptible. However, IRBB 65 (resistant check) showed resistant reaction to BB.

BB resistance and yield performance of selected INGER lines. The experiment was conducted during Boro 2015-16 season in the experimental field of BRRI following a RCB design with three replicates. A set of 24 INGER lines and two standard checks (BRRI dhan28 and BRRI dhan29) were grown with 20 cm×20 cm spacing in 2 m×2 m plots. Plants were inoculated with the most virulent isolate of the major BB race (BXO9) at maximum tillering stage following leaf clipping method. Data on percent leaf area damage were collected at 14 days after inoculation. Yield data (t/ha) were collected at maturity stage. Among the INGER lines, yield was the highest in IR10A 231 (8.05 t/ha) which was statistically identical to the yield of BRRI dhan 29 (8.95 t/ha). The lowest yield was obtained in IR 04A216 (2.94 t/ha). In case of BB resistance, all the test-lines were found to be susceptible to highly susceptible.

BB resistance and yield performance of selected breeding lines. Two bacterial blight resistant advanced lines were selected during T. Aman 2014. In T. Aman 2015, the selected lines were grown following head to row method and 34 plants were selected based on their phenotypic attributes and BB resistance reaction following artificial inoculation. Finally, after observing the segregation pattern and BB reaction, three fixed lines resistant to BB were selected in Boro 2015-16.

Gene pyramiding for BB resistance. In this study, BRRI dhan28, BRRI dhan29 and a local improved variety were used as recipient parents. IRBB60 and IRBB65 were used as donor parents. Phenotyping and genotyping were applied for suitable plant selection. Table 2 presents the result. Pathogenicity results showed that a number of progenies of BC_4F_1 or BC_5F_1 developed from the crosses were resistant to the most virulent BB isolate BXO9. Apart from this, a total of 100 resistant materials were selected from BC_3F_2 and BC_4F_2 generation.

Screening of INGER materials against blast diseases. In T. Aman 2015 season, 63 INGER materials were screened against blast (*Pyricularia oryzae*) pathogen including local resistant check BRRI dhan33 and susceptible check BRRI dhan34. The experiment was conducted under laboratory conditions. Twenty-one-day-old seedlings were artificially inoculated using spore suspension (10^5 spores/ml). Eight materials IRBL9-W/RL IR08L216, IR09N127, IR09L324, IR10A121, IR10A231, IR11N239, and IRN313 showed moderately resistant reaction against blast pathogen. Further conformation will be required.

Evaluation of advanced breeding lines against blast disease. Forty-eight advanced breeding lines with standard susceptible check (LTH) and resistant check BRRI dhan33 were screened against blast (*Pyricularia oryzae*) pathogen. Twenty-one-day-old seedlings were inoculated using spore suspension (10^5spores/ml) of a virulent isolate. The inoculated plants were incubated for 24 hrs in a dew chamber. Data were collected at seven days after inoculation following SES, IRRI (0-9 scale). Among the tested materials, only three favourable Boro rice entries such as BR8626-19-4-1-1, BR8626-19-5-1-2, BR7988-14-

Table 2. Development of BB resistant materials from the crosses of BRRI dhan28, BRRI dhan29 and a local improved variety and bacterial blight resistant pyramid lines of IR24.

Recipient/Recurrent	Donor		Present status
	Designation	Target *R* gene	
BRRI dhan28	IRBB60	*Xa4, xa5, xa13, Xa21*	50 seeds of BC_4F_1
BRRI dhan29	IRBB60	*Xa4, xa5, xa13, Xa21*	35 seeds of BC_4F_1
Local improved	IRBB60	*Xa4, xa5, xa13, Xa21*	40 seeds of BC_5F_1
Local improved	IRBB65	*xa5, Xa7, xa13, Xa21*	40 seeds of BC_5F_1

1-4-4-2; one genotype enriched in micronutrient BR8640-9-7-3 and another insect resistant rice genotype BR7987-31-2-4 showed moderately resistance to blast disease.

Development of tungro resistant variety. The parent materials were grown as five different set at seven days interval for the synchronization of the flowering time among the parents. Seeding started from 3rd January and 30-day-old seedlings were transplanted in hybridization blocks. All management practices such as fertilization, irrigation, weeding, insect and disease management were done during growing period with maintaining proper dose and time. A total of 290 F_1 seeds were produced. Four crosses were made using five parents (Table 3).

Table 3. List of crosses made and number of F_1 seed found, Boro 2015-16.

Parentage	No. of F1 seeds
BRRI dhan48/IR6970-1-1-1-4-2	86
BRRI dhan48/Matatag-1	107
BRRI dhan71/IR81244 (Tw-16)	86
BRRI dhan71/Matatag-1	11

EPIDEMIOLOGY

Rice false smut disease at different flowering times. Two repeated experiments were conducted at the experimental farm of BRRI headquarters at Gazipur. In order to generate wide range of flowering times, seven transplanting times (15 June, 30 June, 15 July, 30 July, 14 August, 29 August and 13 September) of BRRI dhan49 served as treatments in 2014 trial. On the other hand, 12 different transplanting times (19 May, 4 June, 19 June, 4 July, 20 July, 4 August, 19 August, 5 September, 19 September, 5 October, 19 October and 5 November) of the same variety were used in the 2015 trial. For generating ratoons, the hills in the main crops were harvested at maturity by manually cutting the tillers at 40-60 cm height. Data were collected on disease incidence (DI) on main crops and ratoons and five weather parameters such as maximum temperature (°C), minimum temperature (°C), relative humidity (%), sunshine hours and rain-days (number), which were summarized for 5 days prior to 15 days of each record of 50% flowering to find any association of weather to the level of disease incidence. The daily weather data for 2014 and 2015 gathered from the BRRI Physiology Division were used for this purpose. To relate DI with weather parameters, the range of DI in both years was categorized into three sections of flowering window: 'early' (5 August to 12 October), 'mid' (17 October to 23 November) and 'late' (4 December to 28 December). The association of five weather parameters to DI in the three defined periods of flowering window was measured through correlation. The significant weather parameters from correlation study were subjected to regression analysis relating DI. In 2015, the rice false smut (RFSm) disease initiated when the crop flowered on 5 August (Fig. 1). The level of the disease remained low in the crops flowering before mid October. The RFSm reached the peak on 5 November and ceased on 28 December flowering crops. In 2015, the disease level was low in the crops flowering till mid October. The RFSm reached the peak on the crop flowered on 9 November.

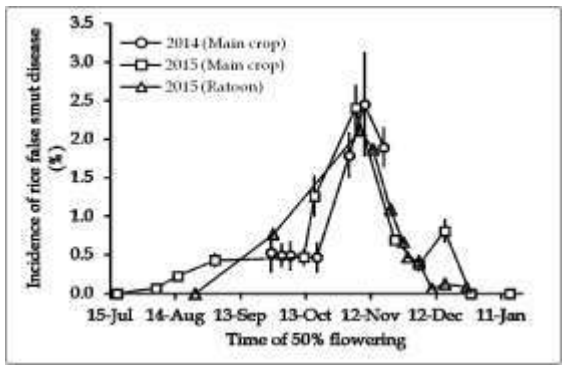

Fig. 1. Incidence of rice false smut disease across the flowering window rice during T. Aman seasons of 2014 and 2015. 'Jul', 'Aug', 'Sep', 'Oct', 'Nov', 'Dec' and 'Jan' denotes for July, August, September, October, November, December and January respectively. Vertical bars indicate 95% confidence intervals.

MANAGEMENT OF RICE DISEASES

Control of seedling blight and raising healthy seedling in tray. The experiment was conducted in T. Aman 2015 and Boro 2015-16. In T. Aman 2015, untreated seeds were sown and seedlings were grown in the trays in different planting times. The incidence of disease was observed and

recorded. In Boro 2015-16, seedling was grown under different soil management conditions. There were nine treatments including untreated and treated control (Table 4). Seeds were treated with fungicides for 20 hours and sown except for the seeds of untreated control. Sprouted seeds were sown on soil and then covered with a thin layer of soil in the trays. Immediate after seeding and subsequent irrigation, a polythene cover was given on the trays for 72 hours continuously and then every night from afternoon to the next morning. Sprinkler irrigation was given for two-three times every day. One treatment (NPK @ 2-3-2 g/tray-uncovered) was kept outside the polythene for 24 hours cycle. Data were collected on diseased area per tray, seedling height, number of roots, fresh and dry weight of shoots.

Effect of fertilizer management. No disease incidence was observed in any treatments with polythene cover or uncovered except for the untreated control (no fungicide) (Table 5). The seedling height increased with the increase of NPK. But the seedling height and leaf age were similar when NPK were applied respectively @ 2-3-2 or 3-4-3 g/tray. Tremendous effect of cow dung on seedling height was observed when compared to the untreated control. However, the seedling height was significantly better in the NPK nutrient combinations than cow dung. The polythene cover showed significant effect on seedling growth as the seedling height was the lowest in treatment (NPK @ 2:3:2-uncover) put outside the polythene. These results suggested that polythene cover at night and soil management with NPK respectively @ 2-3, 3-4 and 2-3 g/tray could be effective for raising good and healthy seedling.

Effect of irrigation. The results indicated that standing water or flooded irrigation controlled the disease effectively irrespective of fungicide treated or untreated seed. The disease incidence in the treated seeds was similar between flooded and sprinkler irrigations irrespective of polythene covered or uncovered. Disease incidence was much higher in sprinkler irrigation than the flooded irrigation in untreated seeds both in polythene covered or uncovered condition. However, the seedling growth was much less in the uncovered environment than the covered one irrespective of treated or untreated seed.

Validation of healthy seedling raising technique at different regions. The experiments were carried out during Boro 2015-16 at Rajshahi and Rangpur regional stations, BRRI. Two experiments were conducted in Rajshahi. In one experiment, seed treatment and seedling spraying methods of fungicide Azoxystrobin + Difeconazole were tested to control the disease at two different concentrations such as 2 ml/L and 3 ml/L water in tray condition. Seeds were soaked in fungicide solution for 12 hours. Seedling was sprayed at three days after sowing in the tray. There was an untreated control (without fungicide treatment) in the experiment. Further seedling emerged in *Aunkuri* (germination technique) were also included as additional untreated control. In another experiment in Rajshahi, the effect of seed treatment period was evaluated. Here seeds were soaked in fungicide (Azoxystrobin + Difeconazole) solution for 8, 12, 16 20 and 24 hours at 3 ml/L. Therefore, six treatments including an untreated control (without fungicide treatment) were tested. In Rangpur, the experiment was conducted both in

Table 4. Percent diseased area and growth characteristic of seedlings in different fertilizer management at 25 days after seeding.

Treatment*	Seedling height (cm)	No. of leaves	No. of roots	Diseased area (%)
Untreated control	7.84 d	3.14 b	7.55 ± 0.21	25.67 ± 0.23 a
Treated control	8.78 d	3.50 ab	7.73 ± 0.50	0.00 b
Cowdung (5%)	9.57 cd	3.36 ab	7.73 ± 0.34	0.00 b
Cowdung (10%)	9.73 cd	3.45 ab	7.72 ± 0.04	0.00 b
Cowdung (5%)+NPK@ 2-3-2 g/tray	12.39 ab	3.81 a	8.93 ± 0.74	0.00 b
NPK@ 1-1.5-1 g/tray	10.96 bc	3.68 a	8.75 ± 0.56	0.00 b
NPK @ 2-3-2 g/tray	13.06 a	3.77 a	8.40 ± 0.36	0.00 b
NPK @ 3-4-3 g/tray	13.78 a	3.62 a	8.47 ± 0.48	0.00 b
NPK @ 2-3-2 g/tray (uncovered)	5.91 e	3.11 b	7.78 ± 0.22	0.00 b
CV (%)	6.47	4.51	9.05	10.94
SE	0.54	0.13	0.60	0.11

*All the treatments were covered with polythene at night except one uncovered. Mean with the same letter are not significantly differed in Tukeys's HSD test.

Table 5. Percent of blighted seedling in trays in seed/seedling treatment methods during Boro in Rajshahi.

Treatment	Azoxystrobin + Difeconazole	Blighted seedling (% area/tray)
Untreated control (Natural)	No treatment	96.6
Untreated control *(Ankuri)**	No treatment	90.0
Seed treatment (12 h)	@ 2ml/L	0.2
	@ 3 ml/L	0.17
Seedling spray at 3 DAS	@ 2 ml/L	0.0
	@ 3 ml/L	0.0
Seedling (Ankuri) spray at 3 DAS	@ 3 ml/L	0.0

*Late infection observed compared to the natural untreated control.

tray and field conditions. Seed treatment and seedling spraying methods of fungicide (Azoxystrobin+Difeconazole) were tested to control the disease at 3 ml/L water solution both in tray and field conditions. Seeds were soaked in fungicide solution for 20 hours. Seedlings were sprayed at three days after sowing both in the tray/field. There was an untreated control (without fungicide treatment) each in tray and field. Data on seedling blight incidence were recorded at 25 days after seeding.

There was no or minimum disease observed in both treated seeds and seedling sprayed with fungicides irrespective of tray or field over the locations (Tables 5 and 6). However, seeds treated for 20 hours in Rangpur showed no disease whereas 12 hours period in Rajshahi results negligible disease incidence in trays. The seedlings produced from the untreated seeds and seedling (from untreated seeds) emerged in *Ankuri* received the highest disease incidence in all locations. However, seedling emerged in *Ankuri* received the disease one week later than the natural untreated control in Rajshahi. The seeds treated for 16 hours to 24 hours result no disease incidence (Table 7). However, seeds treated for 12 hours or less produced minimum disease. The seeds without any treatments were affected the highest. Therefore seed treatment or seedling spray at 2-3 ml/L water solution for 18-20 hours would be effective to control seedling blight disease.

Reaction of BB in different nutrition statuses, Boro 2015-16. The experiment was conducted during Boro 2015-16 following RCB design with three replications. BRRI dhan28 was grown in 2m × 3m plots. Muriate of potash (MOP), Theovit (80% S) and Zn (ZnO) were sprayed alone and in combinations such as MOP+Theovit, MOP+Zn, Theovit + Zn and MOP+Theovit+Zn. Each treatment plot was divided into two equal parts. The plants in one part were inoculated with BB pathogen (BXO9) and then treatments were sprayed at the initiation of disease symptoms. Treatments were applied in another part of each treatment plot at seven days before inoculation. Concentration of both MOP and Theovit 0.5% (w/v) while that of ZnO was 0.2% (w/v) whether applied individually or in combinations. Data were collected on lesion length at 21 days after inoculation. While spraying before inoculation, the lesion length ranged from 10.85-12.62 cm. The lowest lesion length (10.85 cm) was observed with Zn (0.2% w/v). Zn reduced 11.3% lesion length compared to the control treatment. In case of spraying after initiation of disease, lesion length ranged from 10.17 to 13.68 cm. The lowest lesion length (10.17 cm) was observed with MOP + Theovit (0.5% w/v each), which reduced 12.7% lesion length compared to the control. The results suggested that ZnO and MOP + Theovit reduced the disease development. However, further evaluation is required for confirmation.

Effect of soil and seedling treatment on false smut disease development. The experiment was conducted in T. Aman 2015 season at BRRI HQ Gazipur and BRRI RS Rangpur following RCB design with three replications. Rice variety BRRI dhan49 was used in this study. Treatments were as follows- T_1: Seedling treatment using systemic fungicide (Carbendazim); T_2: Soil treatment using systemic fungicide (Carbendazim); T_3: Foliar spray (Propiconazole); T_4: $T_1 + T_2$; T_5: $T_1 + T_3$; T_6: $T_2 + T_3$; T_7: Tilt two spray; T_8: Nativo two spray; and T_9: Control. Data on disease incidence and severity with different treatments were collected at mature stage of the crop. So far, among the nine different treatments, treatment T_5 (seedling treatment along with twice foliar spray) produced the lowest number of infected tiller (13.33) followed by T_7 (20.66) and T_4 (23.66), while the highest number of infected tiller (62.33) was observed in control plot (T_9). Again, the lowest number of infected floret (66.66) was recorded in T_5 treatment, followed by

Table 6. Effect of seed/seedling treatment on seedling blight disease in trays or field during Boro in Rangpur.

Treatment*	Polythene	Blighted seedling (%)
Control (Tray)	Uncovered	96.6
Seed treatment (Tray)	Night covered	0.0
Seedling spray (Tray)	Night covered	0.0
Control (Field)	Uncovered	0.0
Seed treatment (Field)	Night covered	0.0
Seedling spray (Field)	Night covered	0.0
Seed treat/spray (Field)	Uncovered	0.0

*Azoxystrobin+Difeconazole for 20 h @ 3ml/L.

Table 7. Percentage of blighted seedling in the seeds treated for different durations.

Seed treatment period (hour)	Chemical group	Blighted seedling (% area/tray)
Untreated control	No treatment	97.6
8 hour	Azoxystrobin+ Difeconazole	3.33
12 hour	@ 3 ml/L	2.33
16 hour		0.0
20 hour		0.0
24 hour		0.0

T_7 and T_4. The highest number of infected floret (660) was found in control plot. In addition to this, the highest 78.61% disease reduction was detected in T_5 plot. Except T_1, all the treatments showed similar disease severity of scale 5.

Chemical control of false smut disease of rice. The experiment was conducted in T. Aman 2015 season in the experimental field of BRRI following a RCB design with three replicates to test the efficacy of five fungicides (Azonil 56EC @ 2mL/L, Seltima @ 2mL/L, Agroplus @ 20mL/L, Cu Hydroxide @ 2.5 g/L and Cu Acetate @ 2.5 g/L each sprayed twice at seven days interval in booting stage) against the natural incidence of false smut disease on BRRI dhan49. Data were collected on hill infection (%), panicle infection (%) and yield (t/ha). None of the fungicides were found to be effective in controlling false smut being identical to the control treatment in terms of hill infection (%) and yield (t/ha). However, the effect of different fungicides on panicle infection (%) varied to some extent. The lowest degree of panicle infection (11.41%) was found with Cu Acetate.

Management of kresek (*Xanthomonas oryzae* pv. *oryzae*) in rice seedlings. The experiment was conducted in Boro 2015-16 season in the experimental field of BRRI to test the efficacy of different treatments (chemicals) against kresek caused by *Xanthomonas oryzae* pv. *oryzae*. Thirty-days-old seedlings of BRRI dhan28 were inoculated by dipping the trimmed roots in bacterial (*X. oryzae* pv. *oryzae* isolate BXO9) suspension (10^8 cell/mL) for 30 minutes. Inoculated seedlings were then dipped in different treatments (Table 8) for 30 minutes. For treatment application, the seedlings were transplanted in 2m × 2m plots following a RCB design with three replicates. At 30 days after inoculation, data were collected on kresek incidence (%). Yield data (t/ha) were collected at maturity stage. No kresek incidence was observed in the uninoculated control treatment when roots were not trimmed before transplanting. However, among the chemical treatments, the lowest (16.33%) kresek incidence was recorded when inoculated seedlings were dipped in copper hydroxide (2% w/v) solution for 30 minutes (Table 8). Statistically identical results were found with copper oxychloride (2% w/v solution) and MOP (0.6% w/v solution). The highest (35.66%) kresek incidence was recorded with inoculated control treatment.

Among the chemical treatments, the highest yield (4.67 t/ha) was obtained with copper oxychloride (2% w/v solution) which was statistically identical with uninoculated control but significantly higher than inoculated control.

Evaluation of new chemicals against bacterial blight disease of rice. In Boro 2015-16, a set of 16 chemicals were tested against Bacterial blight (BB) in the net house of Plant Pathology Division, BRRI, Gazipur using artificial inoculation. Five bactericides such as Autobac 20 WP (Bismerthiazole), Bactrol 20 WP (Bismerthiazole 20%), BLB Stopper 20 EC (Thiodiazole + Copper), Sunoscar 21.5 WP (Bismerthiazole 20% + Kasugamycine 1.5%) and Radi 20 WP (Streptomycine + Tetracycline) successfully controlled BB (above 80%).

Table 8. Effect of different treatments on kresek incidence and yield of BRRI dhan28, Boro 2015-16.

Treatment	Kresek incidence (%)	Yield (t//ha)
T_1= Copper hydroxide (2% solution)	16.33 (3.33) b	4.41 (0.23) ab
T_2= Zinc sulphate (2% solution)	32.33 (6.67) a	4.17 (0.12) b
T_3= Copper oxychloride (2% solution)	19.33 (3.48) b	4.67 (0.07) ab
T_4= MOP (0.6% solution)	19.66 (0.88) b	4.23 (0.22) ab
T_5= Theovit (0.6% solution)	35.33 (3.53) a	4.38 (0.08) ab
T_6= Inoculated control	35.66 (2.40) a	4.13 (0.26) b
T_7= Uninoculated control (Root trimmed)	4.00 (0.57) c	4.74 (0.28) ab
T_8= Uninoculated control (Root not trimmed)	0.00 (0.00) c	5.12 (0.11) a

Evaluation of new chemicals against blast disease of rice. The experiment was conducted in Boro 2015-16 at the blast nursery, BRRI, Gazipur using a susceptible variety BRRI dhan29. The plants were inoculated artificially. Among the 23 fungicides, only six such as Pazodi 32.5 SC, Oxy Plus 32.5 SC, Navera, Bravo 75 WG, Seltima and Azonli 56 successfully controlled rice blast disease (above 80%).

Chemical control of grain spot disease in rice. The experiment was conducted at BRRI RS farms Rajshahi and Rangpur during T. Aman 2015 to find out effective fungicides against grain spot disease under field condition with natural infection. Seven fungicides such as Seltima (1000 ml/ha), Frostrobin (500 ml/ha), Azotop (500 ml/ha), Folicur (500 ml/ha), Thiovit (2.5 kg/ha), Nativo (250 g/ha) and Rovral (100 g/ha) were tested. All the fungicides were sprayed at five days after flowering and again at 10 days intervals. In Rajshahi, the highest reduction (82.83%) of brown spot on leaf was found in Rovral treated plants followed by 80.0, 75.64 and 75.56% in Seltima, Folicur and Nativo treated plants respectively. In Rangpur, the highest reduction (87.44%) of brown spot on leaf was observed in Nativo treated plants.

Chemical control of sheath blight of rice. Efficacy of 24 fungicides (including one standard check Nativo) was tested against sheath blight disease at BRRI HQ, Gazipur and BRRI RS, Rajshahi in T. Aman 2015 season. In Gazipur, Pazodi reduced the disease by 76.88% followed by Azcor (76.36%) and Mactivo (71.08%). In Rajshahi, most of the test-fungicides successfully controlled the disease by more than 80%. However, 88.27% disease reduction was achieved with Oxyzole followed by Oxyplus (87.28%), Venom (85.14%) and Avtar (84.91%).

TECHNOLOGY TRANSFER

Demonstration on integrated rice disease management and healthy seed production in farmers' field (IAPP project). A farmer's field was selected for each demonstration. Each field was further divided into two parts. Integrated disease management including chemical and cultural practices for different rice disease management were applied in one part of farmer's field. Another part of farmer's field was used as control treatment following farmer's practice.

Sheath blight (Rangpur and Nilphamary). Six demonstrations were conducted in T. Aman 2015 season. In general, sheath blight was controlled more effectively following BRRI recommended practices compared to farmers' practice. In Rangpur sadar, the highest DI (68%) and DS (scale 9) were observed in farmers managed plot, while the lowest DI (10%) was found in BRRI managed plot. All plots treated with BRRI recommended practice showed comparatively lower DS (scale 3). Again, the highest yield (5.38 t/ha) was also achieved in BRRI managed plot, while lowest yield (4.88 t/ha) was recorded in farmer's managed plot. In Nilphamary district, the highest DI (65%) and DS (scale 9) were recorded in farmer's plot, while the lowest DI (8%) and DS (scale of 3) were found in the plots where BRRI recommended practices were implemented. Again, the highest yield (5.34 t/ha) was achieved with BRRI recommended practices, while the lowest yield (4.85 t/ha) was recorded with Farmer's practice.

Blast (Barisal). Three demonstrations were conducted in Barisal region during T. Aman 2015 season. Rice blast disease was managed more effectively following BRRI recommended practices compared to farmer's practice. The highest DI (60%) and DS (scale 7) were observed in farmer's plot, while the lowest DI (5%) and DS

(scale 1) were recorded in plots treated with BRRI recommended practice. Again, the highest yield (3.4 t/ha) was achieved in the plots treated with BRRI recommended practice while the lowest yield (2.3 t/ha) was recorded in farmer's plot.

Bacterial blight (Rangpur and Nilphamary). Six demonstrations were conducted in Rangpur region during Boro 2015-16 season. BB was managed successfully by BRRI treated plots than farmer's plots. In Rangpur sadar, the highest DI (86%) and highest DS (scale 9) were found in farmer's plot while the lowest DI (28%) and DS (scale 3) were found in plots treated with BRRI recommended practice. Again, the highest yield (5.6 t/ha) was achieved in plots treated with BRRI recommended practice, while the lowest yield (5.1 t/ha) was recorded in farmer's managed plot. Again, in Nilphamary, the highest DI (90%) and DS (scale 7) were recorded in farmer's managed plot, while the lowest DI (28%) and DS (scale 1) were observed in BRRI treated plot. Again, the highest yield (5.61 t/ha) was achieved in BRRI treated plot, while the lowest yield (5.16 t/ha) was achieved in Farmer's plot.

Bacterial blight (Barisal). Three demonstrations were conducted in Barisal region during Boro 2015-16 season. Rice bacterial blight disease was managed successfully in BRRI managed plots compared to farmer's plots. The highest DI of 87% and DS of scale 9 were found in farmer's plots, while the lowest DI of 26% and DS of scale 3 were found in the plots BRRI treated with BRRI recommended practice. Again, the highest yield of 5.61 t/ha was achieved in BRRI treated plot, while the lowest yield of 5.22 t/ha was recorded following farmer's practice.

Healthy seed production (Rangpur, Nilphamary and Barisal). Nine demonstrations were conducted in Rangpur and Barisal region during Boro 2015-16 season. A rice field having an area of 33 decimal lands was selected & divided the plot into two parts. One part treated as BRRI managed plot which were used for pure and healthy seed production, while in the other part farmers grown their own seed following their own technique. In Rangpur sadar, the highest 67 kg seeds of BRRI dhan28 were produced in a treated plot. Again, the highest 62 kg seeds were obtained in a treated plot in Nilphamary district. In Barisal, the highest 72 kilogram seeds were produced in a treated plot, while other treated plots produced 66-68 kilogram seeds respectively. All the seeds were preserved in plastic containers with naphthalene and neem leaf for future use.

Demonstration on integrated rice disease management of major rice diseases (PGB). A total of 23 demonstrations were conducted for blast and sheath blight disease management in farmers' field at seven upazilas such as Gopalganj sadar, Tungipara, Kotalipara, Kasiani, Nazirpir, Mollahat and Fakirhat in 2015-16. One farmer's field was selected for each demonstration. Each field were further divided into two parts. BRRI recommended practices for rice disease management were applied in one part of farmer's field. Another part of farmer's field was used as control treatment following farmer's practice. BRRI recommended practices included all cultural (water, weed and fertilizers) and chemical (Nativo spray) management practices according to BRRI guidelines and in FP farmers followed their own practices to grow rice (irregular plant spacing, unclean cultivation, low fertilizer dose rather than BRRI recommended dose and lack of knowledge on disease and its' management). Fungicide Nativo @ 250g/ha was sprayed twice at 8-12 days interval as soon as leaf blast/sheath blight was observed in plots where BRRI recommended practices were followed. Data were collected on DI (%) and yield (t/ha). In T. Aman 2015 season, the highest neck blast was observed in farmer's practice plot compared to BRRI recommended practice in all trial locations. The highest incidence was observed in Nazirpur (34.43%) followed by Gopalganj sadar (26.07%). Leaf blast was only observed in Mollahat. Although leaf blast incidence was similar in the plots treated with BRRI recommended and farmer's practice, higher severity (scale 5) was observed in farmer's practice compared to BRRI recommended practice (scale 3). No blast symptom was observed in Tungipara. Again, the highest yield was obtained with BRRI recommended practice compared to farmer's practice in all locations. Yield increased by 4.00 to 26.79% following BRRI recommended practices compared to farmer's practice in the trial locations. Although there was no blast infection in Kotalipara but the highest yield (26.79%) was recorded in the plots managed following BRRI recommended practices. Higher yield increase (%) was observed in

Mollahat and Nazirpur in BRRI recommended practice compared to farmer's practice. In Boro 2015-16 season, higher leaf blast incidence was observed in farmer's plots compared to BRRI recommended practice plots in all infected locations. The highest neck blast incidence was observed in BRRI dhan28 at Fakirhat. No blast incidence was recorded in other locations including Tungipara, Gopalganj sadar and Nazirpur. Again, in all blast infected locations, higher yield was obtained when BRRI recommended practices were followed compared to farmer's practice. Yield was increased by 5.49-22.41% in different trial sites through BRRI recommended blast disease management practices. Sheath blight (ShB) incidence was found significantly higher (p=.05) in farmer's practice compared to BRRI recommended practices. The highest ShB incidence was observed in Mollahat (41%) followed by Fakirhat (39.43%). Again, higher yield was obtained in BRRI recommended practices in all locations. The highest yield increase was observed in Mollahat (43.78%) and Fakirhat(31.93%) because of proper crop management and control of ShB disease.

Management of sheath blight disease utilizing *Trichoderma harzianum* (PGB project). Compost was prepared in Aus season 2015-16 in Plant Pathology net house, BRRI, Gazipur. Culture of *Trichoderma* sp. was prepared in laboratory. Then the culture was mixed with water hyacinth, cow dung and urea solution (10%) at the ratio of water hyacinth: cow dung: *Trichoderma* culture= 3: 1: 0.25. After that the compost materials were placed in layers in a pit (1m × 1m × 1m). The pit was covered with polythene sheet. Then the compost materials were left for 30 days in the pit. After compost preparation, it was used in farmers' fields in variety BR11 to find the efficacy of this compost in reducing sheath blight disease. Along with compost trial other two trials - farmers' conventional practice and chemical control were set up at the same time adjacent to the compost trial for comparison. All three practices were replicated thrice in RCB design. Data were collected on % RLH and yield (t/ha) in treated plots versus in farmers' practice plots. Analysis of chemical composition of the compost is on-going. There was no statistically significant variation among the treatments. However, the lowest sheath blight incidence (% RLH) was recorded with the compost treatment compared to other two practices. Again, the highest yield (6.56 t/ha, yield increase 29.13%) was obtained with compost application.

Rice Farming Systems Division

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SUMMARY

In evaluation of different cropping patterns for their water requirement in medium highland ecosystem, the tested patterns gave significantly higher rice equivalent yield (REY) as well as higher gross margin and higher water productivity than check pattern. Tomato-Mugbean-T. Aman produced 277% higher REY (36.5 t/ha) than check pattern of two rice systems (9.68 t/ha). This cropping pattern also gave more than 1600% higher gross margin and higher water productivity (20.9 kg/mm/ha). All other tested patterns also showed better performance in respect to REY, gross margin and water productivity than two rice cropping pattern (check).

In long-term effect of three cropped cropping patterns on the agro-economic productivity and soil health, the Potato-Boro-T. Aman cropping pattern produced the highest REY of 17.8 t/ha and 16.7 t/ha in Rangpur and Gazipur respectively, followed by Boro-T. Aus-T. Aman (12.9 t/ha and 14.9 t/ha).

To develop suitable cropping pattern packages for maize based cropping pattern in Chuadanga, the total productivity of intercropping system was compared in terms of maize equivalent yield (MEY), which differed significantly among the treatments. Significantly the highest MEY was obtained from CP_3 (31.0 t/ha) followed by CP_1 (25.6 t/ha). High value vegetables crop produced as intercrop with maize contributed significant difference among the tested patterns. Significantly lower MEY were obtained from sole maize plot.

The highest gross margin was obtained from CP_3 (254000 Tk/ha) followed by CP_1. The CP_3, CP_1, CP_5 and CP_4 gave about 69, 46, 27 and 20% higher gross margin (GM) than the check pattern.

In the development of high intensity cropping pattern for greater Kushtia, the highest REY was found in Maize+Potato/Pumpkin-T. Aus-T. Aman (25.69 t/ha) followed by Maize+Spinach-T. Aus-Aman (17.93 t/ha) and Maize-T. Aman (16.26) cropping patterns. The lowest REY was found in Mustard-Mungbean-Aus-Aman (15.15 t/ha) cropping pattern.

For the improved cropping systems for greater Kushtia, the different ecosystems were selected by the joint effort of researcher and extension personnel in Chuadanga, Meherpur and Kushtia districts. REY of improved cropping patterns Mustard-Boro-T. Aman (12.27- 13.93 t/ha), Maize-Mungbean-T. Aman (13.67- 13.86 t/ha), Maize-Til-T. Aman (15.60 t/ha) and Potato-Mukhikachu-T. Aman (40.06 t/ha) were significantly higher than the existing Boro-Fallow-T. Aman (10.22-11.65 t/ha), Maize-Fallow-T. Aman (11.00-14.42 t/ha) Maize-Jute-T. Aman (14.01 t/ha) and Boro-Mukhikachu-Fallow (30.23 t/ha) cropping pattern respectively. Irrespective of location, all the improved cropping patterns gave higher gross margin than the local check.

From the fertilizer management on yield of double transplanted Aman and Boro rice under T. Aman-Boro cropping systems, the higher grain yield was obtained with the T_4 (4.90 t/ha.), followed by the T_5, T_6 and T_2 and minimum under T_1 (3.83 t/ha). In Boro season, the grain yield of rice was significantly affected by different treatments ($p \leq 0.05$). The highest grain yield was obtained from T_5 (8.55 t/ha), followed by the T_4 and T_2. The lower and statistically similar grain yields were observed in T_7 (6.07 t/ha) and T_1 (6.82 t/ha).

In the Boro season the higher grain yield was obtained from the N_3 treatment (7.10 t/ha) followed by the N_2 (6.88 t/ha), N_4 (6.78 t/ha) and N_1 (6.70 t/ha) treatments and lower was in the N_6 (3.23 t/ha) treatment in BRRI dahn28. In BRRI dhan29, significantly higher grain yield was observed in N_4 (7.80 t/ha) treatment compared to all other treatments and lower was in the N_6 (3.15 t/ha) treatment. BRRI dhan29 achieved higher grain yield compared to BRRI dhan28, irrespective of N treatment.

From the evaluation of BRRI prilled urea applicator in Boro and T. Aman rice in Boro-Fallow-T. Aman cropping system, the output of the study was significantly higher grain yield obtained from T_1 (5.66 t/ha) followed by T_3 (5.60 t/ha) and T_2 (5.53 t/ha) treatments. In Boro season, the highest grain yield was obtained from T_3 (6.73 t/ha) followed by T_1 (6.22 t/ha) treatments in BRRI dhan28. The lowest yield was observed in T_5 in both the seasons.

From the evaluation of fertilizer recommendation in rice-dibbled sunflower cropping sequence under different gradient of salinity, the highest grain yield was recorded in the treatment of recommended dose of N, P, K fertilizer (4.62 t/ha^{-1}), which was statistically

similar to farmers practice (4.59 t/ha^{-1}) and without K fertilizer (4.26 t/ha^{-1}).

In agronomic options for increasing productivity Boro rice in saline soils, the highest grain yield (6.27 t/ha^{-1}) was obtained from BRRI hybrid dhan3 transplanted 10 days earlier compared to farmers' average transplanting date (10 January), which was similar to BRRI hybrid dhan3 at normal planting date and BINA dhan10 both with 2-3 and 5-6 seedling hill^{-1}, BRRI dhan61 with more number of seedling (5-6 hill^{-1}).

In rice-based cropping pattern in partially irrigated ecosystem, the REY among the tested patterns ranged from 23 to 28.13 t/ha^{-1} and apparently the higher REY was observed in CP_3 followed by CP_4 and CP_2. Higher gross return, gross margin and benefit cost ratio (BCR) were also obtained from CP_3 (Tomato-Mungbean-BRRI dhan62) followed by CP_4 (Tomato-Mungbean-BRRI dhan39) and CP_2 (Tomato-Mungbean-BRRI dhan56) and the lower was found in CP_1.

From the evaluation of musk melon intercropping with lentil in three crop systems in tidal non-saline ecosystem, intercropping system gave significantly higher REY of 24.46 t/ha than Lentil-Jute-T. Aman (13.17 t/ha) cropping pattern. The gross margin (GM) of intercropping system was 137% higher than without intercropping system (70747 Tk/ha). The BCR of intercropping and without intercropping system was 1.85 and 1.56 respectively. Musk melon as intercropped with lentil can increase the three crop system productivity at almost double of total REY and GM.

In development of three crop systems for medium high tide wetland non-saline ecosystem the inclusion of mustard, wheat, potato, lentil in Fallow-Jute-T.Aman cropping pattern under four different cropping systems were tested to intensify and diversify the double cropped cropping system at four to twelve dispersed farmer's fields during 2014-15 in Pirojpur district. All of the three crop systems produced significantly higher REY of 42 to 162% than two crop systems of Fallow-Jute-T. Aman cropping pattern (8.57 t/ha). Potato-Jute-T. Aman cropping pattern gave higher REY of 22.47 t/ha among the tested patterns. The gross margin of potato and lentil based three cropped system was 488% and 204% higher than Fallow-Jute-T. Aman system (23746 Tk/ha). The BCR of these two crops based three crop system was 1.71 and 1.57 respectively. For higher profitability, potato was the best followed by lentil, wheat and mustard as Rabi crop in Fallow-Jute-T. Aman cropping pattern.

From the different cropping patterns in Barisal region, to identify the suitable cropping pattern for Barisal, Jhalokathi, Barguna and Patuakhali districts in 2014-15. Inclusion of sunflower and mungbean in Fallow-T. Aus-T. Aman cropping pattern was tested at Amtali, Barguna. Inclusion of sunflower and mungbean gave about 211% and 96% higher REY respectively than two rice systems (7.17 t/ha). Fallow-T. Aus-T. Aman, Mungbean-Fallow-T. Aman, Fallow-Fallow-T. Aman/Grass pea was also trialed in Patuakhali, Jhalkathi and Barisal district respectively. The REY of Fallow-T. Aus-T. Aman, Mungbean-Fallow-T. Aman and Fallow-Fallow-T. Aman/Grass was 151, 55 and 91% higher than single T. Aman cropping pattern (3.19 t/ha).

Evaluation of rice-based cropping pattern in partially irrigated ecosystem

The experiment was conducted at East Byde, BRRI experimental farm, Gazipur during 2014-15. Five cropping patterns viz Tomato (BARI hybrid tomato-5)-Mungbean (BARI mug-6)-DS Aman (BRRI dhan57) (CP_1), Tomato (BARI hybrid tomato-5)-Mungbean (BARI mug-6)-DS Aman (BRRI dhan56) (CP_2), Tomato (BARI hybrid tomato-5)-Mungbean (BARI mug-6)-DS Aman (BRRI dhan62) (CP_3), Tomato (BARI hybrid tomato-5)-Mungbean (BARI mug-6)-DS Aman (BRRI dhan39) (CP_4) and Tomato (BARI hybrid tomato-5)-Mungbean (BARI mug-6)-DS Aman (BRRI dhan33) (CP_5) were evaluated in RCB design with three replications. Recommended management practices were followed for rice and nonrice crops. A simple economic analysis was done to evaluate the total productivity of these cropping patterns. Management practices adopted for different crops**.**

The yields of BARI hybrid tomato-5 ranged from 32.63 to 42.02 t/ha^{-1} among the five tested cropping patterns (Table 1). Cropping pattern (CP) had significant effect on tomato yield ($p<0.05$) and the highest yield was obtained from CP_3 followed by CP_2 and CP_4. The CP_1 and CP_5 produced similar tomato yield and apparently the

Table 1. Yield of tomato, mungbean and rice and REY of different cropping patterns, BRRI, Gazipur 2014-15.

Cropping pattern (CP)	Yield t/ha^{-1}			REY (t/ha^{-1})
	Tomato	Mungbean	DS Aman	
BARI hybrid tomato-5 - BARI Mug-6 - BRRI dhan57 (CP_1)	32.63	0.35	3.95	31.45
BARI hybrid tomato-5 - BARI Mug-6 - BRRI dhan56 (CP_2)	38.31	0.36	3.22	35.31
BARI hybrid tomato-5 - BARI Mug-6 - BRRI dhan62 (CP_3)	42.02	0.34	3.29	38.27
BARI hybrid tomato-5 - BARI Mug-6 - BRRI dhan39 (CP_4)	37.83	0.29	3.92	35.36
BARI hybrid tomato-5 - BARI Mug-6 - BRRI dhan33 (CP_5)	32.83	0.39	3.54	31.36
CV(%)	9.5	25.6	13.9	8.7
F-values for CP	*(6.57)	NS	NS	NS

Price- Tomato: 12 Tk/kg, mungbean: 60 Tk/kg and rice: 15 Tk/kg. NS significant at the 0.05 probability levels and not significant.

lowest yield was observed in CP_1. The CP did not show significant effect on the yields of mungbean, DS Aman and REY ($p>0.05$). The grain yields of BRRI dhan57, BRRI dhan56, BRRI dhan62, BRRI dhan39 and BRRI dhan33 in CP_1, CP_2, CP_3, CP_4 and CP_5 were 3.95, 3.22, 3.29, 3.92 and 3.54 t/ha^{-1} respectively. The variety BRRI dhan57 gave the higher yield (3.95 t/ha^{-1}), followed by BRRI dhan39 (3.92 t/ha^{-1}) and the lower yield was observed in BRRI dhan56 (3.22 t/ha^{-1}). The REY among the tested patterns varied from 31.36 to 38.27 t/ha^{-1} and apparently the higher REY was observed in CP_3. The lower REY was produced under CP_5 followed by CP1**.**

From economic evaluation, higher gross return, gross margin and benefit cost ratio (BCR) were obtained from CP_3 (Tomato-Mungbean-BRRI dhan62). The total variable cost (TVC) was found similar in the tested cropping patterns due to similar monetary involvement**.**

Long-term effect of three cropped cropping patterns on the agro-economic productivity and soil health

The experiment was conducted during 2014-15 at the experimental farms, BRRI, Gazipur. The tested cropping patterns were, Potato-Boro-T. Aman, Maize-Mungbean-T. Aman, Boro-T Aus-T. Aman and Boro-Fallow-T. Aman (check). The experiment was laid out in a RCB design with three replications. Each unit plot was isolated by one meter space and 0.2 m high and 0.2 m wide levees. The levees were covered with polythene sheet inserting into the soil both sides of levee to prevent movement of irrigation water. The yield of each crop was converted to REY (rice equivalent yield) for comparing the system productivity. Utilization of resources like labour and inputs was recorded for calculating the variable cost and market price of the output at maturity was collected for determining the economic return.

In Gazipur 2014-15, during Boro season, grain yield of BRRI dhan29 was 7.38 t/ha at Boro-Fallow-T. Aman cropping pattern and BRRI dhan28 gave 5.85, 4.59 t/ha under Boro-T Aus-T. Aman and Potato-Boro-T. Aman cropping pattern. Potato yielded 23.84 t/ha under Potato-Boro-T. Aman cropping pattern. Maize and Mungbean yield was 8.37 t/ha and 0.6 t/ha respectively under Maize-Mungbean-T. Aman cropping pattern. In three rice cropping pattern, yield of Aus variety BRRI dhan48 was 2.89 t/ha at Boro-T. Aus-T. Aman cropping pattern. Low yield occurred due to serious rat and bird infestation. Grain yields of Aman rice variety BRRI dhan49 were 4.74, 4.63, 4.70 and 4.80 t/ha under Boro-Fallow-T. Aman, Boro-T. Aus-T. Aman, Maize-Mungbean-T. Aman and Potato-Boro-T. Aman cropping pattern. The highest REY (25.22 t/ha) was obtained from Potato-Boro-T. Aman cropping pattern. Maize-Mungbean-T. Aman (13.89 t/ha), Boro-T. Aus-T. Aman (13.43 t/ha) and Boro-Fallow-T. Aman (12.18 t/ha) were statistically similar.

The highest gross margin (Tk 1,69,200/ha) found from Potato-Boro-T Aman cropping pattern which was higher than those of Boro-T. Aus-T. Aman, Boro-Fallow-T. Aman and Maize-Mungbean-T. Aman cropping patterns.

Development of integrated vegetables, fish and fruit system for shallow mini pond

The results showed that the stem aroid yield of T_1, T_2 and T_3 was 20.77, 18.33 and 13.30 t/ha, respectively (Table 2). The highest stem yield was observed in T_1 followed by T_2 and the lowest was in T_3. The stolon yield ranged from 2.7 to 3.6 t/ha and the highest stolon was obtained from T_1 (3.6 t/ha). The highest fish yield was obtained from T_4 (1.18 t/ha) where T_1 gave 0.47 t/ha and T_2 gave 0.24 t/ha fish. Economic analysis of different treatments showed that T_1, T_2 and T_3 gave gross margin of 2,85,200, 2,17,300, 1,53,500 Tk/ha

Table 2. Yield and profitability level of different mixed farming combinations, BRRI, Gazipur 2015-16.

Treatment	Yield (t/ha)			Gross margin (000 Tk/ha)
	Aroid		Fish	
	Stem	Stolon		
T_1= Aroid+Fish (Stocking density: 02 piece/m^2)	20.77	3.6	0.47	28.52
T_2= Aroid+Fish (Stocking density: 01 piece/m^2)	18.33	3.3	0.24	21.73
T_3= Only aroid in the pond	13.3	2.7	-	15.35
T_4= Only fish (Stocking density: 01 piece/m^2)	-	-	1.18	9.95

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

respectively, where T_4 (only fish) gave 99,500 Tk/ha. The gross margin of T_1 was 286, 185 and 131% higher over T_4, T_3, T_2 respectively. The lowest gross margin was found in T_4 where only fish was cultivated.

Validation of integrated rice, fish and vegetables system in *ghers*

This experiment was conducted in the reporting year at BRRI, Gazipur. The treatments consisted of four combinations; T_1=T. Aman (BR23)+ Fish-Boro (BRRI dhan28) and vegetable on the bank of the pond, T_2= T. Aman (BRRI dhan41) +Fish-Boro (BRRI dhan28) and vegetables on the bank of the pond, T_3=T. Aman (BRRI dhan54)+Fish-Boro (BRRI dhan28) and vegetables on the bank of the pond and T_4=Fish-Boro (BRRI dhan28) and vegetables on the bank of the pond. Fish species was Monosex Telapia and vegetables variety was Lalteer. Fish was released as per recommendation on 7 July 2015 and harvested on 6 January 2016. Pest control was done by using sex pheromone trap.

The result showed that the yield of T_1, T_2, and T_3 was 5.30, 5.93 and 4.1 t/ha respectively where BRRI dhan41 gave significantly higher yield (5.93 t/ha) than BR23 (5.30 t/ha) and the lowest yield was found in BRRI dhan54 (4.1 t/ha). In the next Boro season, higher yield of BRRI dhan28 was found in T_4 (6.47 t/ha) where T_1, T_2 and T_3 gave lower yield than Single Fish- Boro cropping pattern. Total fish production was 2.9 t/ha. Higher REY was found in T_2 followed by T_1 and T_3 and the lowest REY was found in T_4.

In *gher* systems fish was released (2 piece/m^2) in nearby dyke and after six months when water was getting decreased fish was harvested. In non-saline *gher* only white fish are released because the mortality rate is less than shrimp cultivation. Total fish production was found 2.9 t/ha in the non-saline *gher* system.

However, vegetable cultivation with rice would be an effective combination for the farmers in non-saline *gher* ecosystem. There is scope of substantial improvement of the productivity of the system with the inclusion of diversified rice, vegetables and fish. Different summer and winter vegetables can be grown in pond bank.

Development of high intensity cropping pattern for greater Kushtia

An experiment was conducted at the farmers' field in two different locations, Kushtia sadar and Meherpur sadar, during the period of November 2014 to October 2015. i) to increase the total productivity through adoption of improved cropping pattern ii) to diversify and intensify of the rice-maize based cropping patterns. Four cropping patterns viz., Mustard (BARI sarisha-14) - Mungbean (BARI mug-6)-T. Aus (BRRI dhan48)-T. Aman (BRRI dhan57), Mustard (BARI sarisha14)-Sweet gourd+ Mungbeans (BARI misti kumra-2+BARI mug-6)-T. Aus (BRRI dhan48)-T. Aman (BRRI dhan57), maize (BARI hybrid bhutta-7/Indian hybrid varity)+Potato (Cardinal)-T. Aus (BRRI dhan48)-T. Aman (BRRI dhan57) and Maize (BARI hybrid bhutta-7/Indian hybrid varity)+Spinach-T. Aus (BRRI dhan48)-T. Aman (BRRI dhan57) were evaluated along with the check Maize (BARI hybrid bhutta-7/Indian hybrid varity)-Fallow-T. Aman (BRRI dhan57/BRRI dhan49) in RCB design with three replications. Recommended management practices were followed for rice and non rice crops. A simple economic analysis was done to evaluate the total productivity of these cropping patterns.

In Kushtia sadar highest REY was found from Maize+Potato-T. Aus-T. Aman cropping pattern (18.36 t/ha) followed by Maize+Spinach-T. Aus-T. Aman (15.07 t/ha) and Mustard-Mungbean-T. Aus-T. Aman (14.50 t/ha). Lowest REY was found from Maize-T. Aman (10.14 t/ha) cropping pattern (Table 3).

Table 3. Performance for different cropping patterns in Kushtia 2014-15.

Cropping pattern	Yield (t/ha)				REY (t/ha)
	Mustard/maize	Mungbean/ spinach/ Potato/ sweet gourd	T. Aus	T. Aman	
Mustard-Mungbean-T. Aus-T. Aman	1.77	0.75	3.85	4.24	14.50
Mustard-Sweet gourd-T. Aus-T. Aman	1.84	3.64	3.91	4.25	13.99
Maize+ Potato-T. Aus-T. Aman	8.20	10.28	4.17	4.30	18.36
Maize+ Spinach-T. Aus-T. Aman	8.44	5.00	4.14	4.20	15.07
Maize-Fallow-T. Aman	9.10	-	-	4.35	10.14
LSD $_{(0.05)}$	-	-	-	-	0.95
F for treatment					**
CV (%)	-	-	-	-	3.5

Mustard=50 Tk/kg, mungbean=70 Tk/kg, Rice=22 Tk/kg, Potato = 10 Tk/kg, spinach=60 Tk/kg, maize=14 Tk/kg, sweet gourd=10 Tk/kg.

In Meherpur sadar highest REY was found from Maize+ Potato-T. Aus- T. Aman cropping pattern (22.95 t/ha) followed by Mustard-Mungbean-T. Aus-T. Aman cropping pattern (19.95 t/ha) and Mustard-Sweet gourd+ Mungbean-T. Aus-T. Aman (19.06) cropping pattern and lowest REY was found from Maize-T. Aman (14.16 t/ha) cropping pattern (Table 4).

Evaluation of Maize intercropping technologies to develop suitable cropping pattern packages for maize based cropping pattern in Chuadanga

A study was conducted at farmer's field of Chuadanga sadar, during the period from October 2014 to November 2015 to indentify the suitable cropping system technology to replace Maize-Fallow T. Aman and Maize-Sweet gourd T. Aman. Five cropping patterns viz., Maize+ Bushbean- Sweet gourd- T. Aman, Maize+Spinach-Sweet gourd-T. Aman, Maize + Lalshak- Sweet gourd-T. Aman, Maize + Potato-Sweet gourd-T. Aman and Maize + Coriander-Sweet gourd-T. Aman were evaluated along with the check Maize-Sweet gourd-T. Aman in RCB design with three replications. Recommended management practices were followed for rice and non rice crops. A simple economic analysis was done to evaluate the total productivity of these cropping patterns.

In Rabi season, similar maize yield in all treatments indicates little effect of intercrops on maize yield. Bushbean, spinach, potato, red amaranth and coriander yielded 5.27, 9.51, 17.38, 5.33 and 2.22 t/ha respectively when intercropped with maize. In Kharif I season, sweet gourd resulted similar yield in all cases. In T. Aman season, BRRI dhan56 gave similar grain yield ranged from 3.82 4.07 t/ha. The total productivity of intercropping system was compared in terms of maize equivalent yield (MEY), which differed significantly among the treatments. Significantly the highest MEY (32.94 t/ha) was obtained from CP_3 followed by CP_1. All the evaluated cropping patterns resulted significantly higher MEY (06-62%) compared to CP_6. It indicates the potential of maize intercropping system in terms of productivity.

Maize yield contributing characters viz plant height, cob/m^2, grain/cob and 100-grain weight were similar in all the treatments. It indicates that

Table 4. Yield performance for different cropping patterns in Meherpur 2014-15.

Cropping pattern	Yield (t/ha)				REY (t/ha)
	Mustard/maize	Mungbean/ potato/ spinach/ pumpkin*	T. Aus	T. Aman	
Mustard-Mungbean-Aus-Aman	1.39	1. 32	5.89	3.80	19.95
Mustard-S. gourd+Mug-T. Aus-T. Aman	1.25	1.31	5.51	3.62	19.06
Maize+Potato-T. Aus-T. Aman	9.82	10.25	6.49	3.49	22.95
Maize+Spinach-T. Aus-T. Aman	10.20	15.09	5.63	3.65	18.96
Maize-T. Aman	10.82	-	-	4.06	14.16
LSD $_{(0.05)}$	-	-	-	-	2.50
F for treatment					*
CV (%)	-	-	-	-	9.0

Mustard = 45 Tk/kg, Mungbean = 100 Tk/kg, Rice (Aus) = 8 Tk/kg, Rices (Aman)=15 Tk/kg, Potato= 10 Tk/kg, spinach = 7 Tk/kg, Maize = 14 Tk/kg, pumpkin= 5 Tk/kg Pumpkin could not be established due to high temperature.

there is no significant effect of maize intercrops on yield contributing characters of maize.

From the economic analysis, the highest gross margin was obtained from CP_3 (192000 Tk/ha) followed by CP_4. CP_1, CP_2 and CP_5 turned out 26, 5 and 14% higher gross margin than the check pattern CP_6.

From above discussion, it can be concluded that Maize+Lalshak-Sweet gourd-T. Aman and Maize+Bushbean-Sweet gourd-T. Aman cropping pattern are appropriate for resource poor farmer. Whereas Maize+Potato-Sweet gourd-T. Aman is a promising pattern for medium and large category farmer.

Validation of improved cropping patterns for greater Kushtia

Different ecosystems were selected by the joint effort of researcher and extension personnel in Chuadanga, Meherpur, Kushtia and Jhenaidah districts to increase the system productivity and income of the farmers through introduction of improved and intensified cropping systems. Seven farmers in each block were selected for the improved cropping system demonstration to show the technological advantage of the improved systems over the existing system. Recommended management practices were followed for rice and non rice crops. Existing cropping system data at farm level were collected from seven farmers in each ecosystem.

Improvement of cropping systems through inclusion of a promising Rabi crop in a double rice cropping system

In double rice cropping system farmers uses BRRI dhan28 in Boro season and Swarna in T. Aman season in Chuadanga. In the proposed cropping pattern Swarna has been replaced by short duration T. Aman varieties. BRRI dhan57 was imposed in Chuadanga sadar whereas BRRI dhan62 in Alamdanga. After harvesting of T. Aman a short duration mustard variety BARI sahrisha-14 was sown in the same land. In Boro season, BRRI dhan28 was replaced by newly released variety BRRI dhan63. In all blocks of Chuadanga proposed improved pattern resulted significantly higher REY compared to the farmers' practice. From the economic analysis, higher gross margin was obtained from proposed cropping system compared to the existing one in all blocks of Chuadanga. About 56% higher gross margin was resulted in Bhultia block of sadar upazila whereas that was 44% in Jahapur block of Alamdanga upazila.

In Kapostia block, Horinahkundu upazila Boro-Fallow-T. Aman is a dominant cropping pattern covering about 24% of the cultivable land. In the existing pattern farmers use local variety Ratna in Boro and a long duration variety BR11 in T. Aman season. In the proposed pattern Ratna was replaced by BRRI dhan28 and BR11 by a short duration variety BRRI dhan56. BARI sarisha-14 was relayed with T. Aman to use the residual soil moisture. REY of proposed cropping pattern was significantly higher compared to farmers' practice. Improved pattern was able to give 15% higher economic benefit over farmers' practice.

Three experimental sites were selected in Kushtia districts where Boro (BRRI dhan28/BRRI dhan29)-Fallow-T. Aman (BRRI dhan39/BR11/ Swarna) cropping pattern is pre-dominantly practiced. In the proposed pattern the system was intensified by adding a crop BARI sharisha-14 that was sown in the T. Aman field in relay method. Furthermore, the medium duration BRRI dhan39 was replaced by a short duration variety BRRI dhan57 in T. Aman season at Paikpara and Hizlakor blocks. On the other hand, long duration variety BR11/Swarna was substituted by BRRI dhan49 in Batikamara block. In all the three sites, calculated REY was significantly higher than that of farmers' practice. The gross margin was also higher by 43-79% over farmers' practice.

In the Mujibnagar Project area, majority of agricultural land belongs to light soil (sandy loam to clay loam) which is obviously suitable for successful production of tuber crops. In some specific area in Chuadanga district, a medium-duration Boro hybrid variety e.g., ACI-1 and a medium-duration T. Aman variety e.g., BRRI dhan39 are cultivated in a double-rice cropping pattern. In a trial BRRI dhan39 was replaced by a short-duration variety BRRI dhan57 and ACI-1 by newly released BRRI dhan63. In this context, potato can be efficiently accommodated in a long lean-period between two rice crops. In this trial Diamant variety of potato was used. Proposed improved pattern gave significantly higher REY over the existing practices (Table 5). About 131% higher gross margin of the improved cropping system indicates its higher profitability.

Table 5. Yield and economic performance of cropping pattern trial at Jahapur block, Nagdaha Union, Alamdanga, Chuadanga, 2014-15.

Cropping pattern	Yield (t/ha)			REY (t/ha)	TVC (000 Tk/ha)	GR (000 Tk/ha)	GM (000 Tk/ha)	% GM over FP (+/-)
	Potato	Boro	T. Aman					
Potato-Boro-T. Aman (IP)	20.35	5.97	3.91	24.15	252	453	201	(+) 131
Boro-Fallow-T. Aman (FP)	-	6.26	5.26	11.51	137	225	87	
CV (%)				6.7	-	-	-	-
F for treatment				**	-	-	-	-
LSD 0.05 for treatment				1.57	-	-	-	-

Price: Potato=12 Tk/kg, BRRI dhan28= 18, Tk/kg, BRRI dhan63= 21.25 Tk/kg, BRRI dhan39= 18 Tk/kg and BRRI dhan57= 21.25 Tk/kg.

In Meherpur district, potato was included in a double-rice cropping pattern where a long-duration Boro variety BRRI dhan29 and a medium-duration T. Aman variety BRRI dhan39 are cultivated in farmers' field. For better accommodation of potato long-duration Boro variety was replaced by medium duration BRRI dhan63 and the medium-duration T. Aman variety was replaced by short-duration BRRI dhan57. The potato variety Cardinal was used in this trial. Proposed improved pattern gave significantly higher REY compared to farmers' practices in all blocks of Meherpur. Economic analysis showed tremendous advantage of the proposed cropping system over famer's practice. About 327-393% higher gross margins were obtained from the improved system.

Improvement of cropping systems through the introduction of pulse crops

Maize is grown in rotation after the traditional monsoon Aman rice crop in Chuadanga. Almost all the maize is grown as a high-input (hybrid seed, large rates of fertilizer, irrigated) crop during the dry and cool winter Rabi season, where it is replacing mostly wheat, chili, mustard or vegetable or Boro rice in some areas. In Chuadanga, most of the winter Rabi season maize is planted after T. Aman rice harvest. Currently farmers cultivate T. Aman rice cultivars that/have a long development cycle (145-150 days, seed to seed). There are some shorter duration varieties with a slightly lower yield potential, but these rice varieties release the lands earlier that can be helpful to accommodate a pulse crop in between maize and rice. Obviously it will help to intensify the existing Maize-Fallow-T. Aman cropping system. On the other hand, early harvest will enable the Aman crop to avoid late season drought during maturity period. A field trial was conducted in Chuadanga including a modern variety of mungbean viz BARI mug-6 in between maize and monsoon rice. In this trial, a short duration variety of T. Aman rice viz BRRI dhan56 was introduced to remove the imported hybrid rice from the pattern. Significantly higher REY was obtained from the proposed cropping system compared to the existing one (Table 6). About 62% higher gross margin of the improved system clearly indicates the economic advantage over the farmer's practice.

Improvement of cropping systems through the introduction of sesame

Maize-Fallow-T. Aman is the dominant cropping system covering about 22% of the net cropped area in Alamdanga. Currently farmers cultivate T. Aman rice cultivars that/have a long development cycle (145-150 days, seed to seed). There are some shorter duration varieties with a slightly lower yield potential, but these rice varieties release the lands earlier that can be helpful to accommodate a crop in between maize and rice. Obviously it will help to intensify the existing Maize-Fallow-T. Aman cropping system. In this trial a modern variety of sesame viz BARI til-3 was introduced in between maize and T. Aman. In the proposed pattern T. Aman variety BRRI dhan39 was replaced by a short duration variety BRRI dhan62. Proposed cropping pattern gave significantly higher REY compared to farmer's practice (Table 7). However, proposed cropping system resulted 7% lower gross margin compared to farmer's practice. Lower yield and price of proposed T. Aman rice created this scenario.

Improvement of cropping systems through the introduction of water efficient crop

Water scarcity for agricultural use in Bangladesh is both season and region-specific. Water is most scarce in the southwestern and northwestern regions of the country during the dry season due to low annual rainfall. Rainfall characteristics

Table 6. Yield and economic performance of cropping pattern trial at Nurbaradi block, Chuadanga sadar 2014-15.

Cropping pattern	Yield (t/ha)			REY (t/ha)	TVC ('000 Tk/ha)	GR ('000 Tk/ha)	GM ('000 Tk/ha)	% GM over FP (+/-)
	Maize	Mungbean	T. Aman					
Maize-Mungbean-T.Aman (IP)	9.77	0.80	3.86	16.11	175	248	73	(+) 62
Maize-Fallow-T. Aman (FP)	8.05	-	4.75	12.80	152	197	45	
CV (%)				8.4	-	-	-	-
F for treatment				**	-	-	-	-
$LSD_{0.05}$ for treatment				1.59	-	-	-	-

Price: Maize=12 Tk/kg, mungbean=50 Tk/kg, ACI-1=17 Tk/kg, BRRI dhan56=17.50 Tk/kg.

Table 7. Yield and economic performance of cropping pattern trial at Nagdaha block, NagdahaUnion, Alamdanga, Chuadanga 2014-15.

Cropping pattern	Yield (t/ha)			REY (t/ha)	TVC ('000 Tk/ha)	GR ('000 Tk/ha)	GM ('000 Tk/ha)	% GM over FP (+/-)
	Maize	Sesame	T. Aman					
Maize-Sesame-T. Aman (IP)	9.58	1.08	3.78	14.56	202	243	40	(-) 7
Maize-Fallow- T. Aman (FP)	9.16	-	5.10	11.93	159	202	43	
CV (%)				7.4	-	-	-	-
F for treatment				**	-	-	-	-
$LSD_{0.05}$ for treatment				1.28	-	-	-	-

Price: Maize=12.13 Tk/kg, Sesame=55 Tk/kg, BRRI dhan39=17.50 Tk/kg, BRRI dhan62= 16.25 Tk/kg.

dominate the precipitation pattern of Bangladesh. The demand for both surface and groundwater for irrigation is on the rise in the dry winter season and amounts to 58.6 percent of the total demand for water. The principal crop during this season is Boro rice, which is entirely irrigated, mostly with groundwater. Groundwater based irrigation system has already reached to critical state in most of the part of the area. In the project area, majority of agricultural land belongs to light soil (sandy loam to clay loam), which obviously intensifies the artificial irrigation during Boro season. But this type of soil is suitable for successful production of roots and tuber crops. However, limited irrigation is required for tuber crops. With this point of view, an attempt was made to replace the Boro-Mukhikachu-Fallow cropping pattern with Potato-Mukhikachu-T. Aman.

In this trial Diamant variety of potato was used. After cultivation of local mukhikachu, a short duration T. Aman variety viz BRRI dhan62 was successfully grown in Kharif-II season. High productivity and less water requirement (29% lower than existing pattern) of the proposed cropping system compared to the existing pattern convinced the farmers of the locality. About 17% higher gross margins (Table 8) of the proposed cropping system obviously will exert a pull on the adoption of this water efficient profitable cropping system in this area.

Table 8. Yield and economic performance of cropping pattern trial at Satgari block, Chuadanga sadar, Chuadanga 2014-15.

Cropping pattern	Yield (t/ha)			REY (t/ha)	TVC ('000 Tk/ha)	GR ('000 Tk/ha)	GM ('000 Tk/ha)	% GM over FP (+/-)
	Potato /Boro	Kachu	T. Aman					
Potato- Mukhikachu-T. Aman (IP)	22.95	18.24	4.23	39.53	333	698	365	(+) 17
Boro- Mukhikachu-Fallow (FP)	5.95	21.75	-	30.81	234	547	313	
CV (%)				2.9	-	-	-	-
F for treatment				**	-	-	-	-
$LSD_{0.05}$ for treatment				5.17	-	-	-	-

Price: Potato=11.25 Tk/kg, BRRI dhan28=17.50 Tk/kg, Mukhikachu=20 Tk/kg and BRRI dhan56=16.25 Tk/kg.

Agricultural Economics Division

SUMMARY

BRRI dhan28 (36%) and BRRI dhan29 (28%) were the most popular rice varieties in Boro season covering 64% of total Boro area, and in T. Aman season, BRRI dhan49 (10%) and BR11 (9%) were the dominant varieties. In Aus season, area coverage of BRRI dhan28 was the highest (15%) followed by BRRI dhan48 (11%) and BR26 (7%). Among BRRI varieties, BRRI dhan29 was the top yielder in Boro (6.44 t/ha) season followed by BR16 (5.90 t/ha). In T. Aman season, BRRI dhan49 ranked the top position in terms of per unit yield (5.02 t/ha) followed by BR11 (4.91 t/ha). In Aus season, BRRI dhan48 produced higher yield (4.52 t/ha) followed by BRRI dhan28 (4.51 t/ha). Hybrids are being adopted as replacement of other MVs in Boro and Aus seasons due to higher yield performance. Farmers faced constraints like higher wage rates of labour and irrigation costs, non-availability of quality seeds and lower market price of their product. Rice farmers used more seed than the recommended dose irrespective of cropping season. Farmers applied mostly consistent amount of urea and TSP, but not splitting into three equal doses as per BRRI recommendation. They applied lower doses of MoP may be due to their ignorance. MV Boro growers obtained higher yield due to better cropping environment, good management practices and use of better genotypes. However, net return was higher in Aman season due to higher market price and lower per unit costs of production compared to that of Aus and Boro. Factor and income share revealed that the human labour contributed the highest effort to the production process; and, on the other hand, farmers earned the highest share of income from T. Aman followed by Boro seasons among all other production participants. There are opportunities in rice production but not risk and threat free. Although, adoption rate (38 %) of BRRI dhan29 was higher than hybrid (22%), average yield of hybrid (6.45 t/ha) was higher than BRRI dhan29 (5.78 t/ha) in haor region. The costs of production of hybrid rice (Tk 88154 t/ha) was 9% higher than BRRI dhan29 (Tk 80493 t/ha), while the gross return of BRRI dhan29 (Tk 82,975 t/ha) was 9% higher than the hybrid varieties (Tk 76,063 t/ha). The return to scale analysis indicated that the farmers had opportunities to increase margin by efficient use of inputs. The rice farmers had to pay about Tk 10 for getting per 100 taka loan from Bangladesh Krishi Bank (BKB) of which official cost was only 9% of the total costs. Farmers used 54% of borrowed money for Boro rice cultivation, 21% for family requirements and the rest 25% was used for other purposes. Cost of production as well as net return of Boro rice growers was higher for credit users than non-users. BCR on cash cost basis was higher for credit users (1.00) than non-users (0.94) indicating that credit borrowers were more benefited than non-borrowers. Tips and bribes involved in loan transaction and insufficient amount of loan were the main constraint as reported by 79% and 59% farmers, respectively. Majority of the farmers who participated in rice production training, were tenant and owner-cum tenant operator, who were not always ready to adopt modern technologies in farming system as owner operator. Nevertheless, participated farmers were significantly benefitted from adopting new technologies and production practices which ensured better yield than before training. Rice bran oil, which is extremely light, versatile, delicious and beneficial for human health getting popularity to the consumers. Total cost of rice bran oil production (including byproducts also) was Tk 176, 206/ton. After deducting the returns of byproducts from the total costs, cost of rice bran oil was Tk 87.02/kg. Value addition by miller, dealer and retailer of the supply chain of bran oil were 15, 10 and 11%, and gross margin obtained by them were 37, 29 and 34%, respectively. The key problems of RBO were unavailability of adequate rice bran and lack of promotional activities. Considering the importance of rice bran oil, government should provide incentives to the millers to increase the supply of bran oil which could save huge amount of foreign exchanges. Access to assets and social perceptions are the main force that shapes the women's participation in rice farming system. Although, women played some roles in operations of other crop cultivation; rice cultivation activities were dominated by male. A number of women had registered ownership for agricultural land. Ownership of other household resources was dominated by men; while the women had little access to those resources. Women in the hilly region participated in the farming activities

and enjoyed more flexibility about mobility than the women of non-hilly region, due to religious and social custom. However, despite the right, hilly women were not significantly empowered in decision making process than the women of the other regions of the country.

FARM LEVEL ADOPTION AND EVALUATION OF MODERN RICE CULTIVATION

BRRI Agricultural Economics Division has been carried out a nationwide survey to monitor the farm level adoption rate and yield performance of different modern and indigenous rice varieties in Aus, T. Aman and Boro seasons with the following objectives:

- Determine the region-wise adoption rate of different rice varieties in different seasons; and
- Estimate the yield of different modern and local rice varieties.

Multistage stratified random sampling technique was adopted in selecting the sample farmers. A total of 4,140 sample farmers under Aus (1,356), T. Aman (1,328), and Boro (1,456) seasons were selected and interviewed from ten (10) agricultural regions of Bangladesh.

Adoption of modern rice varieties

BRRI dhan28 and BRRI dhan29 were the dominant rice varieties in Boro season covering 64% of total Boro area during 2015-16 (Table 1), which is consistent with the national average (BBS, 2014). The overall adoption rate of modern varieties (MVs) in this season was about 96% of which total BRRI varieties' coverage was 72%. Among BRRI varieties, BRRI dhan28 and BRRI dhan29 were grown in almost all regions of Bangladesh.

The adoption rates of hybrid (16%) and Indian varieties (8%) in Boro season increased compared to last year, which were 11% and 6% respectively, indicating these two varieties getting popularity among the farmers. BRRI dhan49 (10%) and BR11 (9%) appeared as the prominent rice varieties covering about 19% areas in T. Aman season. The area coverage of BRRI varieties was about 47% in this season, which was 57% in last year indicating a decreasing trend. On the other hand, adoption rate of Indian variety was (23%), which was 19% during last year indicating Indian varieties getting popularity in this season (Table 2). However, overall adoption rate of modern varieties (MVs) in T. Aman season was about 76%. The adoption rate of modern rice varieties in Aus season was about 69% of which the coverage of BRRI developed varieties was about 59%. Among all BRRI varieties, BRRI dhan28 ranked the top position (15%) in terms of area coverage followed by BRRI dhan48 (11%) and BR26 (7%). In Aus season, coverage of other MVs, Indian and Hybrids were about 3, 1 and 5% respectively (Table 3). Results also revealed that, area coverage of traditional varieties was about 31% in this season.

Table 1. Adoption (%) of different Boro rice varieties by agricultural regions of Bangladesh, 2015-16.

Variety	Barisal	Chitta-gong	Comilla	Dhaka	Jessore				Rang-	Sylhet	Bangla-
BR3	0.17	0.12	1.36	0.20	-	-	0.03	0.34	-	0.25	0.17
BR14	0.18	1.07	0.38	1.33	-	1.31	0.01	-	0.56	0.97	0.63
BR16	0.42	5.38	3.98	0.05	-	0.37	0.66	3.82	2.58	0.05	1.19
BR26	0.12	1.08		0.07	0.90	4.21	0.08	0.21	0.01	0.43	0.83
BRRI dhan28	13.05	32.81	40.48	31.48	50.41	43.20	26.02	33.14	42.42	36.60	36.24
BRRI dhan29	35.48	14.01	39.37	58.62	1.68	33.83	19.48	11.22	21.31	35.31	28.32
BRRI dhan45	0.23	0.38	0.57	0.09	0.07	0.21	0.12	1.53	0.27	1.56	0.34
BRRI dhan47	5.28	1.17	0.31	0.05	0.21	0.04	-	0.58	-	0.04	0.44
BRRI dhan50	0.71	0.91	0.63	0.71	7.93	0.25	0.87	1.82	0.98	0.09	0.05
BRRI dhan58	0.23	0.56	2.84	0.65	0.25	0.65	1.24	0.04	1.19	-	-
BRRI dhan59	0.06	0.12	0.01	0.03	0.01	0.06	0.01	0.49	0.04	0.69	1.55
BRRI dhan62	0.18	0.07	0.04	0.02	0.21	0.05	0.09	0.18	0.03	-	-
BRRI dhan64	0.36	0.08	0.09	0.03	0.04	0.02	0.16	0.69	0.05	0.09	0.13
BRRI dhan69	-1	0.01	0.05	-	-	0.01	0.001	-	0.002	-	0.01
Other BR varieties	0.51	7.14	0.17	0.07	1.36	0.29	2.71	10.29	0.59	-	0.04
All BRRI varieties	56.99	64.90	90.28	93.39	63.05	84.50	51.50	64.01	70.03	78.92	72.25
Other MVs	4.73	4.81	0.59	0.06	1.47	0.53	1.18	0.70	0.11	0.1	1.1
All Indian varieties	-	-	-	0.01	10.10	-	34.23	-	3.66	-	7.72

Table 1. Continued.

Variety	Barisal	Chitta-gong	Comilla	Dhaka	Jessore	Mymen-singh	Ranga-mati	Rajs-hahi	Rang-pur	Sylhet	Bangla-desh
ACI	1.78	2.63	1.26	0.34	0.84	0.95	0.66	5.10	3.02	2.2	1.4
Hira	8.60	11.00	2.30	1.15	4.07	3.01	2.20	11.28	5.70	4.8	4.1
All hybrids	25.14	27.51	8.76	5.82	19.19	14.27	7.05	33.79	23.91	16.55	15.29
All MVs	86.86	97.22	99.63	99.27	93.81	99.30	93.96	98.50	97.71	95.59	96.31
All LVs	13.14	2.78	0.37	0.73	6.19	0.70	6.04	1.50	2.29	4.41	3.69
All varieties	100	100	100	100	100	100	100	100	100	100	100

Table 2. Adoption (%) of different T. Aman rice varieties by agricultural regions of Bangladesh, 2015-16.

Variety	Barisal	Chitta-gong	Comilla	Dhaka	Jessore	Mymen-singh	Raj-shahi	Ranga-mati	Rang-pur	Sylhet	Bangla-desh
BR10	0.14	1.37	0.47	0.43	4.46	0.25	0.02	4.69	-	1.91	1.00
BR11	7.41	8.69	3.84	14.17	4.10	9.52	3.78	25.29	10.82	22.76	8.78
BR22	4.64	8.57	38.85	0.92	1.19	3.65	0.23	3.60	-	7.33	4.11
BR23	4.91	6.11	5.46	0.08	7.80	0.28	0.01	0.25	0.03	1.45	2.80
BRRI dhan30	0.42	0.64	0.05	0.85	4.18	0.14	0.05	1.01	-	0.52	0.80
BRRI dhan32	1.21	3.59	8.25	0.76		9.91	1.19	2.45	0.08	7.26	2.78
BRRI dhan33	3.74	3.65	0.43	0.22	4.93	0.68	1.76	7.84	0.87	0.30	2.25
BRRI dhan34	0.14	0.01	0.63	0.73	0.05	1.63	5.04	0.31	5.06	1.16	2.03
BRRI dhan39	3.48	2.72	1.92	1.12	8.66	0.58	2.99	6.12	0.42	1.34	2.83
BRRI dhan40	3.58	7.36	1.33	1.68	0.14	1.70	0.22	4.47	0.12	0.97	1.83
BRRI dhan41	3.57	4.23	3.02	1.88	0.59	2.17	0.27	4.74	0.19	2.38	1.81
BRRI dhan44	2.82	1.50	1.38		0.06	-	-	0.85	-	1.53	0.77
BRRI dhan46	0.23	1.60	6.16	0.71	0.01	-	-	2.26	-	4.56	0.75
BRRI dhan49	1.42	7.21	11.78	31.95	6.94	22.47	12.64	15.25	3.72	11.86	9.74
BRRI dhan51	1.09	0.94	1.18	1.73	1.26	-	2.21	0.79	2.48	1.72	1.45
BRRI dhan52	3.12	2.19	1.80	1.26	1.79	-	1.31	0.27	4.11	2.95	2.23
BRRI dhan56	0.02	0.09	0.23	0.13	0.17	-	0.30	0.59	0.39	0.02	0.17
BRRI dhan57	0.04	-	0.28	0.03	0.31	-	0.16	0.09	0.17	0.04	0.12
BRRI dhan62	0.17	0.06	0.13	0.15	1.06	-	0.79	0.03	0.11	0.01	0.32
Other BRRI varieties	0.80	0.59	1.57	1.65	0.31	-	0.40	4.02	0.08	1.14	0.53
All BRRI varieties	42.95	61.13	88.74	60.45	48.00	52.99	33.38	84.90	28.64	71.19	47.09
Other MVs	3.19	0.98	1.35	4.67	8.66	5.44	8.45	1.13	3.99	2.11	4.78
All hybrid varieties	0.17	0.46	0.06	0.03	1.68	1.48	0.88	0.91	4.79	-	1.53
All Indian varieties	0.42	1.57	-	4.98	25.34	8.43	48.00	-	57.07	3.95	22.77
All MVs	46.74	64.14	90.15	70.13	83.68	68.33	90.71	86.94	94.48	77.25	76.17
All LVs	53.26	35.86	9.85	29.87	16.32	31.67	9.29	13.06	5.52	22.75	23.83
All varieties	100	100	100	100	100	100	100	100	100	100	100

Table 3. Adoption (%) of different Aus rice varieties by agricultural regions of Bangladesh, 2015.

Variety	Barisal	Chitta-gong	Comilla	Dhaka	Jessore	Mymen-singh	Raj-shahi	Ranga-mati	Rang-pur	Sylhet	Bangla-desh
BR1	1.00	7.07	-	0.30	-	1.42	0.07	1.36	-	8.02	2.25
BR2	7.31	-	5.26	5.00	1.17	3.07	-	0.17	-	0.24	2.32
BR3	2.02	1.85	0.42	0.10	0.04	1.48	0.27	1.26		10.04	2.19
BR14	2.17	3.49	0.54	0.10	0.56	4.97	0.10	-	1.26	4.10	1.85
BR20	2.19	3.48	12.67	0.81	-	2.26	-	0.33	-		2.04
BR21	1.17	4.39	0.01	0.20	0.77	1.15	13.28	1.24		4.62	4.27
BR26	3.86	4.82	5.67	12.41	14.25	18.90	4.19	2.09	1.42	9.23	6.99
BRRI dhan27	11.37	8.58	3.21	0.22	0.48	6.11	1.60	0.88	-	1.54	4.55
BRRI dhan28	0.56	8.11	34.34	12.88	13.68	20.26	15.71	2.13	53.04	19.19	14.74
BRRI dhan42	2.31	3.57	0.66	0.04	0.41	0.22	0.14	1.14	-	2.40	1.40
BRRI dhan43	3.43	6.04	1.85	2.54	0.13	0.88	0.36	1.56	-	5.18	2.46
BRRI dhan48	5.46	4.81	15.94	17.39	11.96	5.25	8.59	1.92	8.90	27.51	10.87
Other BRRI varieties	1.89	5.59	3.92	17.44	2.74	10.80	2.94	5.18	4.54	2.03	3.56
BRRI all varieties	44.74	61.80	84.49	69.43	46.19	76.77	47.25	19.26	69.16	94.10	59.49
Other HYV	7.77	0.35	8.91		3.52	0.29	1.56	-	1.69	0.93	3.40
All Indian varieties	0.08	-	-	-	7.92	-	0.24	-	1.44	-	1.21
ACI	0.01	1.06	0.80		3.15	-	0.36	0.13	4.17	-	0.87
Hira	0.02	0.88	1.73		0.54	0.04	0.66	0.96	4.54	0.02	0.65
All hybrid varieties	-	4.25	4.82	-	16.19	0.18	4.25	3.75	16.80	0.09	4.90
All MVs	52.63	66.41	98.20	69.43	73.82	77.24	53.31	23.04	89.09	95.14	68.98
All LVs	46.67	33.60	1.80	30.57	26.19	22.77	46.69	76.96	10.91	4.86	31.02
All varieties	100	100	100	100	100	100	100	100	100	100	100

Yield of modern rice varieties

Average yield of BRRI varieties was 5.68 t/ha in the Boro season of which BRRI dhan29 was the top yielder (6.44 t/ha) followed by BR16 (5.90 t/ha), BRRI dhan59 (5.89 t/ha) and BRRI dhan28 (5.79 t/ha). Average yield of hybrid rice varieties was 6.89 t/ha in Boro season (Table 4).

Among BRRI varieties, BRRI dhan49 was the top yielder (5.02 t/ha), followed by BRRI dhan51 (4.89 t/ha) in T. Aman season whereas average yield of BRRI varieties was 4.69 t/ha in T Aman season. Overall yield rate of modern varieties (MVs) was 4.76 t/ha (Table 5). In Aus season, BRRI dhan48 produced the highest yield (4.52 t/ha) and BRRI dhan28 and, BRRI dhan42 ranked the second and third position with an average yield of 4.51 t/ha, and 4.49 t/ha, respectively. The yield rate of hybrid rice was also higher (5.60 t/ha) in this season (Table 6).

Table 4. Yield (t/ha) of different Boro rice varieties by agricultural regions of Bangladesh, 2015-16.

Variety	Barisal	Chitta-gong	Comilla	Dhaka	Jessore	Mymen-singh	Ranga-mati	Raj-shahi	Rang-pur	Sylhet	Bangla-desh
BR3	5.13	5.37	5.78	5.76	-	-	6.46	5.94	-	5.50	5.71
BR14	5.87	5.55	5.85	5.84	-	5.59	6.40	-	5.62	5.59	5.79
BR16	5.75	5.64	5.72	6.17		5.32	6.85	5.12	6.84	5.69	5.90
BR26	6.28	5.72		5.94	5.77	5.66	6.19	5.27	5.56	5.24	5.74
BRRI dhan28	5.98	5.67	5.66	6.11	5.99	5.64	6.22	5.52	5.87	5.27	5.79
BRRI dhan29	6.66	6.12	6.18	6.81	6.64	6.48	7.18	5.83	6.88	5.56	6.44
BRRI dhan45	6.39	5.60	5.49	5.82	5.76	5.56	5.85	6.30	5.50	5.27	5.75
BRRI dhan47	5.89	5.67	5.56	5.84	5.35	5.56	5.90	5.00	-	5.56	5.59
BRRI dhan50	6.30	5.69	5.39	5.94	6.57	5.26	5.88	5.21	5.36	5.33	5.69
BRRI dhan58	6.17	5.73	5.94	4.19	6.14	6.40	6.42	5.49	6.56	5.73	5.88
BRRI dhan59	6.25	5.80	5.54	5.23	6.15	5.99	5.73	5.54	6.93	5.78	5.89
BRRI dhan62	5.94	5.56	5.52	4.97	5.66	4.67	6.13	5.59	5.15	5.40	5.26
BRRI dhan64	6.21	5.59	5.39	4.62	5.22	5.69	6.24	5.54	5.67	4.74	5.29
BRRI dhan69	5.27	5.22	5.69	-	-	5.67	5.27	-	5.13		5.37
Other BRRI varieties	5.38	5.22	5.08	5.63	5.30	5.38	5.55	5.08	5.34	4.90	5.29
All BRRI varieties	5.90	5.52	5.64	5.47	5.92	5.66	6.05	5.50	5.79	5.34	5.68
Other MVs	5.88	5.55	5.54	5.69	6.38	5.72	5.90	5.49	5.64	5.11	5.69
ACI	7.17	7.24	6.79	6.38	7.25	6.93	7.20	6.66	7.12	6.38	6.91
Hira	7.20	6.92	7.20	7.52	6.87	7.44	7.28	6.66	6.90	6.45	7.04
Aftab	7.38	6.69	6.82	7.60	7.38	7.30	7.53		6.92	6.11	7.08
Other hybrid varieties	7.19	6.65	6.90	7.31	6.91	6.96	7.26	6.50	6.83	6.22	6.87
All hybrid varieties	7.19	6.68	6.91	7.29	6.93	7.01	7.28	6.51	6.85	6.22	6.89
Miniket	-	-	-	-	5.62	-	5.92	-	5.22	-	5.58
Ratna	-		-	-	5.14	-	5.40	-	5.27	-	5.27
Zira sail	-	-	-	5.68		-	5.92	-		-	5.80
All Indian varieties	-	-	-	5.68	5.03	-	6.01	-	5.33	-	5.51
All MVs	6.33	5.92	6.03	6.03	6.07	6.13	6.31	5.83	5.90	5.56	6.01
All LVs	3.98	5.12	3.37	3.50	5.81	3.60	5.49	4.72	5.39	3.23	4.42
All varieties	5.15	5.52	4.70	4.77	5.94	4.86	5.90	5.28	5.65	4.39	5.22

Table 5. Yield (t/ha) of different Aman rice varieties by agricultural regions of Bangladesh, 2015-16.

Variety	Barisal	Chittagong	Comilla	Dhaka	Jessore	Mymen-singh	Raj-shahi	Ranga-mati	Rang-pur	Sylhet	Av.
BR10	4.76	4.85	4.41	4.52	5.14	4.62	5.19	4.82	3.84	4.70	4.69
BR11	4.90	4.82	4.99	4.62	5.15	4.77	5.41	4.99	4.59	4.90	4.91
BR22	4.13	4.58	4.66	4.48	5.09	4.49	4.64	4.60	4.35	4.59	4.56
BR23	4.77	4.76	4.65	4.80	4.84	4.36	5.40	3.84	4.45	4.66	4.65
BRRI dhan30	4.61	4.83	4.58	4.55	5.13	4.40	5.10	4.61	-	4.77	4.73

Table 5. Continued.

Variety	Barisal	Chittagong	Comilla	Dhaka	Jessore	Mymen-singh	Raj-shahi	Ranga-mati	Rang-pur	Sylhet	Av.
BRRI dhan32	3.62	4.55	4.77	4.33	-	4.78	5.11	4.46	4.53	4.54	4.52
BRRI dhan33	4.53	4.56	4.23	4.71	4.93	4.25	5.22	4.58	4.39	4.57	4.60
BRRI dhan34	4.11	5.18	4.26	4.45	4.03	3.78	3.98	4.32	3.93	4.14	4.22
BRRI dhan39	4.78	4.86	4.40	4.44	4.72	4.45	5.30	4.49	4.51	4.67	4.66
BRRI dhan40	4.88	4.80	4.77	4.62	4.92	4.67	5.01	4.57	4.67	4.76	4.77
BRRI dhan41	4.82	4.76	4.86	4.52	4.94	4.72	4.67	4.65	4.67	4.74	4.74
BRRI dhan44	5.31	4.99	4.56	-	5.30	-	-	4.93	4.68	5.01	4.97
BRRI dhan46	4.54	5.00	4.83	4.64	4.68	-	-	4.74	-	4.74	4.74
BRRI dhan49	5.13	4.71	5.02	4.78	5.23	5.02	5.51	4.96	4.84	5.03	5.02
BRRI dhan51	4.97	4.80	4.54	4.47	5.15	-	5.55	4.88	4.82	4.87	4.89
BRRI dhan52	5.13	4.93	4.56	4.62	5.1	-	5.57	5.18	4.74	4.92	4.97
BRRI dhan56	4.29	4.07	4.56	4.24	5.17	-	5.27	4.77	4.57	4.60	4.62
BRRI dhan57	4.59	-	4.43	4.18	4.70	-	5.35	4.82	4.83	4.73	4.70
BRRI dhan62	4.74	4.32	4.22	3.82	4.80	-	4.98	4.72	4.20	4.43	4.47
Other BRRI varieties	4.84	4.68	4.58	4.73	4.94	4.78	5.18	4.76	4.58	4.83	4.79
All BRRI varieties	4.70	4.71	4.58	4.51	4.91	4.53	5.12	4.65	4.49	4.69	4.69
BINA dhan11	5.12	4.87	4.08	4.59	4.66	-	5.08		4.08	4.59	4.63
BINA dhan7	4.90	4.50	4.64	4.56	5.07	4.48	5.31	4.42	4.44	4.69	4.70
All other MVs	4.82	4.70	4.29	4.15	5.20	4.50	5.14	4.36	-	4.69	4.65
All Hybrid varieties	5.96	6.11	6.57	6.30	6.28	5.63	6.26	7.12	5.41	5.86	6.15
Ranjit	-		-	3.95	4.74	3.67	5.55	-	4.89	4.72	4.59
Swarna	3.82	-	-	4.24	5.11	4.84	5.71	-	5.00	4.69	4.77
Other Indian varieties	-	4.74	-	2.78	4.98	3.81	5.50	-	4.75	4.78	4.47
All Indian varieties	3.82	4.74	-	3.66	4.97	3.91	5.53	-	4.77	4.80	4.52
All MVs	4.89	5.93	4.83	4.63	5.18	3.84	5.41	4.11	3.87	4.89	4.76
All LVs	2.89	2.70	2.81	2.73	2.94	2.85	3.36	3.09	3.20	2.93	2.95
All varieties	3.89	4.31	3.82	3.68	4.06	3.34	4.38	3.60	3.53	3.91	3.85

Table 6. Yield (t/ha) of different Aus rice varieties by agricultural regions of Bangladesh, 2015-16.

Variety	Barisal	Chitta-gong	Comilla	Dhaka	Jessore	Mymen-singh	Rajshahi	Rangamati	Rang-pur	Sylhet	Bangladesh
BR1	3.01	3.88	-	3.87	-	4.00	3.77	4.09	-	4.29	3.84
BR2	4.42	-	4.06	4.09	4.01	4.30	3.67	4.01	-	4.16	4.09
BR3	3.72	4.02	4.20	4.09	4.01	4.34	4.83	4.18	-	4.39	4.20
BR14	3.97	4.00	4.19	4.21	3.87	4.48	4.18	-	4.55	4.48	4.21
BR20	4.16	3.68	4.21	4.34	-	4.28	-	3.92	-	-	4.10
BR21	3.32	3.81	4.01	3.51	5.64	4.21	4.32	5.12	-	4.16	4.23
BR26	4.04	3.93	4.20	4.37	4.46	4.34	4.13	4.24	4.31	4.34	4.24
BRRI dhan27	4.00	4.43	4.36	4.25	4.21	4.47	4.00	4.01	-	4.15	4.21
BRRI dhan28	3.94	4.19	4.35	4.36	4.55	4.55	4.43	5.46	4.97	4.31	4.51
BRRI dhan42	5.30	4.29	4.30	5.85	4.58	3.56	4.07	4.25	-	4.18	4.49
BRRI dhan43	2.81	4.24	4.44	4.37	4.24	3.79	4.34	4.08	-	4.03	4.04
BRRI dhan48	3.95	4.59	4.55	4.59	4.77	4.46	4.74	4.34	4.52	4.72	4.52
Other BRRI varieties	3.86	3.95	4.28	4.06	4.49	4.10	3.99	4.24	3.89	4.03	4.09
All BRRI varieties	3.90	4.01	4.26	4.24	4.49	4.17	4.17	4.40	4.30	4.21	4.21
BINA dhan7	-	-	-	-	4.45	-	4.18	-	4.68		4.44
IR50	-	3.67	4.00	-	4.39	-	4.17	-	-	4.15	4.08
Nerika	3.66	4.27	3.87	-	3.98	-	4.28	-	4.40	4.20	4.09
Other MVS	3.25	4.16	4.27	-	4.04	4.38	4.08	-	-	-	4.03
All other MVs	3.46	4.03	4.05	-	4.21	4.38	4.18	-	4.54	4.18	4.13
ACI	4.94	5.51	4.94	-	5.82	-	5.82	5.34	6.12	-	5.50
Hira	6.13	5.82	5.22	-	5.51	5.17	5.66	6.41	6.27	5.06	5.69
All hybrid varieties	5.43	6.43	4.94	-	6.06	4.77	5.50	6.01	6.10	5.13	5.60
All Indian varieties	4.46	-	-	-	4.72	-	3.90	-	5.43		4.63
All MVs	4.31	4.82	4.41	4.24	4.87	4.44	4.44	5.20	5.09	4.51	4.63
All LVs	2.29	2.22	2.63	1.88	3.08	2.69	2.88	2.35	3.31	2.95	2.63
All varieties	3.30	3.52	3.52	3.06	3.98	3.56	3.66	3.78	4.20	3.73	3.63

IMPACT OF SEASONAL AGRICULTURAL CREDIT ON MV BORO RICE CULTIVATION IN MYMENSINGH DISTRICT

Three main factors that contribute to agricultural growth are increased use of agricultural inputs, technological change and technical efficiency (Baduri, 1973). With savings being negligible among the small farmers, agricultural credit appears to be an essential input along with modern technology for higher productivity. Present government has given much emphasis to supply agricultural credit to the farmers for enhancing and sustaining food self-sufficiency in the country. Farmers, particularly in Mymensingh take institutional credit for MV Boro rice cultivation. It is assumed that the credit taken for agricultural purposes, i.e., MV rice cultivation is not solely used for that purposes. On the other hand, there is an unwanted cost for obtaining agricultural credit. Therefore, it is necessary to know how the credit is obtained and used, and what the impact of credit in MV Boro cultivation is. The specific objectives of the study were as follows:

- Assess the costs of getting agricultural credit and its utilization pattern;
- Measure the relative profitability of Boro rice cultivation for credit users and non-users in the study area; and
- Find out the constraints of getting credit by the farmers.

The study was conducted in Fulbaria Upazilla of Mymensingh District during 2016. At first a detailed list of 90 credit borrowing farmers were collected from Bangladesh Krishi Bank (BKB) and another 90 non-borrowers were selected from the same area with the help of DAE. Then, 30 listed credit borrowers and 30 non-borrowing famers were interviewed with a set of pre designed semi structured questionnaire. Data were collected for the Boro season of 2015-16. Collected data were summarized, tabulated and analyzed in accordance with the objectives.

Cost of credit

Table 7 shows the cost of per Tk 100 loan taken by the farmers in the study area. Overall costs for per Tk 100 was estimated to be at Tk 10.23. Six major cost items were found where the share of official cost i.e. application fee was too little (9%) than unofficial costs (91%). The major unofficial cost item was entertainment (58%), followed by transportation (10) and food (10%). Farmers have to pay a remarkable amount to meet up undue demand of brokers (*dalal*) and sometimes for unscrupulous bank officials, which was entitled under entertainment costs.

Table 7. Costs of getting credit in the study area.

Item	Cost per 100 Tk
Application fee	0.89 (8.70)
Transportation cost	1.05 (10.26)
Expense for food	0.90 (8.80)
Personal cost	0.58 (5.67)
Opportunity cost of getting loan (man/days spent)	0.89 (8.70)
Entertainment cost (Undue privilege)	5.92 (57.87)
Total	10.23 (100.00)

Note: Figure in parenthesis indicates percentages of total.

Credit utilization pattern

Table 8 showed that the farmers received loan Tk 22,550, on average of which about 54% were used for rice production, 21% for family expenditures and the rest 25% were used for different activities other than rice cultivation; like repayment of old loan, investment in other petty business, etc.

Profitability

Table 9 shows per hectare return of credit users and non-users for Boro rice cultivation. Per hectare yield of credit users (5.89 t/ha) was slightly higher than that of non-credit users (5.59 t/ha) may due to better management practices (timely planting, weeding and application of fertilizer by credit users). Per hectare gross return of credit users (Tk 10,5724/ha) was higher than non-credit users (Tk 96,984/ha) as credit user harvested higher yield and higher price of their product for not selling the marketable surplus immediately after harvesting.

Table 8. Credit utilization pattern of the sample farmers in the study villages.

Activity	Amount (Tk)	% of total
Purchase of seed /Seedling	446.49	1.98
Purchase of fertilizer	1431.92	6.35
Paying wage	3405.06	15.10
Land mortgaged in	3120.92	13.84
Power tiller	1585.26	7.03
Buying insecticides	99.22	0.44
Purchase of manure	146.58	0.65
Paying Irrigation charge	1997.93	8.86
i) Rice production	12,233.38	54.25
ii) Family expenditure	4656.57	20.65
iii) Others (Repayment of old loan, investment etc.)	5660.05	25.10
Total	22,550	100

Note: Figure in parenthesis indicates percentages of total.

Table 9. Profitability analysis of MV Boro rice cultivation of credit user and credit non-user.

Item	Credit user	Credit non-user
Yield (kg/ha)	5,880	5,585
Paddy price (Tk/kg)	15.80	15.05
Return from paddy (Tk/ha)	92,904	84,054
Return from straw (Tk/ha)	12,820	12,930
Gross return (Tk/ha)	1,05724	96,984
Variable cost (Tk/ha)	86,323	81,414
Total cost (Tk/ha)	1,04758	1,03108
Gross margin (Tk/ha)	19,401	15,570
Net return (Tk/ha)	966	-6,124
Unit cost of production (Tk/kg)	17.98	17.36
BCR on cash cost basis	1.22	1.19
BCR on full cost basis	1.00	0.94

Constraints

Undue demand of unscrupulous bank officials and influence of local broker on credit sanction were the major constraints reported by 93% and 90% of total respondents, respectively. Farmers reported that lengthy process of sanctioning credit not only the barrier for applying inputs of the crop on time but also they lost interest to receive BKB credit next time. The borrowers said that allocation of BKB credit for each farmer was insufficient to meet up cost of input intensive crop like Boro rice. It also noted that small and marginal farmer got less priority to allocate BKB credit.

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 production process. The viability of the technology mostly depends on its cost and return. Therefore, it is indispensible to know the cost and return of the technology which are practiced by the farmers. 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:

- Determine the level of inputs used in MV Aus, MV T. Aman and MV Boro rice cultivation;
- Estimate the cost of MV rice cultivation in different seasons; and
- Evaluate the profitability of MV Aus, MV T. Aman and MV Boro rice cultivation at the farm level.

Multistage stratified random sampling technique was adopted to select farmers from all agricultural regions of Bangladesh. The study used a sample survey of 60 of each Aus, T. Aman and Boro rice growing farmers. Data were collected through direct interviewing with questionnaire.

Level of inputs used

Majority of the rice farming activities such transplanting, harvesting, carrying and threshing were done on contractual basis. The highest number of human labour (103 man-days/ha) was used for MV Boro followed by MV Aus rice (96 man-days/ha) and MV T. Aman (91 man-days/ha, (Table 13). The seed rates for MV Aus, MV T. Aman and MV Boro rice were 46, 47 and 44 kg/ha, indicating farmer used higher amount of seed than BRRI recommended rate (25 to 30 kg/ha). Farmers were found to apply comparatively lower amount of MoP fertilizer in rice cultivation (Table 10).

Cultivation costs

Per hectare human labour costs were Tk 39,959, Tk 39,821 and Tk 47,323 for MV Aus, MV T. Aman and MV Boro rice cultivation respectively (Table 11). Fertilizer cost of Boro (Tk 11,551/ha) and T. Aman (Tk 8,216/ha) was higher than the cost of Aus (Tk 6,796/ha) rice cultivation. Irrigation cost was much higher (Tk 16,465/ha) for MV Boro rice cultivation than that of MV Aus (Tk 3,368/ha) and MV T. Aman (Tk 3,143/ha).

Profitability

The yield received by the rice farmers from Aus, T. Aman and Boro crops were 4,248, 4,604 and 5,627 kg/ha respectively. However, the MV Boro growers received higher gross return (Tk 94,949 /ha) than MV T. Aman (Tk 81,375/ha) and MV Aus (Tk 64,637/ha) season due to higher yield (Table 12).

Table 10. Per hectare Input used for MV rice cultivation in different season of Bangladesh, 2015-16.

Human labour (man-day/ha):	96	91	103
Hired	42	38	48
Family	54	53	55
Seed (kg/ha)	46	47	44
Fertilizer (kg/ha):			
Urea	164	184	255
TSP	47	73	112
MP	54	54	73
DAP	10	15	10
Gypsum	19	18	56
$ZnSO_4$	-	2	6

Table 11. Per hectare cost of MV rice cultivation in different season of Bangladesh, 2015-16.

Input item	Season		
	Aus	Aman	Boro
Seedling development (Tk/ha)	1,950	2,370	2,370
Seed (Tk/ha)	1,610	2,350	1,980
Human labour	39,959	39,821	47,323
Family labour	12,600	11,400	15,120
Hired labour	16,200	15,900	17,325
Contract	11,159	12,521	14,878
Tillage (Tk/ha)	6,750	5,760	8,645
Fertilizer (Tk/ha)	6,796	8,216	11,551
Urea	2,624	2,944	4,080
TSP	1,034	1,606	2,464
MP	810	810	1,095
DAP	280	420	280
Gypsum	228	216	672
$ZnSO_4$	0	300	900
Cowdung (Tk/ha)	1,820	1,920	2,060
Irrigation (Tk/ha)	3,368	3,143	16,465
Herbicide (Tk/ha)	449	599	1,123
Insecticide (Tk/ha)	898	1,871	1,871
Variable cost (Tk/ha)	61,780	64,130	91,328
Interest on operating capital @10 for five months	1,030	1,069	1,522
Land rent (Tk/ha)	15,215	16,890	20,110
Total cost (Tk/ha)	78,024	82,089	112,960

Table 12. Comparative costs and return of MV rice cultivation in different seasons of Bangladesh, 2015-16.

Item	Season		
	Aus	Aman	Boro
Yield (kg/ha)	4,248	4,604	5,627
Paddy price (Tk/kg)	14.50	17.00	15.50
Return from paddy (Tk/ha)	61,596	78,268	87,219
Return from Straw (Tk/ha)	4,103	10,632	7,730
Gross return (Tk/ha)	65,699	88,900	94,949
Variable cost (Tk/ha)	61,780	64,130	91,328
Total cost (Tk/ha)	78,024	82,089	112,960
Gross margin (Tk/ha)	3,919	24,770	3,621
Net return (Tk/ha)	-12,325	6,811	-18,011
Unit cost of production (Tk/kg)	18.37	17.83	20.07
BCR on cash cost basis	1.06	1.39	1.04
BCR on full cost basis	0.84	1.08	0.84

AN ECONOMIC INVESTIGATION OF BRRI DHAN29 AND HYBRID RICE PRODUCTION: THE CASE OF *HAOR* AREAS

Rice cultural practices of *haor* farmer are different from those of the other parts of the country. A few studies were conducted with regards to delineating the issues of crop production practices in the region. With this view, the present study was undertaken to address the following objectives:

- Determine the comparative profitability of BRRI dhan29 and hybrid rice varieties; and
- Estimate the resource use efficiency and return to scale of the growers.

A total of 60 sample farmers were randomly selected from Sunamganj and Habiganj Distrcits. Mainly descriptive statistics were used to process the data. Cob-Douglas production function was used to estimate the effects of various inputs and to test the efficiency, the ratio of marginal value product (MVP) to the marginal factor cost (MFC) for each input is computed and tested for its equality to 1.

Profitability of BRRI dhan29 and hybrids rice varieties in the *haor* areas

Table 13 shows per hectare costs and return of hybrid and BRRI dhan29 in *haor* areas. Per hectare variable cost of hybrid was about 12% higher than

BRRI dhan29 which indicates that hybrid was more inputs (e.g., human labour, irrigation and fertilizers) intensive than BRRI dhan29. Per hectare yield of BRRI dhan29 (5,780 kg/ha) was about 12% lower than hybrid (6,450 kg/ha). Despite producing lower yield, BRRI dhan29 produce about 8% and 73% higher gross return and gross margin, respectively due to higher paddy price and lower variable cost.

Resource use efficiency and return to scale

Returns to scale analysis revealed that the values of MVPs of BRRI dhan29 for fertilizer, insecticide and irrigation were greater than unity and positive (2.836, 1.389 and 1.507, respectively), indicating that farmers had opportunities to increase per unit yield using more of those inputs. Marginal value product of fertilizer (2.030) and irrigation (1.495) also indicates that there was still scope to increase profit of hybrid rice through efficient use of those inputs (Table 14).

MVPs of human labour (0.729) and seedling cost (0.869) of BRRI dhan29 was positive and less than unity. The results indicate that increasing the use of those inputs may reduce the return of BRRI dhan29. On the other hand, MVPs of human labour (0.495), seedling (0.230) and insecticides (0.605) of hybrid rice were positive but less than one which indicates that farmers should limit the use of these inputs.

Table 13. Costs and return of MVs and hybrid rice in the haor areas, 2015-16.

Costs and return (Tk/ha)	BRRI dhan29	Hybrid
Seeds/seedlings	3475	4165
Labour cost	40160	42760
Land preparation cost	5600	5600
Fertilizer	4425	5637
Irrigation	8027	9262
Herbicide	352	352
Insecticide	1257	3021
Variable cost	63,296	70,797
Interest on operating capital @10 for five months	1319	1,479
Land rent (Tk/ha)	15,878	15,878
Total cost basis (Tk/ha)	80,493	88,154
Yield (kg/ha)	5,780	6,450
Gross return (Tk/ha)	82,975	76,063
Gross margin (Tk/ha)	19,680	5,266
Net return (Tk/ha)	2,483	-12,092
BCR on cash cost basis	1.31	1.07
BCR on full cost basis	1.03	0.86

Table 14. MVPs of inputs in production function.

Inputs	Geometric mean	Co-efficient	MVP
BRRI dhan29:			
Gross Return(Y)	82720.77		
Human labour cost(X1)	40151.88	0.354	0.729
Seedling cost (X2)	3438.52	0.036	0.869
Fertilizer cost (X3)	4393.95	0.151	2.836
Insecticides cost (X4)	1186.66	0.020	1.389
Irrigation cost (X5)	7999.82	0.146	1.507
Hybrid:			
Gross Return(Y)	76052.17		
Human labour cost(X1)	42703.92	0.278	0.495
Seedling cost (X2)	4124.05	0.013	0.230
Fertilizer cost (X3)	5516.86	0.147	2.030
Insecticides cost (X4)	3001.39	0.024	0.605
Irrigation cost (X5)	9191.88	0.181	1.495

Elasticity of production

The elasticity of BRRI dhan29 and hybrid producers were less than one, which clearly point out that the growers allotted their resources in the rational zone of the stage of production (Stage-II) where diminishing returns to scale exists (Table 15). The return to scale analysis indicated that the farmers had opportunities to increase margin by efficient use of inputs.

Table 15. Elasticity of BRRI dhan29 and hybrid rice production.

Inputs	Elasticity	
	BRRI dhan29	Hybrid
Human labour cost (X1)	0.354	0.278
Seedling cost (X2)	0.036	0.013
Fertilizer cost (X3)	0.151	0.147
Insecticides cost (X4)	0.020	0.024
Irrigation cost (X5)	0.146	0.181
Returns to scale	0.707	0.643

Impact assessment of farmers training on rice production

Adaptive Research Division of BRRI has been conducting rice production training program to create awareness and inspire farmers about latest modern rice production technology. It is important to evaluate the ultimate achievement of the participants of the training program in respect of awareness building, new knowledge gather and production of rice. So, the present study was undertaken with the following objectives**:**

- Identify the socio-economic profile of farmers received rice production training and
- Determine the effectiveness of training on rice production at farm level

A total 60 participated farmers, 30 from each of Chittagong and Sylhet Distrcit were selected at random. Information on rice related items were collected through face to face survey method. Collected data were analyzed following before and after method to know the change that occurred due to training.

Effectiveness of training on rice production

Effectiveness of training depends on various relevant factors. From socioeconomic status of the studied farmers, it is revealed that a good number of farmers are illiterate and had no cultivable owned land, so, it is difficult to convince them to adopt new ideas. Besides, majority of the farmers who were included in this study received several rice production trainings from other organizations. Farmers had also rice production knowledge from demonstration trails. So, it is difficult to delineate the separate effect of BRRI training program.

Before participation in rice production training, farmers of both the locations used to apply more amounts of seeds than the required rates in both Boro and T. Aman seasons (Table 16). After training they were able to save more than 20% seeds in Boro and 13% seeds in T. Aman seasons in Chittagong and Sylhet sites, respectively compared to before training. Regarding the fertilizer dose, before training farmers had no ideas about balance dose of fertilizer but after training although; they did not show due interest to use actual doses of fertilizers (Table 16), but applied more amount of different fertilizers than before.

It also revealed that before participation in training course, farmers did not apply TSP and MoP fertilizer in their plots in T. Aman season but after training, they started to apply these two types of fertilizers. After training, farmers in both the locations used a bit younger seedlings than before. Line sowing and parching using scenario were not satisfactory though herbicide use in Boro season was prevailed. In Boro season, some areas were weeded using rice weeder where line sowing is practiced.

There was a notable positive change in the expansion of HYV rice areas during T. Aman season in both the locations (Table 17) but area under modern Boro was almost stagnant. Adoption of BRRI dhan49 increased substantially, although; area under LV decreased in T. Aman season at a remarkable rate but yield increased. Yield also increased in both T. Aman and Boro seasons all over the study areas after training.

VALUE CHAIN ANALYSIS OF RICE BRAN OIL IN BANGLADESH: AN ECONOMIC INVESTIGATION

Rice bran oil (RBO) as a cooking oil is extremely light, versatile, delicious and beneficial for human health getting popularity among the consumers of Bangladesh. The demand for rice bran oil is increasing in Bangladesh due to its nutritional as

Table 16. Effect on seed rate, fertilizer use and other management practices.

Particulars	Chittagong		Sylhet	
	Before training	After training	Before training	After training
Seed				
Boro season	46 kg/ha	35 kg/ha (Saved 23.91%)	44 kg/ha	35 kg/ha (Saved 20.45%)
T.Aman season	56 kg/ha	49 kg/ha (Saved (12.50%)	48 kg/ha	42 kg/ha (Saved 12.50%)
Fertilizer				
Boro (Kg/ha)	168	201	179	221
Urea	40	55	60	70
TSP	25	40	33	47
MoP	50-60	40-45	50-60	40-45
Seedling age (days)				
Herbicides use	Did not use	Used herbicides	Did not use	Used herbicides
Weeder use	Did not use	Used in limited areas	Did not use	Used in limited areas
T. Aman (Kg/ha)				
Urea	134	127	130	120
TSP	-	33	20	33
MoP	-	30	-	23
Use of herbicide	Did not use	Did not use	Did not use	Did not use
Herbicide	Did not use	Did not use	Did not use	Used herbicide
Weeder Use	Did not use No	Used in limited areas	Did not use No	Used in limited areas
Line sowing	line sowing No	10-12 % area	line sowing No	8-10 % area
Parching	parching Not	No parching	parching Not	No parching
Use of rice weeder	used	Not used	used	Not used

Table 17. Effect of area coverage and yield.

Main variety and yield	Chittagong		Sylhet	
	Before training	After training	Before training	After training
T. Aman season				
BRRIdhan49 (% area coverage)	23.43	29.88 (27.53)	17.23	25.21 (46.31)
Yield (t/ ha)	4.59	5.02 (9.36)	4.71	5.11(8.49)
LV (%area coverage)	10.33	7.11 (-31.17)	13.21	10.31(-21.95)
Yield(t/ha)	2.23	2.44 (9.41)	2.12	2.33 (9.90)
Boro season				
BRRI dha28 % area coverage	65.45	68.43 (4.55)	45.43	48.62 (7.02)
Yield (t/ha)	4.75	5.32 (12.00)	4.95	5.49 (10.91)

Note: Figure in the parentheses indicates change.

well as beneficial impact for human health. Consumers are now a days using rice bran oil as cooking oil side by side soybean and its production and marketing is increasing day by day in Bangladesh. Many investors are showing their enthusiasm to invest in this sector. Per day per capita consumption of edible oil in Bangladesh is about 26.57 gm per day (BTC, 2014). Thus, the total demand for edible oil in Bangladesh is about 1.44 million tons of which 2-3% is coming from rice bran oil. At present, daily production of rice bran oil is about 250-300 tons in Bangladesh and its demand is increasing by 5-10% per year (BBS, 2013). So, the present study has been designed to explore the prospect and potential of this sector in the economy of Bangladesh with the following specific objectives.

- Examine the present status of rice bran and bran oil production in Bangladesh;
- Examine the cost of production of bran oil at the mill level;
- Sketch the value addition process and supply chain of rice bran oil; and
- Estimate the share of margin of different actors in the value chain

Cost of production of rice bran oil

All the cost items related to rice bran oil production constituted by costs of production and marketing. Production costs included variable and fixed costs which were about 89% and 6% of total production cost, respectively. Marketing costs was 5% of total bran oil cost. It was found that the summation of total costs of rice bran oil production (byproducts also) including marketing costs which was Tk 176,206/ton. After deducting the returns from byproducts; actual cost of RBO was TK 87019/ton (Table 18).

Tables 18. Costs of bran oil production (Tk/ton).

Item	Amount (Tk)	(% of total production)
A. Total variable cost (Tk/ton)	156,375	88.746
a) Rice bran*	143,000	81.155
b) Chemicals*	7,202	4.087
c) Labors	740	0.420
d) Gas bill	3,600	2.043
e) Electricity	38	0.022
f) Lubricant	29	0.016
g) Income tax	100	0.057
h) Repair and maintenance	1,667	0.946
B. Total fixed cost (Tk/ton):	10,801	6.135
a) Opportunity cost of land	8	0.005
b) Staff salary	4,583	2.601
c) Depreciation of building	2	0.001
d) Depreciation of machines	92	0.052
e) Interest on investment for building	1,513	0.859
f) Interest on investment for machines	1,361	0.772
g) Tax	210	0.119
h) Insurance	38	0.022
i) Administrative cost	2,994	1.699
C. Marketing Cost (Tk/ton)	9,029	5.124
D. Total costs (A+B+C)	176,206	100
E. Returns from by-products (Tk/ton RBO production)	89,187	50.615
F. Cost of production of rice bran oil deducting revenue from byproducts (D - E)	87,019	
G. Per Kg costs of production of rice bran oil	87.02	

Major Chain of rice bran oil

The following value chains were identified in case of rice bran oil marketing:

Value chain-i: Rice Bran Oil Miller>Dealer> Retailer>Consumer

Value chain-ii: Rice Bran Oil Miller>Retailer> Consumer

Value chain-ii: Rice Bran Oil Miller>Consumer

Value addition of different actors involved in the chain

Table 19 presents the total value addition of rice bran oil which was Tk 34981 at different level of actors. It was found that value addition of RBO were respectively 37%, 29% and 34% at miller, dealer and retailer level.

The dominant supply chain of RBO was Miller > Dealer > Retailer > Consumer. Value addition by miller, dealer and retailer of the supply chain were15%, 10% and 11% and gross margin obtained by those actors were 37%, 29% and 34%, respectively. The key problems of RBO were unavailability of adequate rice bran and lack of promotional activities at consumer level. Present production capacity of the industry is about 0.258 million tons, but due to shortage of bran the production is about 0.089 million tons. Considering the importance of rice bran oil, government should provide incentives in this sector to increase the supply of bran oil which could save huge amount of foreign exchanges.

SOCIAL DYNAMICS OF FARM HOUSEHOLD WOMEN IN THE PLAIN AND HILLY AREAS OF RURAL BANGLADESH

Women extensively perform tedious domestic activities as well as participate in the farming activities both as paid and unpaid family labour in Bangladesh. LFS (2010) reported that an additional 6.7 million women commenced to participate in the farming activities while men's participation has been decreased by 3% over the last 10 years. Despite significant contribution of women in agriculture, their roles were mostly ignored in the national agricultural statistics of Bangladesh (Amin, 1995). The specific objectives of the study were as follows:

Table 19. Value addition of different intermediaries of rice bran oil (Tk/ton).

Particulars	Sale price	Purchase price	Value addition	Value addition (%)
Miller	100000	87019	12981	37.11
Dealer	110000	100000	10000	28.59
Retailer	122000	110000	12000	34.30
Total Value addition			34981	100.00

- Identify the socio-demographic features of the study villages; and
- Assess the property rights and roles of women in the family and farm.

Two contrasting ethnic community base Districts namely Mymensingh and Bandarban were selected purposively for this study. Data were collected from four villages, two from each District through Focus Group Discussion (FGD). In total four (one from each village) FGD was conducted with 12-16 respondent included male and female members of farm families in the study villages. The results were validated by the respondents in the following seasons.

Socio-demographic features

The FGD respondents of Mymensingh said that the social and religious custom was not much flexible about mobility (going outside of home for farming, other livelihood activities and shopping) of women. Therefore, women usually go to outside of the house with permission of husband or mother-in-law but there was some variation in the mobility of women between the different household types (e.g. large, medium, small and landless). The women of large and middle farm households go to relatives' house, hospital and market with other members of household or relatives. In the contrary, the majority of informants reported that female members of small farm and landless labourer household enjoyed higher mobility rights as well as more of them ware headscarf and *bourka* (*Purdah*). The women of small farm and landless labourer families go outside of house as group for farming and other livelihood activities with male and female neighbors. On the other hand, social custom of tribal villages was more flexible about women's mobility. Therefore, women independently go to fields or market for buying foods, farm inputs as well selling marketable surplus.

Agricultural Statistics Division

SUMMARY

In T. Aman season, BRRI dhan49 and BRRI dhan52 were found as the stable, while BR4, BR10, BR11, BR22, BR23, BR25, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan51, BRRI dhan53, BRRI dhan54 and BRRI hybrid dhan4 were found having average stability and the other remaining varieties appeared to below average stable among T. Aman varieties.

BRRI dhan68, BRRI dhan69 and BRRI hybrid dhan2 were the most stable variety and BR9, BR14, BRRI dhan28, BRRI dhan29, BRRI dhan55, BRRI dhan58, BRRI dhan59, BRRI dhan60, BRRI dhan61, BRRI dhan63, BRRI dhan67, BRRI dhan74 and BRRI hybrid dhan3 appeared to be average stable in Boro season.

Pure consumers were found to prefer rice varieties BRRI dhan28, Swarna, BRRI dhan29 and Parija on the basis of cleanness, broken percentage, shape of grain, cohesion after cooking, tastiness and keeping qualities. Although, BRRI variety contributes about 90% of total production but it does not reflect in market label because of BRRI variety sale in different brand name, namely BRRI dhan28 sale as Nizersail and BRRI dhan29 as Jhingasail and Miniket etc.

ARIMAX model for measuring the climatic effects on Aus production are ARIMAX (1,1,0), ARIMAX (1,0,0), ARIMAX (0,1,1) and ARIMAX (1,1,0) for Rajshahi, Barisal, Dinajpur and Jessore district respectively. Analysis revealed that, minimum temperature and rainfall have negative and maximum temperature have positive effects on Aus production for Rajshahi district. But in Barisal district minimum temperature have positive and maximum temperature and rainfall have negative effects on Aus production. Again, the regressor variables maximum temperature, rainfall have positive and minimum temperature have negative effects on Aus production for Dinajpur district. Similarly, maximum temperature have positive and minimum temperature and rainfall have negative effects on Aus production for Jessore district.

Maximum temperature, minimum temperature and total rainfall maps of 2013 and 2014 show that though there is no abrupt change over the years but gently changes are observed. Both low temp and low rainfall area shifted from top north-west part to central north-west part over 2013 to 2014 and 2014 was warmer than 2013.

In a nut shell, northern side is suitable and south and eastern sides are not suitable for both BRRI dhan62 and BRRI hybrid dhan4.

Mobile Apps of RKB (Rice knowledge Bank) designed and developed under ICT cell of Agricultural Statistics Division.

The scientists of this division were also engaged in helping scientists of other disciplines in planning experiments, statistical data analysis and interpretation of results. A total of 60 different types of analyses were performed during the reporting year. A number of maps were prepared using GIS and supplied to the scientists of other divisions whenever required. Besides, ICT cell of Agricultural Statistics Division provides ICT related support services to other divisions such as hardware, software and troubleshooting related problems.

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 on BRRI varieties and identify the bio-physical and socio-economic factors causing instability. Experiments are being conducted in the T. Aman and Boro seasons with BRRI released rice varieties since T. Aman 2002-15 in Gazipur and different regional stations. The collaborative regional stations in the T. Aman season are Rajshahi, Rangpur, Comilla, Sonagazi, Barisal, Satkhira and Kushtia and in the Boro season Rajshahi, Rangpur, Comilla, Habiganj, Barisal, Bhanga, Satkhira and Kushtia. In T. Aman season, the number of varieties is 30 and in Boro it is 36. The design is RCB with three replications and the effective plot size (harvest area) is 5-×-2 m^2 leaving the boarder. Recommended crop management practices are followed. Stability analysis of the experimental data was performed by using a newly developed model. The model deals with the performance of the genotypes across the geographical locations differing in land, soil and other biotic and abiotic factors over the years characterizing fluctuation of weather variable, floods, drought etc.

Results and discussion

Tables 1 and 2 present the results. Among T. Aman varieties, BRRI dhan49 and BRRI dhan52 were found stable while BR3, BR5, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan56, BRRI dhan57, BRRI dhan62 and BRRI dhan66 appeared to be below average stable. BR4, BR10, BR11, BR22, BR23, BR25, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan51, BRRI dhan53, BRRI dhan54 and BRRI hybrid dhan4 were found having average stability among T. Aman varieties.

In Boro season, this year the stable variety was BRRI dhan68, BRRI dhan69 and BRRI hybrid dhan2. BR9, BR14, BRRI dhan28, BRRI dhan29, BRRI dhan55, BRRI dhan58, BRRI dhan59, BRRI dhan60, BRRI dhan61, BRRI dhan63, BRRI dhan67, BRRI dhan74 and BRRI hybrid dhan3 appeared having average stability. All other Boro varieties (BR1, BR2, BR3, BR6, BR7, BR8, BR12, BR15, BR16, BR17, BR18, BR19, BR26, BRRI dhan27, BRRI dhan35, BRRI dhan36, BRRI dhan45, BRRI dhan47, BRRI dhan50 and BRRI dhan64) appeared having below average stability.

Table 1. Stability parameters of grain yield for T. Aman season.

Variety	Stability parameter 2001-15			Stability index	Stability rank	Nature of stability
	S_i	D_i	P_i	G_i	R_i	
			Non-aromatic rice			
BR 3	19.46	-7.82	56	0.708	5	BAS
BR 4	11.52	4.88	48	1.389	3	AS
BR 10	12.20	11.98	51	1.614	2	AS
BR11	13.94	7.52	49	1.357	3	AS
BR 22	12.62	8.42	57	1.520	2	AS
BR 23	13.35	5.84	49	1.325	3	AS
BR 25	15.30	1.34	51	1.104	3	AS
BRRI dhan30	12.24	7.72	53	1.483	3	AS
BRRI dhan31	13.68	3.81	49	1.236	3	AS
BRRI dhan32	14.25	9.68	55	1.466	3	AS
BRRI dhan33	19.24	-11.19	54	0.575	7	BAS
BRRI dhan39	18.99	-2.34	53	0.878	4	BAS
BRRI dhan40	10.22	9.96	55	1.725	2	AS
BRRI dhan41	14.50	9.28	51	1.464	3	AS
BRRI dhan44	10.79	14.26	39	1.838	2	AS
BRRI dhan46	10.94	5.49	26	1.460	3	AS
BRRI dhan49	8.94	16.29	25	2.098	1	S
BRRI dhan51	9.82	11.02	23	1.887	2	AS
BRRI dhan52	8.84	15.04	21	2.134	1	S
BRRI dhan53	12.53	4.09	13	1.319	3	AS
BRRI dhan54	12.85	10.43	14	1.548	2	AS
BRRI dhan56	18.12	-9.01	17	0.769	5	BAS
BRRI dhan57	20.83	-22.04	11	0.136	10	BAS
BRRI dhan62	19.27	-28.97	6	0.292	10	BAS
BRRI dhan66		1.56	7	0.840	4	BAS
BRRI hybrid dhan4	15.33	-0.82	3	1.298	3	AS
			Aromatic rice			
BR 5	17.36	-23.22	59	0.255	10(3)	BAS
BRRI dhan34	22.43	-23.42	61	0.144	10(4)	BAS
BRRI dhan37	15.89	-18.63	49	0.373	9(2)	BAS
BRRI dhan38	14.19	-17.26	57	0.556	7(1)	BAS

Note: S=Stable, AS=Average stable, BAS = Below average stable.

Table 2. Stability parameters of grain yield for Boro season.

Variety	Stability parameter 2002-15			Stability index	Stability rank	Nature of stability
	S_i	D_i	P_i	G_i	R_i	
			Non-aromatic rice			
BR 1	10.89	-4.86	66	0.493	8	BAS
BR 2	12.68	-7.70	64	0.179	10	BAS
BR 3	11.15	-0.44	65	0.832	4	BAS
BR 6	14.08	-5.52	64	0.312	9	BAS
BR7	10.06	-8.35	59	0.174	10	BAS
BR 8	14.21	-3.88	69	0.498	8	BAS
BR 9	9.75	5.33	65	1.384	3	AS
BR 12	11.89	-5.84	63	0.368	9	BAS
BR 14	9.55	1.72	76	1.175	3	AS
BR 15	10.96	0.27	67	0.940	4	BAS
BR 16	11.64	0.61	61	0.907	4	BAS
BR 17	13.68	-4.90	67	0.400	8	BAS
BR 18	11.62	-8.92	66	0.114	10	BAS
BR 19	13.71	-5.38	62	0.317	9	BAS
BR 26	9.89	-2.47	69	0.750	5	BAS
BRRI dhan27	11.99	-5.24	60	0.367	9	BAS
BRRI dhan28	12.08	2.17	66	1.043	3	AS
BRRI dhan29	10.47	11.71	71	1.958	1	S
BRRI dhan35	11.33	-3.64	61	0.579	7	BAS
BRRI dhan36	12.39	-2.47	61	0.637	6	BAS
BRRI dhan45	10.57	-1.49	41	0.770	5	BAS
BRRI dhan47	10.95	0.95	30	0.986	4	BAS
BRRI dhan55	10.35	4.25	20	1.337	3	AS
BRRI dhan58	12.73	9.16	26	1.826	2	AS
BRRI dhan59	9.84	3.99	14	1.345	3	AS
BRRI dhan60	9.30	4.65	14	1.395	3	AS
BRRI dhan61	7.36	2.80	12	1.363	3	AS
BRRI dhan63	6.02	-3.89	10	1.361	3	AS
BRRI dhan64	11.62	-1.23	11	0.930	4	BAS
BRRI dhan67	17.21	-0.39	12	1.201	3	AS
BRRI dhan68	4.47	3.36	11	2.204	1	S
BRRI dhan69	11.77	8.66	10	2.003	1	S
BRRI dhan74	8.92	6.01	10	1.977	1	AS
BRRI hybrid dhan2	8.19	10.05	9	2.016	1	S
BRRI hybrid dhan3	9.96	6.81	9	1.587	2	AS
			Aromatic rice			
BRRI dhan50	8.93	-3.62	30	0.719	5(1)	BAS

Note: S=Stable, AS=Average stable, BAS = Below average stable.

DEVELOPMENT AND VALIDATION OF CONSUMER PREFERENCE MODEL FOR RICE VARIETIES

The present study is an attempt to evaluate the factors affecting consumers' preference to rice varieties. For this study four locations/districts i.e. Panchagarh, Lalmonirhat, Kurigram and Thakurgaon were selected. Panchagarh and Lalmonirhat were selected as Rice deficit area. Kurigram and Thakurgaon were selected as 'Rice surplus' area. Fifty pure consumers (Consume rice from market) were selected from the urban areas of Panchagarh, Lalmonirhat, Kurigram and Thakurgaon districts. Information was collected on the choice of varieties for consumption using a pre-designed questionnaire. The model of consumer demand for good characteristics is adapted from Ladd and Suvannunt (1976). Products and demand for the utility they provided, which in turn is a function of the characteristics of the product (Ladd and Suvannunt, p 505). Then Laurian J. Unnevehr (1986) has given a model of consumer demand for rice grain quality and return to research for quality improvement in Southeast Asia. Also Juliano, B.O. (1982) presented a paper at food conference of

Singapore Institute of Food Science and Technology about consumer acceptance and processing characteristics of rice varieties. In the light of the above mentioned authors model and the sample survey report of four districts consumer group, we have proposed a model for consumer preference to rice varieties.

The newly developed model for consumers' preference for rice varieties was used to achieve the objectives of the study. The validation, pure consumers of Kurigram district were found to prefer rice varieties on the basis of cleanness, shape of grain, tastiness and form of grain. In case of Thakurgaon district consumers prefer rice varieties based on whiteness, cleanness, shape of grain, cohesion after cooking, tastiness and keeping qualities (Table 3). Whereas, pure consumers of Pachagarh and Lalmonirhat district prefer rice varieties on the basis of whiteness, cleanness, broken percentage, shape of grains, cooking time, cohesion after cooking, tastiness, keeping qualities and form of grain.

MAINTENANCE OF RICE AND RICE RELATED VARIABLE DATABASE

Secondary data on rice and other important crops are collected periodically from Bangladesh Bureau of Statistics (BBS), Agricultural Marketing Directorate, Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB), Bangladesh Agricultural Development Corporation (BADC) and other sources periodically and computerized.

Existing databases have been updated. Also to make an agricultural database we want to initiate a database system where we can use updated software and database programme to make this database, we will use SQL Server 2005 express edition/2008/2010/2012 versions. We will also use Oracal 9i/10g/11i version.

EFFECT OF CLIMATIC FACTORS ON RICE PRODUCTION

Objective of this study is to develop the best ARIMAX model for measuring the temperature and rainfall effects on rice production in some selected districts of Bangladesh and production forecasting using the same model. National level production data of Aus rice in the time span of 1971 to 2015 were collected from various versions of the yearbook of Agricultural Statistics. Aggregate level monthly data on climatic parameters (Maximum and minimum temperature and rainfall for Rajshahi, Dinajpur, Barisal and Jessore weather stations were collected from Bangladesh Meteorological Department (BMD) for the same period. Autoregressive Integrated Moving Average with External Regressor (ARMIAX) Model was used for analysis.

Table 3. Reasons for liking varieties by the pure consumers in different location (%).

Reason	Kurigram	Thakurgaon	Panchagarh	Lalmonirhat
Whiteness	17 (37.8%)	24 (54.5%)	39 (78%)	41 (82%)
Cleanness	40 (88.9%)	27 (61.4%)	48 (96%)	50 (100%)
Broken (%) Very low	13 (28.9%)	13 (29.5%)	41 (82%)	34 (68%)
Shape of grains (C + F)	38 (1C + 37F) (84.4%)	27 (27F) (61.4%)	43 (43F) (86%)	41 (1C + 40F) (82%)
Cooking time (VQ + Q)	1 (1Q) (2.2%)	9 (9Q) (20.5%)	31 (1VQ + 30Q) (62%)	33 (6VQ + 27Q) (66%)
Cohesion after cooking (WS + NS)	1 (1WS) (2.2%)	28 (27WS + 1NS) (65%)	35 (13WS + 22NS) (70%)	44 (3WS + 41NS) (88%)
Taste (VG + G)	40 (31VG + 9G) (88.9%)	43 (37VG + 6G) (97.7%)	48 (37VG + 11G) (96%)	46 (18VG + 28G) (92%)
Keeping qualities (VL + L)		36 (4VL + 32L) (95.5%)	46 (4VL + 42L) (92%)	41 (1VL + 40L) (82%)
Form of grain	35 (Med) (77.8%)	9 (Long) (20.5%)	34(long) (68%)	36 (Long) (72%)

Note: C=Core, F=Fine, VQ=Very quick, Q=Quick, WS=Weakly sticky, NS=Non sticky, VG=Very good, G=Good, VL=Very long, M=Medium, L=Long.

ARIMAX modeling for Aus production in Rajshahi district

Dickey-Fuller unit root test is used to check whether time sequence of Aus production data satisfied the sationarity conditions. It is found that stationarity condition satisfied at the difference order one with p-value = 0.01 which suggests that there is no unit root at the first order difference of Aus production at the 1% level of significance. For graphical stationarity test Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF) were used. From the tentative order analysis, the best selected ARIMAX model for measuring the climatic effects on Aus production in Rajshahi is ARIMAX (0,1,1) with the Akaike Information Criterion (AIC)= 433.73 and Bayesian Information Criterion (BIC) = 455.61.

From the analysis, it is clear that Aus production depends on the first order Moving Average Lag, which has statistically significant effects at the 5% level of significance. At the same time, minimum temperature and rainfall have negative and maximum temperature have positive effects on Aus production.

ARIMAX modeling for Aus production in Barisal district

Dickey-Fuller unit root test is used to test whether time sequence of Aus production data series are stationary or not. It is found that stationarity condition satisfied without any difference with the $Pr(|t| \geq -13.9946) = 0.01$, which suggests that there is no unit root in the original series at the 5% level of significance. From the original series we found a constant variance. Again, from the ACF and PACF, it is clear that there is no significant spike in the original series, which also indicates that there are no significant effects of Auto-Regressive and Moving Average in the original series, that is, the series is stationary without any difference. From the tentative order analysis, the best selected ARIMAX model for measuring the climatic effects on Aus production in Barisal district is ARIMAX (1,0,0) with the AIC = 206.63 and BIC = 230.45.

From the analysis, it is clear that Aus production in Barisal depends on the first order Autoregressive Lag, which has statistically significant effects at the 10% level of significance. At the same time, maximum temperature, minimum temperature and rainfall have statistically significant effects at the 10% level of significance. Again, minimum temperature have positive and maximum temperature and rainfall have negative effects on Aus production in Barisal.

ARIMAX modeling for Aus production in Dinajpur district

Dickey-Fuller unit root test is used to test whether the time sequence of Aus production series is stationary or not. It is found that stationarity condition satisfied at first order difference with the p-value = 0.01, which suggests that there is no unit root in the first order difference at the 5% level of significance, that is, the series is stationary. From the analysis, it is clear that at the first difference Aus production series show a constant variance but in the original series it is not stationary, that is, our difference order is one to make the Aus production series stationary. Again, from the ACF and PACF, it is clear that there is no significant spike in the first order difference series, which also indicate that there are no significant effects of Auto-Regressive and Moving Average in the first order difference, that is, the Aus production series are stationary at the first order difference. From the tentative order analysis, the best selected ARIMAX model for measuring the climatic effects on Aus production is ARIMAX (1,1,0) with the AIC = 237.95 and BIC = 259.82.

From the analysis, it is obvious that first order Auto-Regressive lag has significant effects on Aus production at the 10% level of significance. Again, the regressor variables of maximum temperature, rainfall have positive and minimum temperature have negative effects on Aus production.

ARIMAX modeling for Aus production in Jessore district

Dickey-Fuller unit root test is used to test whether the time sequence series are stationary or not. It is found that stationarity condition satisfied at the difference order one with the p-value < 0.01, which suggests that there is no unit root in the first order difference at the 1% level of significance, that is, the Aus production series become stationary at first order difference. From the analysis, it is obvious that the first difference series shows more stable

variance than the original series, that is, our difference order is one to make the series stationary. Again, from the ACF and PACF, it is clear that there is no significant spike in the first order difference series, which also indicate that there are no significant effects of Auto-Regressive and Moving Average in the first order difference, that is, the Aus production series is stationary at the first order difference. From the tentative order analysis, the best selected ARIMAX model for measuring the climatic effects is ARIMAX (0,1,1) with the AIC = 194.93 and BIC = 216.8.

From the analysis, it is obvious that first order Moving Average lag has significant effects on aus production at the 5% level of significance. Similarly, maximum temperature have positive and minimum temperature and rainfall have negative effects on Aus production.

The Autocorrelation and normality assumption for Rajshahi, Barisal, Dinajpur and Jessore districts refers there is no autocorrelation among the residuals of the fitted models and also accept the normality assumption that is the residuals are from normal distribution.

PROBABILITY MAPPING OF TEMPERATURE AND RAINFALL

Year by year climatic factors mapping would be great tool for climatic factors analysis and assist to increase crop production. Data were collected from Bangladesh Meteorological Department (BMD) and maps were prepared by GIS Software.

Maximum temperature. Both 2013 and 2014 years maximum temperature maps showing increasing trend from east to west. North-west is high temperature area like, Chapai-nawabganj, Rajshahi, Nator, Meherpur, Kushtia, Chuadanga districts and low temperature area is south-eastern side like Cox-bazar, Bandarban, Chittagong etc, districts. But in year 2014 maximum temperature was little bit higher than that year 2013.

Minimum temperature. Unlikely maximum temperature the value of minimum temperature shows increasing trend from west to east. North-west is low minimum temperature area and south-east side like, Cox's Bazar, Bandarban etc are high minimum temperature area. But, likely maximum temperature, value of minimum temperature of 2014 was higher than that of 2013 also a noticeable matter is low minimum temperature area shifted from top north-west part to central north-west part over the year 2013 to 2014. In year 2013 most low minimum temperature area was Pacchagarh, Thakurgaon, Nilphamari, Dinajpur, Rangpur area where in year 2014 most low min temp area was Rajshahi, Nator, Kushtia, Meherpur, Chuadanga area.Minimum temperature maps for the year 2013 and 2014.

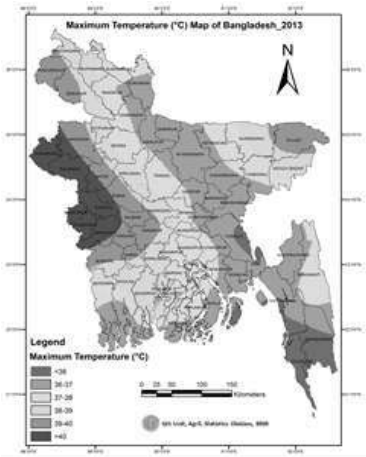
Total rainfall. Total rainfall maps of 2013 and 2014 also showing increasing trend from west to east. North-east like Sylhet, Sunamganj, Moulovibazar and south-east like Chittagong, Bandarban and Cox's Bazar areas are most high rainfall area. Likely, low min tem, the low total rainfall area also shifted from top north-west part to central north-west part over the year 2013 to 2014. Value of the highest total rainfall as well as range of variation of total rainfall decreased in year 2014 compared to 2013.

SUITABILITY MAPPING OF NEWLY RELEASED BRRI RICE VARIETIES

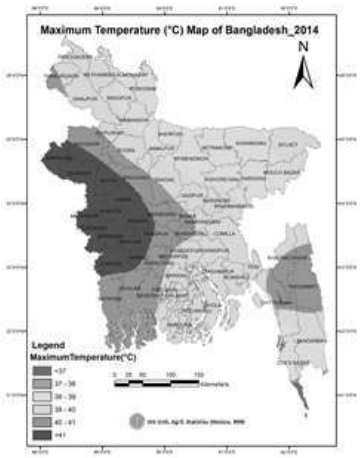
As we need to high production with limited land, so it will be very helpful if we have variety wise suitability map based on soil properties. BRRI dhan62 and BRRI hybrid dhan4 are very prospective varieties in Aman season. As the suitability map of these two varieties are very important, the maps prepared by GIS software.

Mainly top north-west and central north-west areas in the map are suitable for BRRI dhan62. The districts are Panchagarh, Nilphamari, Thakurgaon, Rangpur, Chapainawabganj, Naogaon, Rajshahi, Meherpur, Chuadanga, Jhenaidah but central part of Bangladesh i.e. Gangeas flood plain, Southern and Eastern part of Bangladesh are not suitable for BRRI dhan62.

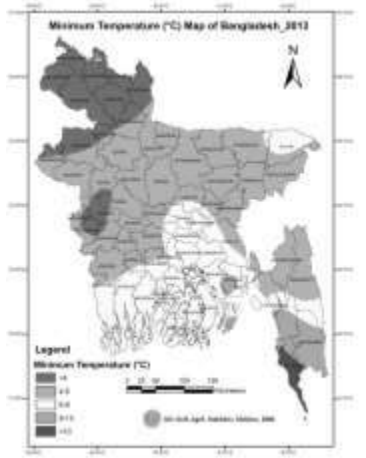
Not very areas are suitable of BRRI Hybrid dhan4 but wide areas are moderately suitable. North-west areas like Dinajpur, Nawgaon, chapainawabganj and Rajshahi are suitable for BRRI Hybrid dhan4, central and eastern part of Bangladesh are not suitable for BRRI hybrid dhan4.



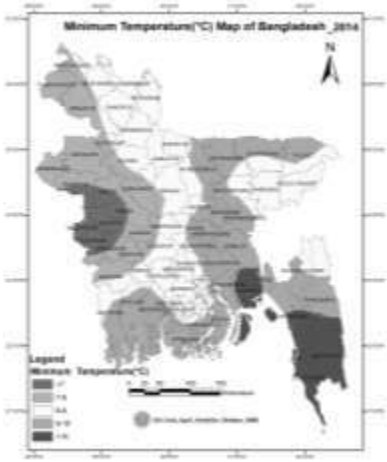
Map 1. Maximum temperature of Bangladesh for 2013.



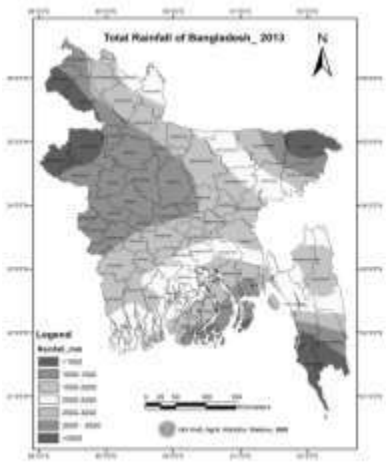
Map 2. Maximum temperature of Bangladesh for 2014.



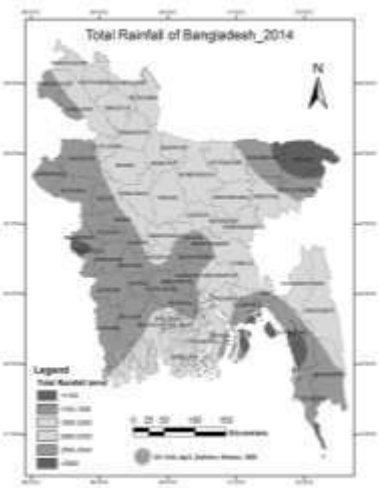
Map 3. Minimum temperature of Bangladesh for 2013.



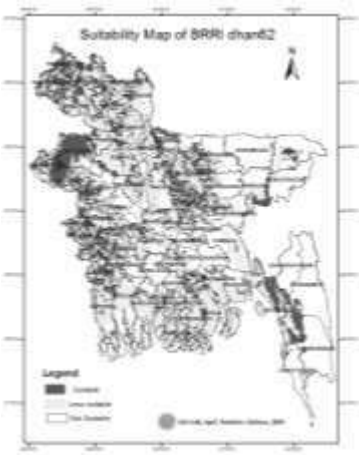
Map 4. Minimum temperature of Bangladesh for 2014.



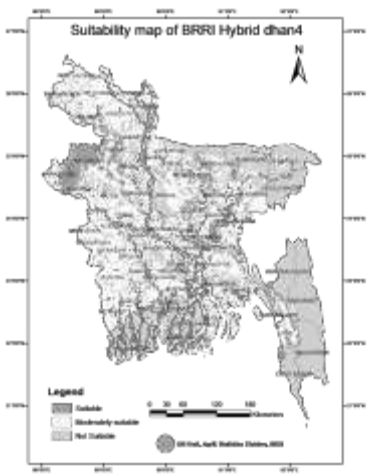
Map 5. Total rainfall of Bangladesh for 2013.



Map 6. Total rainfall of Bangladesh for 2013.



Map 7. Suitability map of BRRI dhan62.



Map 8. Suitability map of BRRI Hybrid dhan4.

ICT ACTIVITIES

ICT Cell of the Agricultural Statistics Division also makes the web poprtal of BRRI, maintains BRRI local area network and internet connectivity, management information system (MIS), personal data sheet (PDS), digital signature system, web mail, group mail and Facebook group BRRI Networks.

Heritage of BRRI

The objectives of this work are to develop a heritage for all retired scientists, officers, staffs and labourers of BRRI; it is aimed at fulfilling awareness among the present employees of BRRI about retired scientists and officers activities. So, they can follow their instructions and about their works and importance of preserving their documents as a digital format in the BRRI web portal. Heritage is updating regularly. It is also routine work.

Video conference system

A video conference is a live connection among people in separate locations for the purpose of communication, usually involving audio and often text as well as video. The main objective is to develop 'video conference system of BRRI' to connect administration, all divisional and regional station heads of BRRI for research and administration works. We have created Skype account for all divisional heads and regional station heads. The communication between BRRI headquarters and other regional station has been enhanced by video conference system in monthly co-ordination meeting.

Mobile apps of RKB

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. Main objectives are that to develop the blank pages and modify the design of 'RKB'. It manages and maintains through regular updating.

It has hosting at Google play store and also available at android-base smart phone. So anybody can download it from Google play store of any android mobile. Otherwise, this mobile app can be shared from other smart phone by 'SHAREit' software. RKB is regularly updating including all varietal information. It has included rice cultivation methods, soil and fertilizer management, insects and their management, diseases and their management, irrigation and water management and photo gallery.

e-Tender system

An e-tender system manages tenders through a web site. The government has initiated a process to introduce electronic-tendering in its public procurement system. It is a part of the digital Bangladesh. So, ICT cell of Agricultural Statistics Division has taken a plan to start an e-Tender system of the Central Procurement Technical Unit (CPTU), IMED. The objectives are to develop

'e-Tender system' of BRRI as per requirement of the Ministry of Agriculture (MoA) and introduce the online tendering system to facilitate the procurement process of BRRI.

BRRI introduced *e-Tender* on 1st July of 2016. BRRI is incorporated with it as a first organization among the NARS institute and also a first organization under Ministry of Agriculture (MoA). BRRI has already submitted total six tenders into e-GP portal and the submission process is continuing under the provisions of the Public Procurement Act-2006 (PPR-2006), Public Procurement Rules-2008 (PPR-2008) and the ICT Policy Act-2009.

Support services

The scientists of this division are also engaged in helping scientists of other disciplines in planning experiments, statistical data analysis and interpretation of results. Sixty different types of analyses were performed during the reporting year. A number of maps were prepared using GIS and supplied to the scientists of other divisions whenever required.

ICT cell of Agricultural Statistics Division has taken initiative in accordance with government perspectives but 'BRRI Network' group is first introduced among all National Agricultural Research System (NARS) and also first among all research institutes. The ICT cell of Agricultural Statistics Division provides e-Filing management system related support services, Anti-virus related support services to other divisions such as setup antivirus software, clean virus etc.

Farm Management Division

SUMMARY

The experiment was conducted at the west byde of BRRI farm, Gazipur during T. Aman 2015 to investigate the seed quality of different rice cultivars that are affected by rainfed during reproductive and ripening phases. The treatments were two planting dates (D_1=16 August and D_2=12 September) and three rice varieties (V_1=BRRI dhan40, V_2=BRRI dhan41 and V_3=BRRI dhan46). The treatments were arranged in a randomized complete block (RCB) design with three replications. The interaction between planting dates and variety was not significant in all the parameters of yield and yield components. The germination percentage (GM %), seedling vigour index (SVI), high density grain (HDG %), shoot dry weight (SDW) and root dry weight (RDW) were also not significantly affected by the interaction between planting dates and variety. Sixteen August planting produced higher number of tillers m^{-2}, panicles m^{-2}, grain panicle^{-1}, 1000-grain weight (TGW), grain and straw yield. Panicles m^{-2}, grain panicle^{-1}, TGW were significantly affected by variety. BRRI dhan46 produced the highest TGW and grain yield. The SVI, HDG%, SDW and RDW were significantly affected by planting dates. All of these parameters performed better in 16 August planting than 12 September planting. All the seed quality parameters were significantly affected varieties. The highest GM %, SVI, HDG %, SDW and RDW was obtained from BRRI dhan46.

The experiment was conducted at the west byde of BRRI farm, Gazipur during T. Aman 2015 to determine the tillering pattern, growth, yield and yield components of rice as affected by seedling age. The treatments were six different seedling ages, such as 15, 20, 25, 30, 35, and 40 days. The treatments were arranged in a RCB design with three replications. The unit plot size was 4 m×4 m. One seedling per hill at 20 cm×20 cm spacing was transplanted. Irrespective of seedling age, the stem dry weight of all sampling dates increased slightly at PI stage (about 60 DAT) then sharply increased at FS (about 90 DAT) after that decreased and reached minimum at maturity stage. The leaf dry weight also followed the same trend as stem dry weight. The panicle dry weight in all the treatments sharply increased from flowering to maturity stage. Irrespective of seedling age, the tiller number gradually increased with the DAT and reached maximum at 45 DAT then gradually decreased and reached minimum at ripening and maturity stage. Fifteen-day-old seedling produced the highest number of tiller per hill from 15 to 120 DAT. The lowest number of tillers was recorded in 40-day-old seedling in all the sampling dates. The panicle number m^{-2} also increased with decreasing seedling age. It was the highest in 15-day-old seedling and lowest in 40-day-old seedling. Fifteen to 30-day-old seedling produced statistically identical and higher number of grain panicle^{-1} and 40-day-old seedling gave the lowest number of grain panicle^{-1}. The highest grain yield was obtained from 15-day-old seedling transplanted plot followed by 20, 25, 30, 35 and the lowest in 40-day-old but no significant difference was observed from 15 to 30-day-old seedling.

This experiment was conducted during T. Aman 2015 and Boro 2015-16 seasons in three locations of west byde of the BRRI farm, Gazipur to find out the suitable tillage operation for rice cultivation. The treatments were T_1=Normal cultivation practices i.e. four ploughing followed by laddering, T_2=Herbicide application followed by one ploughing and laddering and; T_3=One ploughing then removal of grass by hand followed by laddering. In each location the treatments were non-replicated i.e. full set of treatments were replicated in three locations called dispersed replication. The variety BRRI dhan49 and BRRI dhan29 were used in T. Aman and Boro season respectively. The total variable cost in Aman season was Tk 1,11,574; 1,02,974 and 1,09,174 in T_1, T_2 and T_3 respectively. In Boro season it was Tk 1,37,300; 1,28,700 and 1,35,400 in T_1, T_2 and T_3 respectively. In Aman season, application of T_2 instead of T_1 and T_3 Tk 8,140 and 7,260 ha^{-1} respectively will be more profitable. But in Boro season, application of T_2 treatment instead of T_1 and T_3 Tk 7,572 and 7,184 ha^{-1} respectively will be more profitable.

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 424-470. The wage rate day^{-1}during the peak periods of the year Tk 480 to 500 in May, Tk 440 to 500 in July-August and Tk 450 to 500 in

December-January were existed. The wage rate varied between Tk 375-400, 350-400, 400-450, 375-425, 400-425, 400-450, 350-400 and 400-425 at Habiganj, Rangpur, Rajshahi, Barisal, Sonagazi, Comilla, Satkhira and Khulna respectively.

A total of 17,773 kg rice was produced of which 11,660 kg, 275 kg and 5,838 kg was seed, noon seed and mixed rice, respectively. A total of 7,663 kg breeder seed was produced in collaboration with the GRS division.

BRRI has 783 labourers of which 522 are regular and 261 are irregular. In the BRRI HQ the number of total labourer was 484 of which 339 were regular and 145 were irregular. The institute has 274 ha of land of which 163 ha was cultivable. Total labour utilization in different divisions was 1,84,768 man days of which 57.72, 37.52 and 4.76% were utilized for research, support service and holidays respectively. A total of Tk 5,24,25,380 was paid as labour wages of which Tk 3,02,61,890.06 and Tk 1,96,68,029.59 and Tk 24,95,460.34 were paid to the labours for research work, support service works and leaves respectively. About 75.06 ha of land was utilized by different divisions in different season of which 7.89 ha in Aus, 33.74 in Aman and 33.43 ha in Boro season. This division manages the BRRI flower garden to maintain the aesthetic view of the campus including visible flower garden during summer and winter season.

RESEARCH ACTIVITIES

Seed quality of different T. Aman rice as affected by rainfed (drought) in ripening (seed formation) phase

The experiment was conducted at the west byde of BRRI farm, Gazipur during T. Aman 2015 to investigate the seed quality of rice that are affected by rainfed during reproductive and ripening phases. The treatments were two planting dates (D_1= 16 August and D_2= 12 September) and three rice varieties (V_1= BRRI dhan40, V_2= BRRI dhan41 and V_3= BRRI dhan46). The treatments were arranged in RCB design with three replications. The unit plot size was 4 m × 3 m. Yield and yield components data were taken. The germination percentage (GM%), seedling vigour index (SVI), high density grain (HDG%), shoot dry weight (SDW), and root dry weight (RDW) of seeds of harvested crop were also taken for observing the performance of seed quality. The collected data were analyzed using Crop Stat Software programme.

Interaction effect on yield and components. The interaction between planting dates a variety was insignificant in all the parameters of yield and yield components. Therefore, only the main effect has been described and discussed below:

Effect of planting dates. The planting dates had significant effect on yield and yield components (Table 1). Sixteen August planting gave higher number of tillers m^{-2}, panicles m^{-2}, grain $panicle^{-1}$, TGW, grain and straw yield. The grain yield significantly decreased in 12 September planting might be due to decrease in rainfall, temperature and solar radiation during reproductive and ripening phases (Fig. 1 and 2).

Effect of variety. Panicles m^{-2}, grain $panicle^{-1}$ and TGW were significantly affected by planting dates but number of tillers $m,^{-2}$ grain and straw yield were not significantly affected by planting dates (Table 1). BRRI dhan46 gave the highest grain yield due to highest number of panicles m^{-2}, grain $panicle^{-1}$ and TGW.

Interaction effect on seed quality. The interaction between planting dates and variety was not significant on seed quality such as GM %, SVI, HDG %, SDW and RDW (Table 2). Therefore, only the main effect has been described and discussed below:

Effect of planting dates on seed quality. The SVI, HDG %, SDW and RDW were significantly affected by planting dates but GM % was not significantly affected by planting dates. All these parameters performed better in 16 August planting than 12 September planting.

Effect of variety on seed quality. Variety had significant effect on all the parameters. The highest GM % (94.66) was recorded in BRRI dhan46 followed by BRRI dhan41 and the lowest in BRRI dhan40 (90.66). The SVI was also the highest in BRRI dhan46 and the lowest in BRRI dhan40. The HDG % also followed the same trend as GM % and SVI. The SDW was the highest in BRRI dhan46 (44.0 mg) followed by BRRI dhan40 and the lowest in BRRI dhan41 (39.67 mg).

Table 1. Yield and yield components of rice as affected by the planting date and variety in T. Aman 2015.

Treatment	Tiller m^{-2} (no.)	Panicle m^{-2} (no.)	Grain panicle^{-1} (no.)	1000- grain wt (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
		Planting date				
16 Aug	229	198	96	24.16	4.50	6.00
12 Sept	205	183	89	22.58	3.50	5.41
LSD at the 5% level	*12.95*	*2.27*	*2.51*	*1.06*	*0.49*	*0.58*
		Variety				
BRRI dhan40	218	189	91	22.30	3.95	5.70
BRRI dhan41	213	189	90	23.68	3.92	5.57
BRRI dhan46	220	194	95	24.13	4.12	5.86
LSD at the 5% level	*ns*	*2.78*	*3.07*	*1.30*	*ns*	*ns*

In a column, different small letters indicate the differences among treatments. ns=Not significant.

Table 2. Seed quality of rice as affected by the planting date and variety T. Aman 2015.

Treatment	GM %	SVI	HDG %	Shoot dwt of 10 Seedling (mg) at 10-day-old	Root dwt of 10 seedling (mg) at 10-day-old
				Planting date	
16 Aug	93.00	1306.56	89.94	42.44	41.17
12 Sept	92.00	1152.33	85.43	40.88	39.66
LSD at 5% level	*ns*	*142.46*	*0.61*	*0.83*	*0.81*
				Variety	
BRRI dhan40	90.66	1208.17	86.99	41.33	40.09
BRRI dhan41	92.50	1214.50	87.34	39.67	38.47
BRRI dhan46	94.66	1265.67	88.72	44.00	42.68
LSD at 5% level	*2.42*	*174.47*	*0.74*	*1.02*	*0.99*

In a column, different small letters indicate the differences among treatments. ns=Not significant. (GM%=Germination percentage, SVI=Seedling vigour index, HDG%=High density grain).

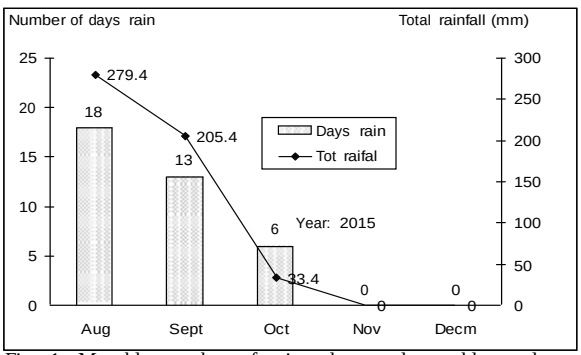


Fig. 1. Monthly number of rainy days and monthly total rainfall, T. Aman 2015.

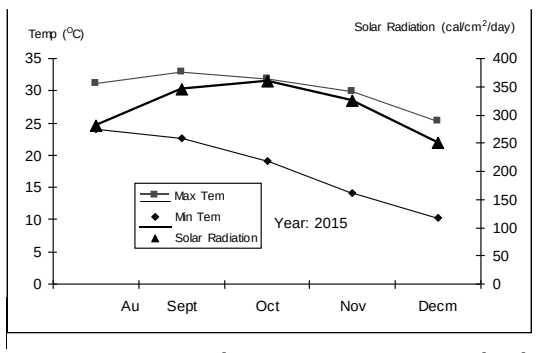


Fig. 2. Maximum and minimum temperature and solar radiation, T. Aman 2015.

The variety had also significant effect on RDW but it was the highest in BRRI dhan46 (42.68 mg) and the lowest in BRRI dhan41 (38.47 mg).

Therefore it may be concluded that sixteen august planting gave higher grain yield than 12 September planting. Among the varieties, BRRI dhan46 was the highest yielder than BRRI dhan40 and BRRI dhan41. Considering seed quality, 16 August performed better than 12 September planting. In case of varieties, BRRI dhan46 was the best in terms of GM%, SVI, HDG%, SDW and RDW.

Effect of seedling age on the growth, yield and yield components of rice

The experiment was conducted at the west byde of BRRI farm, Gazipur during T. Aman 2015 to determine the tillering pattern, growth, yield and yield components of rice as affected by seedling age. The treatments were six different seedling ages such as 15, 20, 25, 30, 35, and 40 days. The treatments were arranged in a RCB design with three replications. The unit plot size was 4 m×4 m. One seedling per hill at 20 cm×20 cm spacing was transplanted. Tillers were counted from transplanting to maturity with 15 days intervals.

Dry weight of leaf, stem and panicle were taken 15 days interval from 15 days after transplanting (DAT) to maturity of crop. Yield and yield components data were also taken at maturity. The collected data were analyzed using Crop Stat Software programme.

Tiller production. The number of tillers produced at different days after transplanting (DAT) was significantly affected by seedling ages (Fig. 3). Regardless of seedling age, the tiller number gradually increased with the DAT and reached maximum at 45 DAT then gradually decreased and reached minimum at ripening and maturity stage i.e. 105 to 120 DAT. 15-day-old seedling produced the highest number of tiller per hill from 15 to 120 DAT which was statistically identical with the tiller number produced from 20 and 25-day-old seedling. The lowest number of tillers was recorded in 40-day-old seedling in all the sampling dates, which was statistically similar to the tiller number produced from 35-day-old seedling.

Dry matter production. The dry matter weight of leaves stems and panicles were recorded at 15 days interval from transplanting to maturity of the crop as affected by seedling ages (Fig. 4). Irrespective of seedling age, the stem dry weight of all seedling ages increased gradually and reached maximum at 75 to 90 DAT (flowering stage) then decreased and reached minimum at maturity stage. The leaf dry weight also followed the same trend as stem dry weight. The panicle dry weight in all the treatments sharply increased from flowering to maturity stage. The panicle dry weight of lower seedling ages at 105 DAT and maturity stage comparatively higher than the older seedling ages. It has been observed that stem and leaf dry weight increased up to flowering stage after that decreased but panicle dry weight increased from flowering to maturity indicating that dry matter transferred from stem and leaf to the panicles.

Yield and yield components. The tiller number m^{-2}, panicle number m^{-2}, grain $panicle^{-1}$ and grain yield were significantly affected by seedling age but TGW and straw yield were not significantly affected by seedling age (Table 3).

Tiller number. The 15-day-old seedling produced the highest number of tiller. The tiller number m^{-2} decreased gradually with increasing seedling age and the lowest number of tiller was recorded in 40-day-old seedling. Fifteen to 30-day-old seedling gave statistically similar number of tiller m^{-2}.

Panicle number. The panicle number m^{-2} also increased with decreasing seedling age. It was the highest in 25-day-old seedling, which was statistically identical with the number of panicle produced from 15 to 35-day-old seedling. Forty-day-old seedling gave the lowest number of panicle.

Grain number. Fifteen to 35-day-old seedling produced higher number grain $panicle^{-1}$ which was statistically identical. Forty-day-old seedling gave the lowest number of grain $panicle^{-1}$.

Grain yield. The highest grain yield was observed in 15-day-old seedling transplanted plot which was statistically identical with 20, 25, 30 and the lowest in 40-day-old seedling.

It is concluded that **y**ield and yield components was higher in younger seedling used plot that produced more tillers and panicles. The plants those are produced from younger seedlings translocated more carbohydrate from source to sink might be the reason of higher yield in younger seedling used plot.

Effect of different tillage operations on the productivity and profitability of rice cultivation

This experiment was conducted during T. Aman 2015 and Boro 2015-16 seasons in three fields of west byde of BRRI farm, Gazipur to find out the suitable tillage operation for rice cultivation. The treatments were- T_1=Normal cultivation practices i.e. four ploughing followed by laddering, T_2=Herbicide application followed by one ploughing and laddering and; T_3=One ploughing then removal of grass by hand followed by laddering. In each location the treatments were non-replicated. The variety BRRI dhan49 and BRRI dhan29 were used in T. Aman and Boro season respectively. The unit plot size was 25 m×10 m irrespective of seasons. Labour requirements for different operations such as land preparation, seedling uprooting, transplanting, weeding, harvesting, threshing and winnowing were done through direct supervision. Data of three locations of each treatment were averaged and mean data were presented.

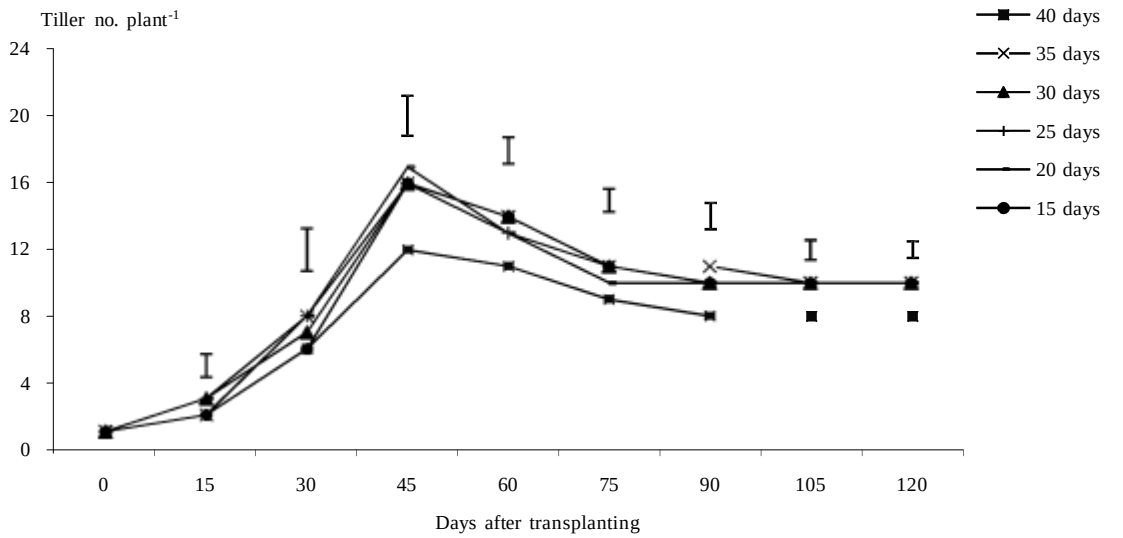


Fig. 3. Tiller number at different days after transplanting (DAT) as affected by seedling ages. (Vertical bar represent the Lsd (0.05) value indicates the differences between different seedling ages under same sampling date).

Table 3. Yield and yield components of rice as affected by different seedling ages.

Seedling age	Tiller m^{-2} (no.)	Panicle m^{-2} (no.)	Grain panicle^{-1} (no.)	1000-grain wt (g)	Grain yield (tha^{-1})	Straw yield (tha^{-1})
40 days	246	236	84	22.87	4.11	5.01
35 days	254	243	94	23.27	4.67	4.97
30 days	258	253	93	23.87	5.08	5.16
25 days	260	259	94	23.60	5.11	5.30
20 days	261	251	90	22.95	5.12	5.36
15 days	262	253	92	22.88	5.23	5.38
LSD at 5% level	6.63	11.49	3.02	ns	0.63	ns

In a column, different small letters indicate the differences between treatments. ns=Not significant.

The labour requirement from seed bed preparation to harvesting in T_1, T_2 and T_3 was 266, 249 and 264 md ha^{-1} respectively in T. Aman season. But in Boro season it was 282, 265 and 280 md ha^{-1} in T_1, T_2 and T_3 respectively (Table 4). The cost for land preparation in T. Aman season was Tk 6,000, 2,500 and 4,200 in T_1, T_2 and T_3 respectively (Table 5). But in Boro season it was same for T_1 and T_2 but about 12% higher in T_3 treatment due to higher number of labour involved for removal of grass. Generally, irrespective of treatment higher number of labour required in Boro season due to more number of labour required for shorter type of seedling uprooting, transplanting. In both the seasons T_2 required the lowest number of labour. Irrespective of season, the grain yield had no significant difference in different treatments (Table 6). In both the seasons, total variable cost was the highest in normal cultivation practices followed by removal of straw/grass by hand and the lowest in herbicide applied plot. Total variable cost was higher in Boro season due to higher cost of irrigation, fertilizers and labourers. In both the seasons the highest gross margin was obtained from T_2, hence the cost of per kg of rice was the lowest in T_2. It was Tk 19.65 and Tk19.03 in Aman and Boro season respectively. Irrespective of treatments, the BCR was higher in Boro season than Aman. In Aman season, it was 1.25, 1.35 and 1.26 in T_1, T_2 and T_3 respectively. In Boro season, it was 1.29, 1.37 and 1.30 in T_1, T_2 and T_3 respectively. Gross margin showed that in Aman

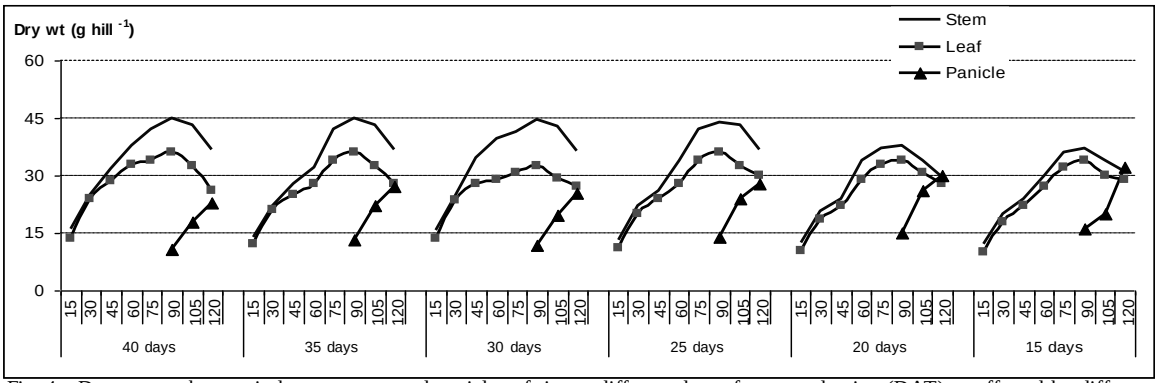


Fig. 4. Dry matter changes in leaves, stems and panicles of rice at different days after transplanting (DAT) as affected by different seedling ages.

Table 4. Labour requirement (md ha^{-1}) of different tillage operations for rice cultivation in Aman 2015 and Boro 2015-16 season.

	Seed bed preparation, seedling uprooting etc		Transplanting		1st weeding		2nd weeding		Harvesting		Carrying threshing cleaning drying		Total	
	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro
T_1	26	28	58	60	40	42	30	34	44	48	68	70	266	282
T_2	26	28	58	60	30	32	25	29	44	48	66	68	249	265
T_3	26	28	58	60	40	42	30	34	44	48	66	68	264	280

Labour wage Tk 300 per labour.

Table 5. Cost (Tk ha^{-1}) of different tillage operation for rice cultivation in Aman 2015 and Boro 2015-16 season.

Cost item	Aman (BRRI dhan49)			Boro (BRRI dhan29)		
	T_1	T_2	T_3	T_1	T_2	T_3
Land preparation: Diesel, driver, labour and herbicide	6,000	2,500	4,200	6,000	2,500	4,700
Labour for different operation	79,800	74,700	79,200	84,600	79,500	84,000
Seed	700	700	700	700	700	700
Fertilizer	6,574	6,574	6,574	12,000	12,000	12,000
Insecticide	10,000	10,000	10,000	10,000	10,000	10,000
Irrigation	8,500	8,500	8,500	24,000	24,000	24,000
Total variable cost (TVC)	1,11,574	10,2,974	10,9,174	1,37,300	1,28,700	1,35,400

Labour wage Tk. 300 per labour.

Table 6. Yield, gross return, gross margin, cost of production of per kg rice and BCR for different tillage of rice cultivation in Aman 2015 and Boro 2015-16 season.

Item	Aman (BRRI dhan49)			Boro (BRRI dhan29)		
	T_1	T_2	T_3	T_1	T_2	T_3
Grain yield (t ha^{-1})	5.25	5.24	5.21	6.80	6.76	6.74
Straw yield (t ha^{-1})	6.56	6.45	6.28	7.21	7.20	7.21
Gross return (Tk ha^{-1})	139120	138660	137600	177716	176688	176204
Total variable cost (Tk ha^{-1})	111574	102974	109174	137300	128700	135400
Gross margin (Tk ha^{-1})	27546	35686	28426	40416	47988	40804
Cost of production (Tk kg^{-1} rice)	21.25	19.65	20.95	20.18	19.03	20.09
BCR	1.25	1.35	1.26	1.29	1.37	1.30

Price of rice and straw per kg : Tk 24 and Tk 2 respectively.

season, application of T_2 instead of T_1 and T_3 Tk (35,686-27,546) ha^{-1}=Tk 8,140 ha^{-1} and Tk (35,686-28,426)=Tk 7,260 ha^{-1} respectively will be more profitable. But in Boro season, application of T_2 instead of T_1 and T_3 Tk (47,988-40,416) ha^{-1}=Tk 7,572 ha^{-1} and Tk (47,988-40,804)=Tk 7,184 ha^{-1} respectively will be more profitable.

The conclusion is that land preparation in BRRI Gazipur farm, no need to four/five ploughing followed by laddering. Land can be prepared as option 1: One ploughing followed by removal of grass by hand and laddering or option 2: Herbicide application followed by one ploughing and laddering is sufficient.

Farm Machinery and Postharvest Technology Division

SUMMARY

A programme was undertaken to develop a prototype of combine harvester using locally available materials in Janata Engineering workshop, Chuadanga under private public partnership (PPP). BRRI provides design, drawing, technical and financial support to develop and fabricate the machine. The study was aimed at design, fabrication and testing the performance of the prototype. The preliminary performance of the 2nd version was tested in wheat and Aus2016 season to find out the capacity, efficiency, operation fault etc. It was found that harvesting capacity and fuel consumption were 0.23~0.27ha/h, 3.5~3.80 l/hrespectively.

The existing prilled urea applicator was modified for long duration Boro variety. The gap between impeller center and release lever was 13 mm and 19 mm for long and medium durationBoro varieties, 37 mm for Aman or Aus varieties. The urea dispensed rate per wheel revolution of the machine for 13 mm, 19 mm and 34 mm distance of impeller 17.0~17.50 gm, 13.0~14.0 gm and 9.0~10.0gm respectively. The length and width of the impeller was 9.7 and 1.8 cm.Now farmer can apply prilled urea by this applicator for Aus, Aman and long duration Borovariety as well.

A push-pull type single row conical weeder was designed and fabricated in the FMPHT divisional research workshop. The weeder can uproot and bury the weeds in a single row at a time with push pull operation. The conical weeder was found suitable to control weeds in the line transplanted field. Moreover, farmers can use this weeder in their field to get more comfort ability in weeding and mulching.

A comparative study of BRRI manually operated and self-propelled mechanical rice transplanter was conducted at BRRI experimental plot, during Boro2015-16season. The seedling was raised in plastic tray and 20-day-old seedling of BRRI dhan63 was transplanted in all the experimental plots. The field capacity of the mechanical and BRRI manual rice transplanter was 0.14 ha/h and 0.033 ha/h.The field efficiency of the self-propelled transplanter and BRRI manual transplanter was found 54 and 57 percent respectively. Percentages of missing hills of mechanical rice transplanter and BRRI manual rice transplanter was 10 and 11 percent respectively. The yield performance of BRRI manual rice transplanter was 5.89 t/ha and that of the mechanical rice transplanter was 5.83 t/ha.

The reaper machine can't be popularized due to scatters of harvested paddy and lack of binding facilities. The actual field capacity of reaper binder was 0.313 ha/h at an average operating speeds of 3.2 km/h. The average fuel consumption was found 657.50 ml/h. The cutting height was found 8-35 cm from ground level, which is quite similar to traditional sickle cutting. As the reaper binder has binding facilities and overall field performance was found quite good, so this reaper bindercan be used in farmers field until the combine harvester gets fully introduced.

A prototype of manually operated seed sower machine was designed and fabricated in FMPHT research workshop. The performance of the prototype was tested on the plastic tray and was compared with the manual sowing of same area. It revealed that the adjusting lever keeping on the middle of the 3 and 4 marked position of the machine gives the desired rated seed 120 g/tray and uniformity of the seeds (2-4 seeds per square cm). Furthermore, the time saving between seed sower machine and the manual sowing is 1:487.

A manually operated four-row (fixed row to row 30 cm) handle-type rice transplanter was designed and fabricated at FMPHT Research workshop according to the Auto CAD design. The transplanter are fabricated with locallyavailable materials such as iron strips, iron rods, plain sheet,nuts and bolts, rivets, aluminum plates,rods, springs etc. One person can operateit but two people can alternatively operate the machine for reducing human drudgery. The capacity of the machine was found 0.05 ha/h. The number of plants per hill varies from 4 to 6. Compared with manual transplanting the machine can save about 60% labour and 45% transplanting cost.

A de-husking machine was developed to improve the performance of rice processing. The capacity of developed de-husker was more than 600 kg/h in one pass and about 800 kg/hin second pass operation. Hulling efficiency was more than 90% in one pass and 100% in second pass. Milling recovery was 61.67% for BRRI dhan50 polished in friction type polisher. The average head rice recovery based on input paddy was 54%, which is

promising for processing of premiere quality of rice. In addition separately produced, husk and bran can be used for making briquette and extracting edible oil respectively.

Modified air blowing type (one-pass) huller was developed for processing parboiled paddy. An attemptwas madeto process unparboiled paddy with this huller by reducing rotor rpm with different sizes of pulleys. Among the five sizes of pulley, 254 mm size with 730 rotor rpm produced 44% head rice (based on input paddy supply) which was promising. In the field engelburg huller operate at 1200 rpm that's suitable speed for parboiled rice processing. At that rpm unparboiled paddy produces more broken rice. In this experiment, 1200 rpm for processingunparboiled paddy gives lowest head rice recovery (32%) and the highest broken rice (31%) percentage. Farmers and millers both will be benefited by using modified huller mill for both parboiled and unparboiled paddy in single pass operation.

Parboiled BRRI dhan63 with six different moisture contents (9.3, 10.1, 11.3, 12.2, 13.3 and 14.1%) were processed in the air blow typeengelberg huller to find out the optimum moisture content for milling. It was found that 10-11% moisture content (wb.) is suitable for milling of parboiled paddy processed in the air blow type engelberg huller and around 10% moisture content (wb.) was found best in terms of head rice recovery.

As BRRI dhan70 is premium quality rice, it could not be milled as unparboiled condition in existing steel engelberg huller mill effectively. It could be milled in semi and auto rice mill successfully in parboiled and unparboiled condition. However, it needs to follow special drying. Everyday four hours drying followed by stacking for tempering and continues three to four days to remove moisture content up to 11%.

Mechanization at four different selective levels was evaluated in the farmer's field at Pirgacha, Rangpur during wet season (June to November) 2015. Mechanical transplanting reduced 61% labour and 18% cost compared to manual transplanting. BRRI weeder, BRRI power weeder and herbicide application reduced 74, 91 and 98% labour whereas 72, 63 and 82% cost was same compared to hand weeding. Herbicide application reduced the substantial amount of labour and cost in weeding operation. Mechanical harvesting also saved 96% labor and 72% cost compared to traditional harvesting method using sickle. Herbicide with mechanical transplanting and harvesting by reaper were the most cost and labour saving operation in rice cultivation.

A study was performed to develop a business model based on the pros and cons of using small self-propelled reaper in harvesting rice at Bamonkanda, Bhanga, Faridpur and Satashia, Muksudpur, Gopalganj during Boro season 2016. Two models of reaper were used in harvesting rice. Data on the field performance of reaper were collected and socio-economic relationship between farm holders and labourers affecting different steps of harvest and post harvest operation was carefully observed. Fuel consumption was obtained 10 l/ha. Farmer's response on harvesting by reaper was satisfactory. The business on harvesting by reaper was found feasible in areas with acute labour shortage and high wage rate.

AGRICULTURAL MACHINERY DEVELOPMENT AND TESTING

Design and development of a combine harvester

A second prototype of whole feed combine harvester was fabricated using locally available materials in the Janata Engineering workshop, Chuadanga under private public partnership (PPP) programme. BRRI provides design, drawing, technical and financial support to develop and fabricate. The faults of first version were taken in consideration to fabricate the second version. The important functional elements are cutter bar, reel, grain screw conveyer, feeding conveyer, threshing drum, blower fan, paddy screw conveyer and driving power of the combine. The grain holding tank and bagging system are also considerable parameters to design a combine harvester. The designparameters were:

- The rotational speed of the screw conveyer was higher than the forward speed of the combine to avoid grain loss;
- The capacity of conveying feeder was designed to match with the reel speed;
- The cutting height of the plant can be adjusted from 10~80 cm with the cutting speed

400~450 rpm, and reel peripheral speed 25–50% greater than the machine forward speed;

- The threshing drum speed considered 550~600 rpm, which is same as close drum thresher;
- The inclination of grain conveyer is greater than 30°;

As per design, specifications and considering the first prototype's faults, second prototype was fabricated and tested in wheat and Aus2016 season to evaluate the performance. Tables 1 and 2 present the preliminary test results.

Harvesting wheat

Harvesting rice

Plate 1. Field operation of BRRI combine harvester.

Salient feature

Dimension (Length×Width×Height) cm		305×152×180
Feeding capacity, kg/s		2.5
Working efficiency/ Area coverage	(ha/h)	0.21~0.31
	(Bigha/h)	1.58~2.29
Effective cutting width (cm)		120
Number of reaped (row to row distance: 20cm)		6
Type of reaping		Cutting blade and two blades sliding cutting
Operators needed		2
Threshing type	Whole feeding	Single threshing drum
	Threshing drum Type	Axial flow, spike tooth
	Threshing drum (Diameter and length)	46 cm×86 cm
Cleaning		Chaffer sieve + fan (front blowing and rear suction) + two time vibrate
Engine	Type	Water cool, four stroke, single cylinder, diesel engine
	Model	2H130ND
	Output/rpm, kw/rpm	23.86/2200
	Starting system	Self
	Fuel tank capacity, L	10
Traveling system	Crawler specification (width×pitch×No.of tooth)	40 cm ×9 cm ×46
	Ground pressure,kpa	21
	Ground clearance, cm	26
	Transmission	Hydro-static transmission (HST)
Fuel consumption, l/h		3.5~4.0
Working speed, km/h		1.69~2.45
Screw conveyer typer		Extendible transverse conveyer
Grain tank capacity (kg)		40 and two bagging system
Wet field passing (Depth)		15cm
Grain unloading method		Manually

Table 1. Field performance of combine harvester.

Plot no.	Duration of test (Working hrs.)	Travel speed (km/h)	Rate of work				Fuel consumption l/h
			Area covered		Grain output	Straw output	
			(bigha/h)	(ha/h)	(kg/h)	(kg/h)	
1	3.0	2.00	1.79	0.24	1078.92	863.14	4.00
2	2.5	2.39	2.24	0.30	1346.63	1077.30	3.50
3	4.0	2.23	2.08	0.28	1255.50	1004.40	4.20
4	5.0	1.73	1.61	0.22	972.00	777.60	4.10
5	3.0	2.12	1.98	0.27	1194.75	955.80	3.90
Average		2.17	2.00	0.27	1206.77	965.41	3.80
Crop: *Wheat*							
1	4.0	1.98	1.85	0.25	742.50	519.75	3.75
2	5.0	2.45	2.29	0.31	918.00	642.60	3.90
3	2.0	2.12	1.98	0.27	796.50	557.55	4.00
4	3.5	1.69	1.58	0.21	634.50	444.15	3.70
5	3.0	1.87	1.75	0.23	702.00	491.40	3.50
Average		1.85	1.73	0.23	693.00	485.10	3.65

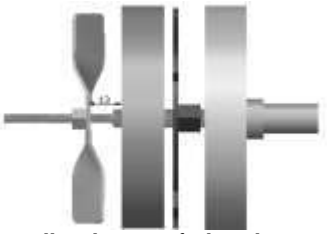
The fuel consumption was 3.65~3.80 l/h and field capacity 0.23~0.27 ha/h. However, it was observed abnormal exhaust gases/colour with lower engine performance, so that engine power needs to increase for obtaining better capacity. In general, developed combine harvester is appropriate in both dry and muddy fields, but some minor defects were observed during the testing.

Modification of BRRI prilled urea applicator (PUA) for long duration variety

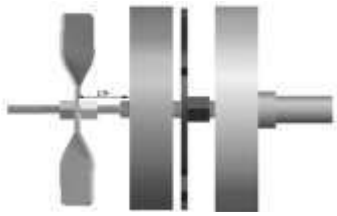
The existing prilled urea applicator was suitable for placing urea fertilizer in short to medium duration variety and maximum 180~190 kg urea can be placed by the machine. This amount of urea was not enough for long duration (more than 145 days) variety. That's why the machine has been modified for long duration variety. The gap between impeller center and discharge outlet lever has readjusted to increase pressure on urea release lever. If pressure increase on urea releases lever then it opens more and dispenses more urea. The gap between impeller center and release lever was 13 mm and 19mm for long and medium duration Boro varieties, 37 mm for Aman/Aus varieties. The urea dispense rate per wheel revolution of the machine for 13 mm, 19mm and 34mm distance of impeller 17.0~17.50gm, 13.0~14.0gm and 9.0~10.0gm respectively. An impeller was connected bellow of the tank as well as metering device that conveyed urea without clogging. Length and width the impeller was 9.7 and 1.8 cm. Both sides of the impeller were twisted about 35° angles with its horizontal axis (plate 2).

An observation trial was conducted during Boro 2015-16season at BRRI HQ and BRRI dhan29 was used as variety. Urea management options were: T_1=BRRI prilled urea applicator (225 kg/ha), T2=Hand broadcasting of prilled urea (270 kg/ha, recommended rate). Hand broad casting of prilled urea (T_2) was applied in three equal splits i.e. 1/3 at active tillering stage and 1/3 at 5-7 days before PI stage and rest of 1/3. Used as top dose. Transplanting operation was done on 2 February 2016 and prilled urea application was done on 10 February 2016. Phosphorous, potassium, sulphur and zinc fertilizers were applied at final land preparation. All intercultural operations were done properly when required. Data of tillering ability was collected in three times i.e. 38 days after transplanting (DAT), 51 DAT, 61 DAT and 105 DAT (Table 2). Effective tiller difference was found in between two treatments from the observation trial. Higher effective tiller was found in the treatment of T_1 followed by the other treatment. The higher plant height and number of tiller was found in treatment T_1 compared to treatment T_2. Even the grain yield (t/ha) was differed among the two treatments. Higher yield was found in treatment T_1. Prilled urea application by applicator (225 kg/ha) gave the highest grain yield of 5.86 t/ha followed by hand broadcasting (270 kg/ha, recommended rate).

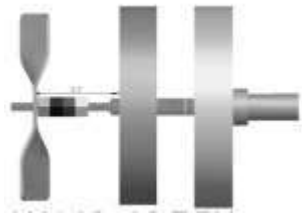
In this applicator without changing impeller, one option was added for applying urea for long duration variety. Now farmer can apply prilled urea by BRRI prilled urea applicator for Aus/Aman season and long duration variety. Farmer may be suggested to apply BRRI prilled urea applicator for



Impeller adjustment for long duration Boro



Impeller adjustment for medium duration Boro



Impeller adjustment for Aus/Aman

Plate 2. Arrangement of PUA impeller for different seasonseason. and variety.

long duration variety as well as saving urea so that they will be economically benefited.

Test and evaluation of single row conical weeder

A manually operated conical weeder was designedon the basis of locally available low cost materials considering 14-16 cm width of operation for uprooting weedes and mulching of soil. At first engineering design was done with the help of AutoCAD programming and a prototype was fabricated according to design. The fabricated weeder was tested in the BRRI research field and Jogitola, Gazipur. The force requirement of operation was measured in the field using spring balance, rope and three person involved in the test.

General features and detail specifications of the weeder:

Particulars	Specification
Function	For weeding in between rows of line sowing paddy crop
Power	Manually operated
Number of operators	One person
Type of operation	Push pull operation
Operating condition	Water must be more in the field at the time of weeding
Number of rows	Single row
Weight	5.4 kg.
Width of operation	130-150 mm
Number of cones (rotors)	2 Nos. Cones are made of 20 gage MS sheet.
Blades	1.2 mm thickness Each cone has the following blades (20 gage MS sheet) i) 6 numbers of plain blades and, ii) 6 numbers of serrated blades
Cone rotor holder spindle/ axle and nail	2 Nos. ; 12 mm dia and 118 mm length with 24 mm diameter head on the top of the spindle/axle
Skid / float assembly	1.2 mm thickness of 20 gage MS sheet used Size: 220×121×62 mm with front 140 mm length of skid apex Float angle 25 Degrees.
Handle	Main pipe: Dia: 26 mm Length: 1363 mm Cross bar: Dia: 26 mm; Length: 303 mm
Height adjustment lever	2 Nos Length: 160 mm; width 20 mm; thickness : 4 mm
General information	The BRRI conical weeder has two cone shape rotors mounted in tandem with opposite orientation. Smooth and serrated blades are mounted alternately on the rotor to uproot and burry weeds when the rotors create a back and forth movement in the top 3 cm of soil.

Table 2. Effect of fertilizer dose adjustment for long duration variety by applicator.

Treatment	Agronomic parameter	38 DAT	51 DAT	61 DAT	105 DAT	Effective tiller (No.)	Avg. yield (t/ha) at 14% mc
T_1	Average Plant height, cm	42.6	63.8	77.8	102	68	5.86
	No of tiller (5 hill)	72	102	99	81		
	Average Plant height, cm	38.2	53.6	61.8	88.2		

Note: T1 = BRRI prilled urea applicator (225 kg/ha), T2 = Hand broadcasting of prilled urea (270 kg/ha, recommended rate).

Plate 3. Operation in Jogitola ,Gazipur and BRRI research field.

Field performance of the weeder

The fabricated weeder was tested in the BRRI research field and outside of the BRRI at Jogitola, Gazipur and data were collected (Plate 3). Table 3 presents the performance of the weeder. The pushing force of weeder was measured by using spring balance. The soil was clay loam with paddling soil. The average pushing force of the weeder was found 43.42 N.

The conical weeder comprises of a long handle to push conical rotors for trampling the weedes growing between paddy rows. The weight of the conical weeder is 5.4 kg. The conical weeder was found suitable to control weeds in the line transplanted field. The weeding efficiency of the conical weeder was 81.68, 82.16% at Jogitola, Gazipur and BRRI research field, Gazipur respectively. The effective field capacity of the conical weeder was 0.02 ha/h, 0.021 ha/h at Jogitola, Gazipur and BRRI research field, Gazipur respectively.The operating cost on the basis of Tk/ha for conical weeder 2,431**.** The weeder can uproot and bury the weeds in a single row at a time with push-pull operation. Maximum weeds uproot only by pushing the weeder in forward direction. It is easy to operate by women labouresalso. Moreover, farmers can use this weeder in their field to get more comfort ability in weeding and mulching.

Comparative performance of rice transplanters

BRRI manually operated (6rows) and self-propelled mechanical walking type (4 row) transplanter was evaluated in this study. The evaluation was conducted inBoro2015-16season at BRRI HQ research plot using 20-day-old seedling of BRRI dhan63. The field capacity of the mechanical and BRRI manual rice transplanter was 0.14 ha/hand 0.033 ha/h.The field efficiency of the self-propelled transplanter and BRRI manual transplanter was found 54 and 57 percent respectively. Percentages of missing hills of mechanical rice transplanter and BRRI manual rice transplanter was 10 and 11 percent respectively. The yield performance of BRRI manual rice transplanter was 5.89 t/ha and that of the mechanical rice transplanter was 5.83 t/ha. It was observed that there was no significant yield difference between BRRI manual rice transplanter and Mechanical rice transplanter.

Test and evaluation of reaper binder

Harvesting by machine is only in the demonstration phase in Bangladesh.During harvesting of Boroand Aus paddy, often rains and storms occurs causing considerable damage to standing crops. Shortages of labour, farmers are compelled to delay harvesting and sometimes they can't harvest. Thus, harvesting is considered as a major pain point in Bangladesh agriculture. The reaper machine doesn't have binding facilities and harvested crop sometimes laydown haphazardly on the field. That's why an imported self-propelled walking type reaper binder introduced to find out as alternative harvesting machine in Bangladesh. After cutting, the crop is conveyed vertically to the binding mechanism and released to the ground in the form of bundles. Reaper binders are suitable for standing rice and wheat crop.

Table 3. Field performance of the weeder.

	Effective field capacity (ha/h)	Degree of weeding / weeding efficiency (%)	Plant damage (%)	Walking speed (k/h)	Comment
Operation in Jogitola, Gazipur					
	0.020	82.55	1.64	1.32	Clay type muddy soil with medium weed infestation
	0.019	82.23	1.57	1.23	Clay type muddy soil with light weed infestation
	0.017	82.41	2.30	1.20	Clay type muddy soil with medium weed infestation
	0.022	80.26	3.03	1.57	Clay type muddy soil with high weed infestation
	0.021	80.96	1.46	1.37	Clay type muddy soil with high weed infestation
Avg.	0.02	81.68	2	1.34	
Operation in BRRI research field, Gazipur					
	0.021	81.15	1.57	1.28	Clay type muddy soil with medium weed infestation
	0.020	79.65	1.83	1.37	Clay type muddy soil with high weed infestation
	0.021	85.21	2.45	1.16	Clay type muddy soil with light weed infestation
	0.020	81.96	2.15	1.24	Clay type muddy soil with medium weed infestation
	0.022	82.82	3.16	1.35	Clay type muddy soil with medium weed infestation
Avg.	0.021	82.16	2.23	1.28	

A 5.0 HP single cylinder 4 stroke, air cooled diesel run (Model: CF178F) reaper binder was used for paddy harvesting. It has fixed cutting width of 60 cm with an adjustable cutting height of 7-35 cm from ground level. The crop was left aside after cutting at the right side of the machine. Table 4 presents the detailed technical specification of reaper binder. Observations on speed of operation, width of cut, total time taken to cover the area and fuel consumption were recorded.

The reaper was tested during Aman2015 and Boro2016 season. Technical performance of reaper binder was determined by measuring different harvesting losses, cutting area and fuel consumption at BRRI field. It was observed that the actual cutting width of binder was 60 cm. The actual field capacity was 0.313 ha/h at an average operating speeds of 3.2 km/h. The average fuel consumption was measured at 657.50 ml/h. It was revealed that the machine can cut the paddy at an average 8-35 cm height from ground level, which was quite similar to traditional manual sickle cutting. The average diameter of the reaping bundle was found 10.09 cm and number of tiller was 190 per bundle.

The rope available in Bangladesh is not suitable for reaper binder. The rope holder was modified according to available rope. The location of exhaust pipe, operating handle, star wheel, position of ledger plate etc have been changed to improve the performance of the machine. As this reaper has binding facilities and overall field performance was found quite good, so this reaper can be used in farmers field until the combine harvester fully introduced.

Design and development ofseed sower machine for mat type seedling

The engineering design of the seed sower machine was done with the help of AutoCAD engineering tools (software).The prototype of the machine was fabricated in FMPHT research workshop according to the design (Plate 4a and b) criteria. The performance tests of the BRRI seed sower machine are indicated mainly by field efficiency, sowing rate, operating time and uniformity. The seed sower machine was tested extensively in laboratory and field conditions.

Table 4. Technical specification of reaper binder.

Item	Dimension
Engine type	Single cylinder (vertical), 4-stoke, air cooled diesel engine
Bore × stroke (mm)	78×62
Normal speed rpm	3000
Rated output (kW/hp)	3.68/5.0
Fuel consumption (ml/h)	375
Dimensions (L×W×H) mm	495×485×530
Weight (kg)	36
Cutting width (no. of row) mm	60 (2 row for machine transplanting and 3 for hand transplanting)

Plate 4a. Auto CAD drawing of BRRI seed sower machine.

Plate 4b. View of BRRI seed sower machine.

Plate 5a. Auto CAD drawing of seed meter.

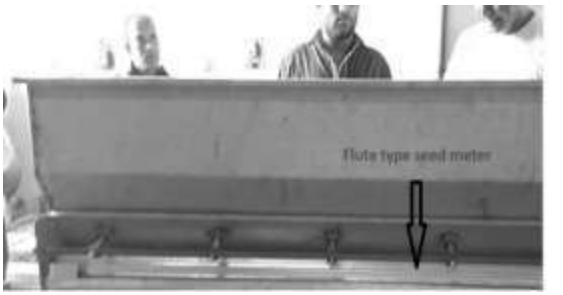


Plate 5b. Flute type seed meter.

Metering device. Flute type seed metering device has been provided in the seed box. The outer diameter of seed meter 54 mm and length is 1250 mm. There are 14 number of seed cells are provided at periphery of each seed meter. An elliptical hole is provided at the center of seed meter. Elliptical shape of the hole provides positive engagement of the shaft. The seed meter is shown in Plate 5a and b.

Power transmission. Power to the shaft of the seed metering mechanism is transmitted by means of roller chain and sprocket arrangement. The power to the seed meter shaft provided at center is transmitted from ground wheel shaft. The three sprockets are used to transmit power to the shaft. Two sprockets are mounted on ground wheel shaft having 12 teeth and one sprocket on seed meter shaft having 16 teeth. The chain and sprocket arrangement is shown in Plate 6a and b.

Seed box with adjustment lever. It is made up of 2 mm thick plain sheet. The each seed box capacity is 40 kg of rice seed. The overall length and width of the seed box are 1290 mm and 380 mm respectively. The box is mounted on frame with the help of support. Seed rate is maintained by sliding mechanism controlled by adjusting the lever provided at one side Plate 7c and d. The seed box is shown in Plate 7a and b.

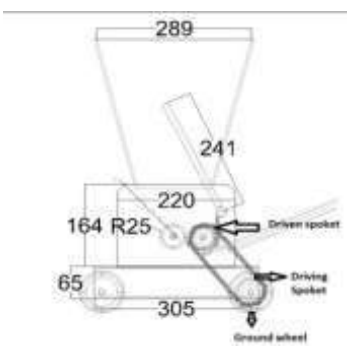


Plate 6a. Chain and sprocket arrangement.

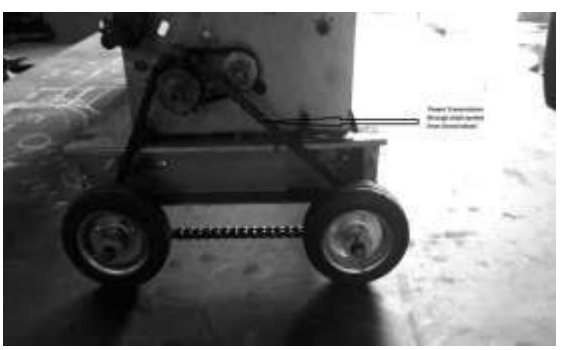


Plate 6b. Chain and sprocket arrangement in the sower machine.

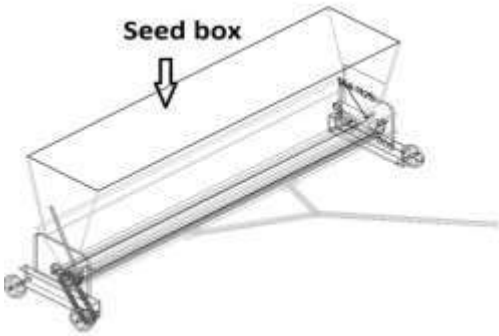


Plate 7a. Auto CAD drawing of seed box.

Plate 7b. Seed box.

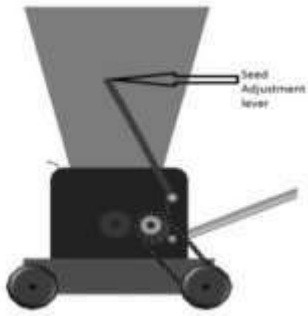


Plate 7c. Drawing of seed adjustment lever.

Plate 7d. Seed adjustment lever in the machine.

Working principle of seed sower machine. When the sower machine moves in forward direction with the help of handle, the ground wheel in contact with the soil rotate. The ground rotation of ground wheel shaft is also rotate along with sprocket rotate. The rotary motion of the ground wheel is transmitted power to the seed meter shaft by using a chain mechanism. The seed box shaft rotate with the help of pully and belt arrangement along with rotates the vertical rotors with cells on the periphery fitted inside the seed box. The seed are stored under seed meter with the help of sliding mechanism maintaining the level of seed in the box and the metering device pick up the seeds from the seed hopper in the cells and drop them in the field.

Field performance of the BRRI seed sower machine

The preliminary field performance of the machine was conducted both laboratory and BRRI field. Sowing is carried out simultaneously by sower machine and manual method in the fields having 0.001008 ha areas. The time was taken 16sec and 7800 sec respectively. It revealed that the adjusting lever keeping on the middle of the three and four marked positions of the machine give the desired rated seed 120g/tray and uniformity of the seeds (2-4 seeds per square cm). The time of sowing was saved with the ratio of 1:487.5 between seed sower machine and manual method.

Design and development of handle type manual rice transplanter

A manually operated four-rowhandle-type rice transplanter was fabricated at FMPHT research workshop according to the Auto CAD design. The transplanter are fabricated with localllyavailable materials such as iron strips, iron rods, plain sheet, nuts and bolts, rivets, aluminum plates, rods, springs etc. Table 5 shows salient features of the machine. The row-to-row spacing is 30 cm whereas plant-to-plant spacing can be changed as per requirement. The machine is backward pull-type and it can transplant four rows in a single pass. Floating facilitate the transplanter to slide over the puddled soil surface. Fixed opening type pickers were used with the transplanting arm of the machine.

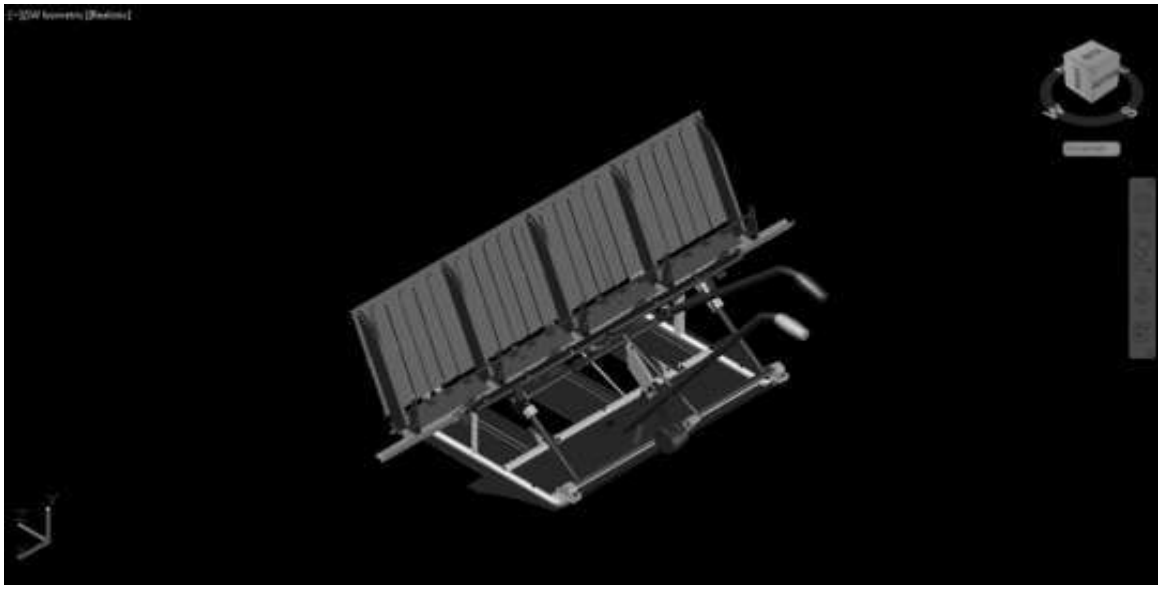


Plate 8. AutoCAD drawing of the BRRI manual rice transplanter.

Table 5. Salient features of the BRRI manual operated rice transplanter.

Particular	Specification
Machine type	Manually operated
Overall dimensions of the machine, cm	140x120x50
Weight of the machine	30
Source of power	Manual
Type of seedling use	Mat type
No. of rows	4
Row to row spacing, cm	30
Plant to plant spacing, cm	13-15
Width coverage, cm	90
Type of fingers	open
No. of persons required to work on machines	2
Including nursery uprooting and transport	
Cost of the machine, Tk	25,000.00

Performance test

The preliminary performance of the machine were tested in BRRI research field is shown in Plate 9 and10.

Plate 9. Field operation of the machine.

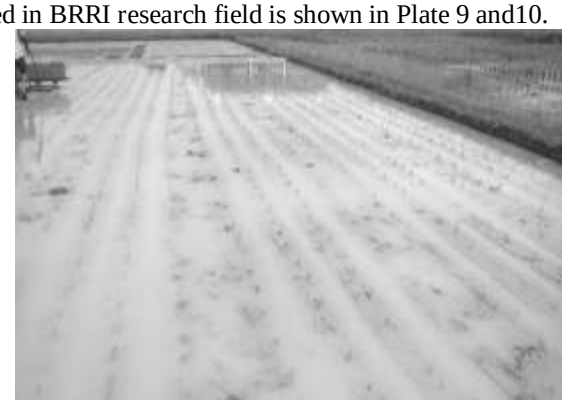


Plate 10. Machine transplanted field.

The performance of the machine for transplant paddy has been found to be satisfactory. One-person can operation it but two person can alternatively operate the machine for the whole day. The capacity of the machine is 0.05 hac/h. The number of plants per hill varies from 4 to 6. Compared with manual transplanting the machine can save about 60% labour and 45% transplanting cost.

MILLING AND PROCESSING TECHNOLOGY

Test, evaluation and modification of rubber roll de-husker

Existing rubber roll de-husker was modified introducing a cyclone separator attached in the de-husker for collecting husk. Previously, husk was directly collected from aspirator discharge outlet with gunny bag that created huge amount of dust in the working area. De-husked paddy was processed in MNMP-15 model friction type polisher to evaluate the milling parameter.BRRI dhan50 (unparboiled) was used in this experiment and the moisture content was 11% (wb.) and each sample size was 20 kg.

It was found that the average capacity of the husker was 618 kg/h. Husking efficiency was found 92% in one pass and 100% second pass. Husking efficiency can be increased by closing the adjustable roller in single pass. However, the breakage percentage might be increased. The average brown rice percentage was found 77% (based on input paddy). Brown rice of BRRI dhan50 from rubber roll de-husker was polished in friction type polisher. It was found that the average milling recovery was 61.67% and head rice recovery (based on input paddy) was 54%.

Improvement of air-blow type engelberg huller

Modified air blowing type (one-pass) huller was developed for processing parboiled paddy. BRRI FMPHT Division takes initiative to process unparboiled paddy with this huller by reducing rotor rpm with different sizes of pulley. BRRI dhan29 was used as unparboiled as milling materials and the moisture content was 11% (wb). The capacity was ranged from 145-200 kg/h for unparboiled paddy using different sizes of rotors pulley. This was lower than the capacity of parboiled paddy (250-300 kg/h) because un-parboiled paddy cannot feed in the milling shaft of its full capacity. Milling recovery of BRRI dhan29 was about 63-64% and no difference was found for different types of pulley. Head rice recovery was 32, 35.2, 39.37, 41.59 and 44% (Based on input paddy) for the pulley size of 152 mm, 178 mm, 203 mm, 229 mm and 254 mm respectively. Maximum head rice recovery (44%) was found in 254 mm size pulley with 730 roller rpm and at that stage less broken percentage (20%) was found. Electric consumption was also varying from 75 kWh to 103 kWh for processing one ton of paddy for different sizes of pulley varied from 152 mm to 254 mm. No unhulled paddy was found in the milled rice processed by air blow type engelberg huller with the different sizes of pulley.

Study on milling recovery of BRRI dhan63 at different moisture content

BRRI dhan63was used under parboiled condition to find out milling recovery at the different moisture contents of 9.4, 10.1, 11.5, 12, 13.3 and 14.1% (wb.). The paddy was processed in air blow type steel huller mill. The milling capacity of air blow type engelberg huller was found from 399 to 433 kg/h for parboiled BRRI dhan63. Milling recoveryat moisture content of 9.3, 10.1, 11.3, 12.2, 13.3 and14.1% were 67.0, 67.5, 68.0, 68.5, 69.0 and 70% respectively. Head rice recovery (based on input paddy) atmoisture content of 9.3, 10.1, 11.3, 12.2, 13.3 and 14.1% were 54.0, 59.4, 57.46, 53.10, 50.71 and 50% respectively. Higher head rice recovery at 10.1% and 11.3% moisture content (wb.) was 59.4 and 57.46% respectively. Broken rice percentage (based on input paddy) was found as the lowest (8.0%) in 10.1% moisture content (wb.) and the highest (20.25%) in 14.1% moisture content. No unhulled paddy was found in the milled rice processed by air blow type engelberg huller. It is concluded that 10-11% moisture content (wb.) is suitable for milling of parboiled paddy processed in the air blow type engelberg huller. Moisture content (wb.) around 10% was found most suitable in terms of head rice recovery and less broken percentage.

Milling quality evaluation of BRRI dhan70 milled in different types of rice mill

BRRI dhan70 is one of the premium quality rice among the BRRI released varieties. As BRRI dhan70 is a long grain variety, farmers have faced problem to process the paddy in existing steel engelberg rice mill as unparboiled condition. Three existing laboratories, improved air blow type and Korean rice mill was used to observe the milling performance of BRRI dhan70. Seven months aged paddy was processed as parboiled and unparboiled condition at 11.0 and 11.5% moisture content respectively. The sample size was 200gm for laboratory mill and 50 kg for other two mills. Three replications were taken for each rice mill. High head rice yield is one of the most important criteria for measuring milled rice quality. Broken grain has normally only half of the value of head rice. The head rice of laboratory, air blow type and Korean rice mill was 96.24, 88.70 and 81.29% respectively as parboiled condition (based on total milled rice), whereas 93.28, 71.73 and 78.88% was for unparboiled condition respectively. The degree of milling was found 8.20, 10.45 and 12.30% in laboratory, engelberg huller and rice mill respectively.

Workshop Machinery and Maintenance Division

SUMMARY

The gearbox of self-propelled power unit was developed in the WMM Division and fabricated in BRRI research workshop. Power transmission unit of the reaper was tested in paddy and wheat field. The problem of this gearbox was identified through performance evaluation of power transmission systems. The performance of the self-propelled reaper was found satisfactory. The gearbox is functionally well but it is a little bit heavy. So, a new type of gearbox with compact size and reduced weight has been designed with the help of AutoCAD tools and developed at BRRI research workshop. In this machine for easy power transmission, a gearbox with mechanism of two forward and a backward speed have been introduced. Fabrication of power transmission system of the reaper is going on and it will be tested in the next season.

The reaper travelling wheels was modified by increasing the width of the wheels. Fabrication of the reaper wheels have been completed according to the design using the locally available materials at BRRI research workshop. The width of reaper travelling wheels was increased to resist the soil resistive force. It has been tested in the semi-wet paddy field at BRRI farm, Gazipur. It performed well at semi-wet land condition due to the increased contact area between the reaper travelling wheel and soil. But, there was a problem in tail-wheel to operate it in wet land. A tail wheel has been modified by increasing the width and fabricated it at BRRI research workshop to overcome this problem. It will be tested in the next season.

Experiments were conducted at BRRI RS Rajshahi in Aman 2015 and Boro 2016 seasons to determine paddy yield as influenced by different tillage depths. There were three tillage depths such as: 4-5, 5-6 and 6-7 inches. Tillage depths affected both the yield of BRRI dhan34 in Aman 2015 and BRRI dhan28 in Boro 2016 season. The highest grain yield of BRRI dhan34 in Aman 2015 season was found 2.12 t/ha in the tillage depth up to 6-7 inches and the lowest yield was found 1.61 t/ha in the tillage depth up to 4-5 inches. On the other hand the highest grain yield of BRRI dhan28 was found 4.37 t/ha in the tillage depth up to 6-7 inches and the lowest yield was obtained 3.10 t/ha in the tillage depth up to 4-5 inches in Boro 2015 season. The highest yields of all the seasons were found under the higher tillage depths up to 6-7 inches and the lowest yields were obtained in the tillage depth up to 4-5 inches. Fuel consumption and time in different plots were more or less same in both the seasons.

The survey was conducted on machinery used in farmer's field at Bonogram and Bbiprobel Goria villages in Noldanga upazila of Natore district. Power tiller, shallow tube well, sprayer, open drum thresher and close drum thresher have been used in these villages. There are no weeder, reaper, combined harvester, transplanter etc at the farm level of these areas. So, there is a scope to introduce these machinery in the area. The problem is that the operator of the machine is unskilled and they never follow proper machinery maintenance schedule, which increases their operation time and repair cost. So, proper training should be arranged for the machinery operators.

Agricultural machinery workshops were surveyed at different places in Bangladesh. The facilities of machinery of the workshops are foundry, lathe, shaper, drill, milling, grinding, welding, metal cutting and colour compressor. Close drum thresher, open drum thresher and maize sheller are the common machinery produced by the manufacturers, and someone also produce chopper, bed planter, winnower and weeder. Local workshops play an important role to reach the agriculture machinery at farm label because they use the locally available materials to manufacture the machinery. As a result, the manufacturing cost of the machinery will be low. So, we should look after at our local manufacturer. Lack of fund is the main problem to the manufacturers to produce machinery. They need subsidy and proper support from the government, which will help them to produce the machinery by improving their workshop.

Repair and maintenance works of transport/vehicles and different farm machinery of BRRI were done under WMM Division. There were 36 vehicles (4-wheeler), 99 motor cycles, three tractors with accessories, 23 power tillers,

seven hydro-tillers, one reaper, one BRRI field mower, 18 pumps, one open drum thresher, two engines, and other farm machineries were repaired and changed of spare parts under major and moderate/minor repair and maintenance work. The total cost of major and moderate/minor repair and maintenance was Tk 50,68,436.00 from July 2015 to June 2016. The major repair and maintenance work was done by direct cash purchase, direct contracting through work order, RFQ (Request for quotation) and OTM (Open tender method) but the moderate/minor repair and maintenance work was done only by revolving fund.

DEVELOPMENT OF AGRICULTURAL MACHINERY

Design and development of power transmission system of a power unit

The power unit of a self-propelled reaper was developed by WMM Division and fabricated in BRRI research workshop. The problem of the power transmission unit of this reaper was tested in paddy and wheat field and its performance was found satisfactory. This gearbox is functionally well but it is little bit heavy. So, it is necessary to design a new gearbox with compact size and reduced weight. In this machine for easy power transmission, a gearbox with mechanism of two forward and a backward speed have been designed with the help of AutoCAD tools and developed at BRRI research workshop. Fabrication of power transmission system of the reaper is going on and it will be tested in the next season.

Power transmitting unit

Compact size with reduced weight power transmission unit of self-propelled reaper has been designed with the help of AutoCAD tools (Fig. 1) and developed at BRRI research workshop. Fabrication of reaper will be completed very soon and this will be used in the next season. Major components of self-propelled reaper have also been designed and these are given below:

- Power transmission system
- Chassis of the power unit
- Prime mover and
- Control accessories etc.

Fig. 1. AutoCAD drawing of power transmission unit of BRRI developed reaper.

Chassis of self-propelled reaper unit

The chassis of the self-propelled reaper unit consists of the following items:

- Gearbox
- Mainframe
- Ball bearing and journal bearing
- Positive clutch slider Driving
- wheels with axle Driving
- handles with tail wheel
- Gear shifting lever along with accessories
- Main power transmission shaft along with pulley and sprocket

Gearbox

The gearbox is a power-transmitting unit. It is simple in construction with forward and backward speed and a neutral gear position (Fig. 2). Figure 3 shows the gearbox with casing. In this gearbox, for forward speed of the reaper, gears are moving along with shaft carrying with load. The gearbox consists of different parts as listed below:

- Gearbox casing Gear
- shaft with key Gear
- pinion and Clutch
- Ball bearing and journal bearing
- Positive clutch slider
- Slider guide pin
- Gear liver mechanism etc.

Fig. 2. AutoCAD drawing of gearbox casing of BRRI developed reaper

Fig. 3. AutoCAD drawing of gearbox with of BRRI developed reaper.

Mainframe

The main frame was made of 3.0 mm thickness 50.8 × 50.8 mm m/s angle bar. It was fitted horizontally to the ground. The driving handle was fitted to the upper end of the mainframe by electric arc welding. The tail wheel also fitted to the back engine base frame by the arc welding.

Ball bearing and journal bearing

Five shafts were mounted to the side wall of the gearbox by four pairs of ball bearing. A pair of ball bearing was also used at the partition in the gearbox. Another two pairs of ball bearing were used at the wheel axle and one pair of ball bearing was used with power transmission shaft so that they move around the shaft independently.

Positive clutch slider

Two common forms of clutches are the square-jaw clutch and the spiral-jaw clutch. One of the members must always slide axial on feather keys or spines to engage and disengage the clutch. The square-aw clutch is the simplest form and can theoretically transmit torque in either direction without introducing a component of force. The spiral-jaw clutch can be engaged at somewhat higher speeds without serious clashing, but it can transmit torque in only one direction without requiring an external axial force to maintain the engagement. Straight spines are also widely used to give positive engagement with no tendency to develop an axial force.

Driving wheels with axle

The diameter of wheel was 69.4 cm. One pair of 45 mm diameter ms shaft was used for driving wheel axle. Two pair's ball bearings with pillow type casing were used to fit the wheel axle to the inclined trusses. A pair of 21.9 cm diameter sprocket was used in this axle to transmit power from the gearbox by a roller chain.

Driving handles with tail wheel

The driving handles were made of 20 mm diameter ms pipe. It is fitted to the upper end of the main frame by electric arc welding. Two ms rods were used to connect the other ends of the engine base frame to driving handles by electric arc welding.

Gear shifting lever along with accessories

Clutches are used to connect or disconnect shafts as required by the gear shifting lever. Two common forms of clutches are the square-jaw clutch and the spiral-jaw clutch. In this study, the positive spiral jaw clutches was used.

Main power transmission shaft along with pulley and sprocket

Continuous mechanical power is usually transmitted along and between rotating shafts. The transfer between shafts was accomplished by gears, belts, chains or other similar means for matching the torque/speed characteristics of the interconnected shafts. Shafts were supported by two bearings (sliding or rolling), which allowed the shafts to turn freely - there was no appreciable torque exerted by the bearings. A sliding bearing needed a lubricant film in the clearance space between shaft and bearing bush; in the fully hydrodynamic bearing illustrated the oil was dragged into the wedge-shaped gap causing a pressure build-up (similar to that in hydroplaning), which supported the shaft without metal-to-metal contact and little friction.

Modification of reaper travelling wheel for wet land condition

A low cost self-propelled reaper has been developed by WMM Division of BRRI using locally available material for harvesting rice and wheat. The performance of this reaper is good in fragmented land as well as dry-land condition but it has a problem in wet-land condition. During harvesting in wet-land, it does not move forward because its wheels (travelling wheel and tail wheel) goes down the soil and rotates in the same place. So, there is a scope to modify reaper travelling wheel and tail wheel for wet-land condition for harvesting rice and wheat. For this reason, this experiment has been undertaken at research workshop in BRRI, Gazipur, to modify a self-propelled reaper wheels using locally available materials.

The complete design of self-propelled reaper wheels has been done with the help of AutoCAD tools (Fig. 4). Fabrication of the reaper wheels have been completed according to the design using the locally available materials at BRRI research workshop (Fig. 5). It has been tested in the semi-wet paddy field at BRRI farm, Gazipur. It performed well at semi-wet land condition due to the increased contact area between the reaper travelling wheel and soil, which reduced the soil resistive force. But, there was a problem in tail-wheel to operate it in semi-wet land because it goes down the soil during operation due to its low width. A tail wheel has been modified by increasing the width (11.5 cm where the old was 3 cm) and it has been fabricated at BRRI research workshop to overcome this problem (Fig. 6). It will be tested in the next season.

Determination of tilling efficiency of power tiller at selected areas of Bangladesh

Tillage is an important agronomic practice to make the soil physically, chemically, and biologically suitable to improve seed germination, seedling emergence and for optimal plant growth. Tillage had significant effect on paddy yield. This might be due to exposure of roots to absorb more moisture and nutrients in deep tillage practices. Crop production could be increased by adopting appropriate tillage operation with different depths which needs intensive field research.

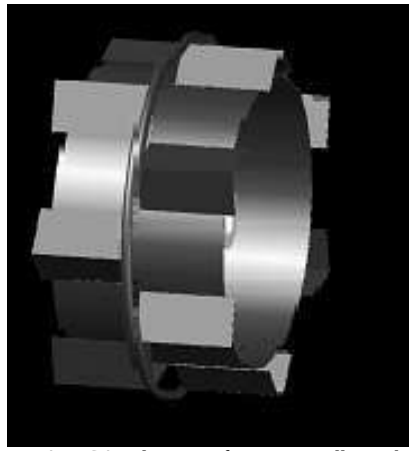


Fig. 4. AutoCAD drawing of reaper travelling wheel.

Fig. 5. Actual view of reaper travelling wheel for wet-land condition.

Fig. 6. Actual view of reaper tail wheel for wet-land condition.

Experiments were conducted at BRRI R/S Rajshahi in Aman 2015 and Boro 2016 seasons. The tillage depths were 4-5, 5-6 and 6-7 inches where BRRI dhan34 in Aman 2015 and BRRI dhan28 in Boro seasons were cultivated. The tillage depths were maintained by a power tiller. Time and fuel were recorded in every ploughing to measure fuel consumption. The paddy was irrigated and, weeding and other intercultural operations were done as and when necessary. Paddy was harvested at full maturity. The weights of paddy were recorded plot-wise.

The effects of tillage depths on grain yield of BRRI dhan34 in Aman 2015 and BRRI dhan28 in Boro 2016 seasons were varied from different tillage depths. Highest grain yield of BRRI dhan34 in Aman 2015 season was found 2.12 t/ha in the tillage depth up to 6-7 inches and the lowest yield was found 1.61 t/ha in the tillage depth up to 4-5 inches (Table 1). Table 1 also showed the highest grain yield of BRRI dhan28 was found 4.37 t/ha in the tillage depth up to 6-7 inches and the lowest yield was obtained 3.10 t/ha in the tillage depth up to 4-5 inches in Boro 2015 season.

Fuel consumptions were measured at different tillage depths during ploughing in Aman 2015 and Boro 2016. Table 2 and Table 3 showed the values of fuel consumption at different tillage depths in different plots in aman 2015 and Boro 2016 respectively. Fuel consumptions in first and second ploughing in different plots were same but it little bit varied in third and fourth ploughing in each and different plots at different tillage depths. Fuel consumptions decreased chronologically in each plot from first ploughing to final ploughing. Area of each plot was same and it was 820 m^2.

Required time was recorded at different tillage depths in different plots during ploughing in Aman 2015 and Boro 2016 and it was shown in Table 2 and Table 3 respectively. Time consumed in each ploughing in different plots at different tillage depths was more or less same but it decreased chronologically in each plot from first ploughing to fourth/final ploughing. Area of each plot was same and it was 820 m^2.

Survey on status and constraint of farm machinery used in farmer's field at selected areas

Mechanization is an important tool for profitable and competitive agriculture. The need for mechanization is increasing fast with the decrease of draft power. Without mechanization it will not be possible to maintain multiple cropping patterns, which need quick land preparation, planting, weeding, harvesting, processing etc. (MoA, 2009). But mechanization in the country is always associated with some inherent drawbacks like, fragmented lands, poor buying capacity of farmers, lack of quality machines for farm operation, inadequate knowledge of the users about machines and insufficient awareness building activities. So, it is necessary to identify the problems and demand of agricultural machinery. This result will help to make our future plan for accelerating the mechanization.

The survey was conducted on machinery used in farmer's field at Bonogram and Bbiprobel Goria villages in Noldanga upazila of Natore district.

Table 1. Yield of paddy with different tillage depths.

Year	Season	Paddy	Tilling depth (inch)	Paddy yield (t/ha)
2015	Aman	BRRI dhan34	4-5	1.61
			5-6	1.92
			6-7	2.12
2016	Boro	BRRI dhan28	4-5	3.10
			5-6	3.57
			6-7	4.37

Table 2. Fuel consumption and time of different plots and depths in Aman 2015.

	1st plot (820 m^2)		2nd plot (820 m^2)		3rd plot (820 m^2)	
	Fuel (ml)	Time (min)	Fuel (ml)	Time (min)	Fuel (ml)	Time (min)
1st ploughing	1365	28	1365	28	1365	28
2nd ploughing	980	21	980	21	980	21
3rd ploughing	800	18	650	14	700	15
4th ploughing	750	15	550	12	650	14
Total	3895	82	3545	75	3695	78
Fuel consumption (l/hr)	2.86		2.83		2.84	

Table 3. Fuel consumption and time of different plots and depths in Boro 2016.

	1st plot (820 m²)		2nd plot (820 m²)		3rd plot (820 m²)	
	Fuel (ml)	Time (min)	Fuel (ml)	Time (min)	Fuel (ml)	Time (min)
1st ploughing	1000	20	1000	20	1000	20
2nd ploughing	700	16	600	15	625	15
3rd ploughing	600	14	500	12	575	12
Total	2300	50	2100	47	2200	47
Fuel consumption (l/hr)	2.77		2.69		2.82	

Different kinds of farm machinery have been used in these villages and these machinery are power tiller, shallow tube well, sprayer, open drum thresher, close drum thresher which were shown in Table 4. Some farmers are the owner of these machinery and some others used the machinery by custom hire service. From this Table 4, we can see that power tiller, shallow tube well and open drum thresher are the mostly popular agricultural machinery among these used machinery.

Farmers are facing different kinds of problem in these areas to use the machinery and these are shown in Table 5. Some farmers pointed out that the quality of the machinery is low but most of the farmers partially or completely disagree with this point. Most of the farmers realize that the repair cost of the machinery is high. They have to go to upazila or zila market to buy parts if repair is necessary. Some of them feel that the use of machinery is not profitable because of high rate of fuel and oil.

Some farmers realize the importance of machinery and some of them want to buy new machinery in future. Some farmers want to buy machinery because of their used machinery is obsolete, and some of them want to use new kind of machine because they think that machinery use is profitable. Some farmers want to buy reaper, because of labour shortage and high rate of labour at the time of harvesting.

A little number of machinery is used in the Bonogram and Bbiprobel Goria villages. There are no weeder, reaper, combined harvester, transplanter etc. at the farm level of these area. So, there is a scope to introduce these machinery in the area. The problem is 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.

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 crops for enhancing farm mechanization in our country. As a result, cropping intensity has been increasing day by day. Most of the machinery were imported and costly which were used in agriculture 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.

Table 4. Agricultural machinery used in the farmers' field.

Name of machinery	Personal	By custom-hire service	No use
Power tiller	12	7	1
Shallow tube well	15	5	0
Sprayer	3	-	-
Open drum thresher	11	5	4
Close drum thresher	1	2	17

Table 5. Problems faced to use machinery by the farmers.

Selected problems	Partially agree	Completely agree	Partially disagree	Completely disagree
Low quality machinery	1	4	8	7
Repair cost is high	6	7	4	3
Need to go to upazila or zila to buy parts	9	8	2	1
Machinery use is not profitable	5	6	5	2

Agricultural machinery workshops were surveyed at different places in Bangladesh. The facilities of machinery of the workshops are foundry, lathe machine, shaper machine, drill machine, milling machine, grinding machine, welding machine, metal cutting and colour compressor and these are shown in Table 6. They produce different kinds of agricultural machinery using locally available materials by using these machinery facilities. Table 7 shows the result of the produced machinery by the manufacturers. Close drum thresher, open drum thresher and maize sheller are the common machinery produced by the manufacturers, and someone also produce chopper, bed planter, winnower and weeder. They have no facility of foundry works but they can do any kind of foundry related works from other workshops in their locality if it is necessary.

Various kinds of materials are used to make different parts of the agriculture machinery. Metal sheet, angle bar, rod/sheet, wood and glass are the common materials to make these machinery which are available in the market.

There is no way to develop the agriculture sector without mechanization. High rate of imported machinery is a great problem to spread the mechanization. Local workshops can play an important role to reach the agriculture machinery at farm label because 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. So, we should look after at our local manufacturing workshop. 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 6. Machinery facilities of the 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.)	Colour compressor (no.)
Sarkar Engg. Industry	-	1	-	10	-	10	20	3	-
KMT Workshop	-	3	-	3	6	6	4	2	1
M/S Kamal Machine Tools	-	3	-	4	6	7	5	2	1

Table 7. List of machinery produced by manufacturers.

Machinery / Workshop	Open drum thresher	Close drum thresher	Maize sheller	Chopper	Bed planter	Winnower	Weeder
Sarkar Engineering Industry	√	√	√	-	-	√	√
KMT Worksop	√	√	√	√	√	√	√
M/S Kamal Machine Tools	√	√	√	√	√	√	√

Adaptive Research Division

SUMMARY

In the reporting year, 32 advanced breeding lines for different seasons were evaluated by conducting 14 advanced line adaptive research trials (ALART) in different agro ecological regions of Bangladesh. Considering specialty on some important characteristics and farmers' opinion, 13 advanced lines for different seasons were recommended for proposed variety trial (PVT). During T. Aus 2015, NERICA Mutant was recommended for PVT. During T. Aman 2015, one advanced line for rainfed lowland rice, one for BB resistance, two for flash flood submergence tolerance were found suitable for PVT. During Boro 2016, two lines for short duration in favourable condition, two for short duration micronutrient enrichment, one for long duration green super rice, two lines developed by Biotechnology Division for short duration and one line as short duration for Comilla region developed by BRRI RS, Comilla were recommended for PVT.

In Aus 2015, Aman 2015 and Boro 2016, seed production and dissemination programmes (SPDP) were conducted by using different BRRI varieties and other technologies under different projects. A total of 464 demonstrations were conducted in 147 upazilas of 50 districts, from which about 289 tons of paddy grains were produced and 38 tons were retained as seeds by the farmers for next year cultivation. About 37 thousand farmers gained awareness and knowledge about BRRI varieties through demonstrations, knowledge sharing, field days, field visit and other interactions. Among them, about 15 thousand farmers were motivated to adopt BRRI varieties.

In Aus 2015, Aman 2015 and Boro 2016, adaptive trials were conducted in different locations of Barisal and Rangpur regions under IAPP to identify the most suitable varieties for those specific areas. BRRI dhan27 and BRRI dhan48 were found suitable for Barisal and Rangpur region respectively in T. Aus season. BRRI dhan41 and BRRI dhan52 were suitable for Barisal region in T. Aman season, whereas it was BRRI dhan49 for Rangpur region. In Boro season, BRRI dhan67 and BRRI dhan69 were found most suitable for Barisal region and BRRI dhan58 and BRRI dhan63 for Rangpur region. Adaptive Research Division (ARD) conducted 53 farmers' training programmes at different locations in which 1,755 trainees (1,490 farmers and 265 SAAOs of DAE) participated. The division also conducted 66 field days at different locations. About 11,550 persons participated in those occasions. A total of 7.76 tons good quality seeds of different BRRI varieties were produced by ARD at BRRI farm those were used for follow up adaptive research trials.

TECHNOLOGY VALIDATION

Advanced line adaptive research trial (ALART) T. Aus 2015. Table 1 shows that none of the two evaluated lines out yielded (4.00-4.35 t/ha) the average yield of BRRI dhan48 (4.58 t/ha) but both the lines gave higher yield than the check variety BR26 (3.54 t/ha). Mean yield performance of NERICA Mutant (4.35 t/ha) was higher than the advanced line BR7718-55-1-3 (4.00 t/ha) with an average growth duration of 111 days and it was lodging tolerant. Considering all the characteristics and farmers' opinion and other aspects, NERICA Mutant was recommended for PVT.

T. Aman 2015, MER (Micronutrient enriched rice). Table 2 shows that all the advanced lines gave higher yield (4.38-4.89 t/ha) than the check variety BR25 (3.95 t/ha) but not out yielded other check varieties BRRI dhan32 and BRRI dhan39. Only entry no. 3 gave 4.89 t/ha mean yield which, was higher than the check varieties except BRRI dhan32 but the growth duration was not so early (127 days) along with larger bold type grain (1000-grain wt around 27.0 g). So, considering all characteristics and farmers opinion, none of the advanced lines was recommended for PVT.

T. Aman 2015, RLR (Rainfed lowland rice). Table 3 shows that the line, WAS161-B-4-B-1-TGR51 (NERICA-L-32) (entry no. 4) produced the average highest grain yield (4.80 t/ha) with medium growth duration (119 days). Considering all the characteristics and farmers' opinion, WAS161-B-4-B-1-TGR51 (NERICA-L-32) was found suitable for PVT.

T. Aman 2015, BBR (Bacterial blight resistant). One advanced line resistant to bacterial blight, BRC245-4-19-2-1 with the checks were tested at farmers' field (Table 4). The tested advanced line BRC245-4-19-2-1 gave

Table 1. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of some advanced lines under ALART grown in different locations of Bangladesh during T. Aus 2015.

Genotype	Location												Duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)														
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	Mean	Mean	Mean	Mean
BR7718-55-1-3	4.97	4.65	3.60	3.94	4.14	3.89	3.16	3.70	4.58	3.41	4.03	4.00	109	23.04	110
NERICA Mutant	4.91	5.14	4.30	4.07	4.53	3.36	3.59	4.06	4.25	4.49	5.22	4.35	111	26.43	112
BR26 (ck)	4.61	4.27	3.27	4.04	3.73	3.14	2.41	3.04	2.93	3.30	4.25	3.54	113	24.78	113
BRRI dhan48 (ck)	5.21	5.26	4.50	5.56	4.92	4.00	3.61	3.50	4.78	4.77	5.16	4.58	108	24.12	106
LSD (0.05)						0.61						0.18	0.30	0.22	0.87

L1-Satkhira (Kolaroa),L2-Habiganj (Sadar), L3-Bagerhat (Kochua), L4-Rangpur (Pirgonj), L5-Kushtia (Sadar),L6-Barisal (Bakerganj), L7-Naogaon (Manda), L8-Khagrachari (Sadar), L9-Gazipur (BRRI), L10-Chittagong (Mirsori), L11- Sherpur (Nokla).

Table 2. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (MER) grown in different locations of Bangladesh during T. Aman 2015.

Genotype	Location													Duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)															
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Mean	Mean	Mean	Mean
BR7840-54-3-2-2	3.96	4.88	3.81	4.22	5.06	3.94	3.89	4.72	5.33	4.20	4.51	4.03	4.38	116	24.3	115
BR7879-17-2-4-HR3-PI	5.45	4.08	3.37	5.27	5.02	3.75	3.75	4.17	5.47	3.86	4.95	3.63	4.40	129	27.2	141
BR8143-15-2-1	5.87	5.01	4.31	5.25	6.09	5.04	5.02	5.46	5.71	4.53	4.39	2.03	4.89	127	27.2	125
BR25 (ck)	5.03	3.98	3.30	4.57	5.46	3.92	3.21	3.33	4.78	3.70	3.74	2.33	3.95	132	19.5	140
BRRI dhan32	4.98	4.82	4.15	5.73	5.82	4.12	4.33	5.93	5.21	4.38	4.00	2.80	4.69	130	23.5	123
BRRI dhan39	4.46	4.38	4.02	5.31	5.25	4.16	4.14	4.57	4.82	4.25	4.35	3.97	4.47	123	24.6	106
LSD (0.05)							0.75						0.21	0.37	0.30	1.32

L1-Barisal (Sadar), L2-Rangpur (Sadar), L3-Mymensingh (Sadar), L4-Thakurgaon (Sadar), L5-Dinajpur (Sadar), L6-Rajshahi (Godagari), L7-Gazipur (BRRI), L8-Feni (Sadar), L9-Habiganj (Sadar), L10-Khulna (Dumuria), L11-Chittagong (Hathazari), L12-Satkhira (Sadar).

Table 3. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (RLR) grown in different locations of Bangladesh during T. Aman 2015.

Genotype	Location												Duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)														
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	Mean	Mean	Mean	Mean
NERICA Mutant	4.20	4.40	3.42	3.09	3.60	4.17	4.80	4.51	4.55	4.97	4.76	4.22	110	24.6	104
WAS 122-IDSA14-WAS B-FKR 1 (NERICA-L-8)	4.04	4.68	3.44	5.06	5.09	4.72	5.01	4.53	4.31	4.91	5.07	4.62	118	24.9	101
WAS 161-B-6-B-1 (NERICA-L-36)	3.77	4.77	4.50	5.12	5.34	5.09	4.69	3.98	4.12	4.61	5.15	4.65	119	25.5	102
WAS 161-B-4-B-1-TGR 51 (NERICA-L-32)	4.15	4.88	4.98	4.68	4.63	5.76	4.82	4.40	4.40	5.21	4.91	4.80	119	25.5	103
BRRI dhan39	4.35	5.12	5.57	4.24	4.30	5.02	4.61	4.09	4.46	4.58	4.51	4.62	122	24.1	107
BRRI dhan57	4.04	4.50	3.95	3.41	2.62	3.91	4.41	3.74	4.20	4.65	3.98	3.95	105	19.1	106
BRRI dhan62	4.21	4.06	3.90	4.08	2.69	4.12	4.39	4.35	4.52	4.29	4.16	4.07	103	24.2	102
LSD (0.05)						0.50						0.15	0.28	0.21	0.99

L1-Mymensingh (Sadar), L2-Dinajpur (Sadar), L3-Thakurgaon (Sadar), L4-Rajshahi (Godagari), L5-Gazipur (BRRI), L6-Barisal (Sadar), L7-Rangpur (Sadar), L8-Chittagong (Hathazari), L9-Khulna (Dumuria), L10-Satkhira (Sadar), L11-Habiganj (Sadar).

4.84 t/ha grain yield, which was similar (4.85 t/ha) to that of check variety BRRI dhan31 but little bit lower than another check variety BR11 (5.26 t/ha). The mean growth duration of the above advanced line was 126 days, which was the shortest among all the entries and found tolerant to Bacterial blight (BB). Considering all the characteristics and farmers' opinion, BRC245-4-19-2-1 was recommended for PVT.

Table 4. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (BBR) grown in different locations of Bangladesh during T. Aman 2015.

Genotype	Location												Duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)														
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	Mean	Mean	Mean	Mean
BRC245-4-19-2-1	5.40	6.02	5.23	5.25	4.94	5.09	5.16	3.30	4.03	4.08	4.39	4.84	126	25.91	108
BR11 (Sus. & Std. ck)	5.67	6.21	5.98	5.42	5.29	5.86	5.18	4.50	4.82	4.01	4.74	5.26	143	25.71	116
BRRI dhan31 (Res ck)	5.41	6.21	5.07	4.84	4.72	4.87	5.77	4.03	4.31	3.73	4.46	4.85	137	26.79	115
LSD (0.05)						0.51						0.34	2.77	0.58	2.74

L1-Barisal (Sadar), L2-Rangpur (Sadar), L3-Habiganj (Sadar), L4-Gazippur), L7-Dinajpur (Sadar), L8-Mymensing (Sadar), L9-Khulna (Dumuria), L10-Chittagong (Hathazari), L11-Satkhira (Sadar).

T. Aman 2015, FFS (Flash flood submergence). Among 10 tested locations, the trial in Kurigram, Habiganj and Gaibandha were damaged due to flood. Table 5 shows that the advanced lines gave similar yield (3.48-3.50 t/ha) which was statistically similar to that of check variety BRRI dhan49. The mean growth duration of both the advanced lines was same (142 days) and similar to BRRI dhan49 (143 days) but about seven days earlier than BRRI dhan52 (149 days). Considering grain yield and shorter growth duration, submergence tolerance level, the advanced lines, BR9159-8-5-40-13-52 and BR9159-8-5-40-14-57 were recommended for PVT.

T. Aman 2015, hybrid. Table 6 shows that none of the advanced lines gave higher yield than any of hybrid and inbred check varieties. The tested advanced lines were very much succeptible to disease and the grain size of the lines were bold type. Considering all characteristics and farmers' opinion, none of the advanced lines was recommended for PVT.

Boro 2016, FB-SD (Favourable Boro-short duration). Table 7 shows that yield of the advanced lines and check variety BRRI dhan28 was found to be close to each other, although BRRI dhan29-SC3-28-16-10-8-HR1 (Com) gave significantly higher mean yield (0.34-0.40 t/ha) than BR7358-5-3-2-1-HR2 (Com) and BRRI dhan28 with similar growth duration (141-143 days). Mean TGW of the advanced lines (21.60-21.80g) was slightly lower than BRRI dhan28 (22.2g). Considering all characteristics and farmers' opinion, both the tested advanced lines BRRI dhan29-SC3-28-16-10-8-HR1 (Com) and BR7358-5-3-2-1-HR2 (Com) were recommended for PVT.

Boro 2016, HY-SD (High yielding-short duration). Table 8 shows that all the advanced lines gave higher yield than the check variety BRRI dhan28. In this experiment, check variety (BRRI dhan28) was not selected properly. Growth duration of the check variety should be similar to that of advanced lines. But the duration of the lines was 6-11 days longer than the check variety. So, it is not fare to compare the grain yield between advanced lines and check variety. Thus, the experiment should be repeated by selecting the proper check variety (BRRI dhan58) in coming Boro season, especially for BRH11-9-11-4-5B.

Table 5. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (FFS) grown in different locations of Bangladesh during T. Aman 2015.

Genotype	Location						Duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)								
	L1	L2	L3	L4	L5	Mean	Mean	Mean	Mean
BR9159-8-5-40-13-52	4.22	2.99	2.25	2.83	5.21	3.50	142	21.34	92
BR9159-8-5-40-14-57	4.00	3.36	2.30	2.83	4.92	3.48	142	21.58	91
BRRI dhan49 (Sus. ck)	4.15	2.45	1.89	2.60	5.22	3.26	143	20.84	87
BRRI dhan52 (Res. ck)	3.55	2.39	1.63	-	5.02	3.15	149	26.17	100
LSD (0.05)			0.59			0.26	0.53	0.46	2.10

Note: BRRI dhan52 at Nilphamari was fully damaged L1-Rangpur (Gongachara), L2- Sylhet (Golapganj), L3- Lalmonirhat (Sadar), L4- Nilphamari (Sadar), L5- Jamalpur (Sadar).

Table 6. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (Hybrid) grown in different locations of Bangladesh during T. Aman 2015.

Genotype	Location													Duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)															
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Mean	Mean	Mean	Mean
BR1366 H	4.73	3.81	4.25	5.51	3.60	3.45	3.89	3.95	2.57	4.16	4.34	4.91	4.10	118	24.43	103
BR1659 H	4.41	3.90	4.58	5.75	3.83	3.49	3.51	4.51	2.79	4.26	4.71	5.27	4.25	117	25.54	106
BRRI hybrid dhan4 (ck)	3.56	4.21	5.54	5.49	5.17	5.26	4.27	4.56	3.3	4.51	5.58	4.22	4.65	118	25.64	105
BRRI dhan39 (ck)	5.01	4.10	5.20	4.56	4.13	4.23	4.69	4.62	4.36	4.42	4.24	4.70	4.52	122	24.28	104
BRRI dhan49 (ck)	5.18	4.54	5.55	5.07	5.11	5.12	4.35	4.77	4.84	4.57	5.12	3.51	4.81	132	20.84	101
LSD (0.05)						0.64							0.18	0.28	0.36	0.92

L1-Dinajpur (Sadar), L2-Mymensingh (Sadar), L3-Thakurgaon (Sadar), L4-Habiganj (Sadar), L5-Rajshahi (Godagari), L6-Gazipur (BRRI), L7-Rangpur (Sadar), L8-Barisal (Sadar), L9-Feni (Sadar), L10-Khulna (Dumuria), L11-Chittagong (Hathazari), L12-Satkhira (Sadar).

Table 7. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (FB-SD) grown in different locations of Bangladesh during Boro 2016.

Genotype	Location													Duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)															
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Mean	Mean	Mean	Mean
BRRI dhan29-SC3-28-16-10-8-HR1 (Com)	5.93	6.32	6.28	7.00	5.42	6.12	6.53	5.72	6.27	5.60	5.48	6.52	6.10	143	21.8	94
BR7358-5-3-2-1-HR2 (Com)	5.97	6.40	5.69	7.12	5.45	6.00	6.74	5.11	5.70	4.35	4.41	6.21	5.76	142	21.6	97
BRRI dhan28 (Ck)	6.01	6.15	5.38	6.45	5.60	5.98	6.25	5.02	6.42	5.10	4.53	5.57	5.71	141	22.2	102
LSD (0.05)							0.67						0.20	0.70	0.3	2

L1-Barisal (Sadar), L2-Khulna (Dumuria), L3-Satkhira (Sadar), L4-Jessore (Jhikorgacha), L5-Rajshahi (Godagari), L6-Dinajpur (Sadar), L7-Thakurgaon (Sadar), L8-Rangpur (Sadar), L9-Habiganj (Sadar), L10-Chittagong (Hathazari), L11-Sunamganj (Sadar), L12-Gazipur (BRRI).

Table 8. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (HY-SD) grown in different locations of Bangladesh during Boro 2016.

Genotype	Location													Duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)															
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Mean	Mean	Mean	Mean
BRH11-9-11-4-5B	5.90	6.60	6.86	5.70	6.48	6.78	5.43	5.63	5.11	5.77	6.08	5.16	5.96	146	18.34	96
BRRI dhan29-SC3-8-HR1(Com)	6.61	6.43	6.10	6.15	6.70	7.10	6.63	6.11	6.71	6.98	6.94	5.15	6.42	151	21.70	101
BRRI dhan29-SC3-28-16-15-HR2(com)	6.83	6.40	6.20	6.14	6.60	7.17	6.74	4.95	6.47	7.01	7.00	5.81	6.45	150	21.61	101
BRRI dhan28(ck)	6.12	5.33	5.10	6.01	6.09	6.14	5.88	5.21	4.97	5.30	5.81	5.90	5.66	140	22.18	103
LSD (0.05)							0.60						0.17	0.20	0.30	0.80

L1-Khulna (Dumuria), L2-Sherpur (Nokla), L3-Gopalganj (Sadar), L4-Satkhira (Sadar), L5-Comilla (Burichang), L6-Jessore (Jhikorgacha), L7-Sunamganj (Sadar), L8-Rajshahi (Godagari), L9-Barisal (Sadar), L10-Rangpur (Sadar), L11-Gazipur (BRRI), L12 Habiganj (Sadar).

Boro 2016, ME-SD (Micronutrient enriched-short duration). Table 9 shows that none of the advanced lines out yielded (5.32-5.37 t/ha) BRRI dhan28 (5.54 t/ha) but the yield difference between advanced lines and check variety was very low (0.17-0.22 t/ha) with similar growth duration (140-142 days). Mean TGW of BR7831-59-1-1-4-9-1-2-P3 (entry no. 2) was the lowest (20.94 g), followed by BRRI dhan28 (22.11 g). Having characteristics similar to that of BRRI dhan28, both the lines have extra benefit like zinc enrichment. So, considering similar grain yield and growth duration of BRRI dhan28, fine grain type, micronutrient enriched and farmers' opinion, both the lines BR7831-59-1-1-4-5-1-9-P1 and BR7831-59-1-1-4-9-1-2-P3 were recommended for PVT.

Table 9. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (ME-SD) grown in different locations of Bangladesh during Boro 2016.

Genotype	Location													Duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)															
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Mean	Mean	Mean	Mean
BR7831-59-1-1-4-5-1-9-P1	6.01	5.74	5.48	5.96	4.16	5.04	3.48	5.33	6.11	5.32	5.72	6.12	5.37	141	22.86	111
BR7831-59-1-1-4-9-1-2-P3	5.73	5.96	5.38	5.87	4.98	4.95	3.12	5.22	6.19	4.95	5.64	5.82	5.32	140	20.94	105
BRRIdhan28 (Ck)	5.80	6.00	5.51	6.45	4.51	5.83	4.25	5.28	6.22	5.68	4.79	6.01	5.54	139	22.11	104
LSD (0.05)	0.49												0.14	0.23	0.29	0.98

L1-Khulna (Dumuria), L2-Dinajpur (Sadar), L3- Satkhira (Sadar), L4- Thakurgaon (Sadar), L5- Chittagong (Hathazari), L6- Jessore (Jhikorgacha), L7- Sunamganj (Sadar), L8- Rajshahi (Godagari), L9- Barisal (Sadar), L10-Rangpur (Sadar), L11-Habiganj (Sadar), L12- Gazipur (BRRI).

Boro 2016, GSR-LD (Green super rice-long duration). Table 10 shows that the advanced lines (entry no. 1 and 2) gave similar yield (6.40-6.45 t/ha) to that of check varieties BRRI dhan58 (6.55 t/ha) and BRRI dhan29 (6.53 t/ha). But the growth duration of the above entries ranged from 153-155 days which was similar with BRRI dhan58 but earlier than BRRI dhan29 (160 days). Mean TGW of entry no. 1 and 2 ranged from 23.02-23.52 g which was very close to that of check varieties (22.99-23.04 g). The advanced line, specially HHZ15-DT4-DT1-Y1 (entry no. 1) had some more advantages than the check varieties in terms of growth duration and plant height and was characterized by green super rice (stable grain yield, more stress tolerant, survival to low inputs, less insects and disease attack etc). So, considering green super rice characteristics and farmers' opinion, HHZ15-DT4-DT1-Y1 (entry no. 1) was recommended for PVT.

Boro 2016, BIO-SD (Biotechnology-short duration). Table 11 shows that both the advanced lines gave similar yield (5.43-5.62 t/ha) to that of check variety BRRI dhan28 (5.54 t/ha) with similar growth duration (141-142 days). Mean TGW of both the advanced lines was also similar to BRRI dhan28 (22.12-23.23 g). In addition, the plant height of the lines was less than BRRI dhan28 and lodging tolerant while BRRI dhan28 was lodged in some locations. Considering more lodging tolerance than BRRI dhan28 and farmers' opinion, both of the tested advanced lines were recommended for PVT.

Boro 2016, BIO-LD (Biotechnology-long duration). Table 12 shows that the advanced line gave yield (6.57 t/ha) similar to BRRI dhan58 (6.55 t/ha) and BRRI dhan29 (6.53 t/ha). The advanced line required the longest period (162 days) to mature. Besides, the line was found as bushy type plant. Considering plant type, phenotypic acceptance and farmers' opinion, BR (BE)6158-RWBC2-1-2-1-1 was not recommended for PVT.

Boro, 2016, SD-Comilla (Short duration-Comilla). The trials were conducted in seven locations of greater Comilla region. Table 13 shows that the line, HHZ23-DT16-DT1-DT1 produced higher grain yield (6.04 t/ha) than BRRI dhan28 (5.20 t/ha) but statistically similar to that BRRI BRRI dhan60 (5.84 t/ha). Growth duration of this line was higher (144 days) than check variety BRRI dhan28 (139 days) but similar to BRRI dhan60. The average TGW (22.61 g) of the line was very close to that of BRRI dhan28 (21.88

Table 10. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (GSR-LD) grown in different locations of Bangladesh during Boro 2016.

Genotype	Location													Duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)															
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Mean	Mean	Mean	Mean
HHZ15-DT4-DT1-Y1	6.82	7.52	6.40	7.03	7.0	6.16	5.82	5.98	6.85	6.40	7.64	5.05	6.56	153	23.41	94
HHZ6-SAL3-Y1-SUB2	7.11	6.13	5.83	6.78	6.89	5.98	5.55	6.09	6.30	7.01	7.76	5.37	6.40	155	23.02	95
BRH10-3-12-21-4B	6.90	7.60	6.20	6.73	5.02	5.19	5.48	5.42	6.45	6.29	7.19	5.25	6.14	162	24.15	101
BRRIdhan58 (ck)	7.60	6.33	5.98	6.93	6.82	6.49	6.20	5.83	6.86	6.34	8.00	5.21	6.55	155	22.99	99
BRRIdhan29 (ck)	8.01	5.07	5.50	7.15	6.46	6.38	6.28	6.53	6.57	7.09	8.19	5.18	6.53	160	23.04	103
LSD (0.05)	0.78												0.23	0.38	0.27	0.94

L1-Khulna (Dumuria), L2-Gopalganj (Sadar), L3- Satkhira (Sadar), L4-Sherpur (Nokla), L5-Comilla (Burichang), L6- Jessore (Jhikorgacha), L7- Sunamganj (Sadar), L8- Rajshahi (Godagari), L9- Barisal (Sadar), L10-Rangpur (Sadar), L11- Gazipur (BRRI), L12-Habiganj (Sadar).

Table 11. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (BIO-SD) grown in different locations of Bangladesh during Boro 2016.

Genotype	Location: Grain yield (t/ha)													Duration (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Mean	Mean	Mean	Mean
BR(BIO)8072-AC5-4-2-1-2-1	5.63	5.19	5.13	6.58	5.83	5.01	4.87	5.05	6.60	4.80	4.89	5.59	5.43	142	22.84	92
BR(BIO)8072-AC8-1-1-3-1-1	5.51	5.39	5.41	6.29	5.79	5.23	4.52	6.02	6.62	5.48	5.50	5.75	5.62	141	23.23	93
BRRIdhan28 (ck)	5.80	6.07	5.50	6.55	4.51	5.83	4.25	5.28	5.22	5.68	5.71	6.01	5.54	140	22.12	103
LSD (0.05)							0.69						0.20	0.23	0.27	0.98

L1-Khulna (Dumuria), L2-Dinajpur (Sadar), L3- Satkhira (Sadar), L4- Thakurgaon (Sadar), L5- Chittagong (Hathazari), L6- Jessore (Jhikorgacha), L7-Sunamganj (Sadar), L8- Rajshahi (Godagari), L9- Barisal (Sadar), L10-Rangpur (Sadar), L11-Habiganj (Sadar), L12- Gazipur (BRRI).

Table 12. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (BIO-LD) grown in different locations of Bangladesh during Boro 2016.

Genotype	Location: Grain yield (t/ha)													Duration (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Mean	Mean	Mean	Mean
BR(BE) 6158-RWBC2-1-2-1-1	6.70	6.00	6.26	6.78	7.21	5.72	6.02	6.99	6.54	7.40	7.52	5.45	6.57	162	24.17	106
BRRIdhan58 (ck)	7.60	6.33	5.98	6.93	6.82	6.49	6.20	5.83	6.86	6.34	8.00	5.21	6.55	154	22.99	99
BRRIdhan29 (ck)	8.01	5.06	5.50	7.15	6.46	6.38	6.28	6.53	6.56	7.09	8.19	5.18	6.53	160	23.04	104
LSD (0.05)							0.81						0.23	.32	0.26	0.85

L1-Khulna (Dumuria), L2-Gopalganj (Sadar), L3-Satkhira (Sadar), L4-Sherpur (Nokla), L5-Comilla (Burichang), L6-Jessore (Jhikorgacha), L7-Sunamganj (Sadar), L8-Rajshahi (Godagari), L9-Barisal (Sadar), L10-Rangpur (Sadar), L11-Gazipur (BRRI), L12-Habiganj (Sadar).

Table 13. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (SD-Comilla) grown in different locations of Bangladesh during Boro 2016.

Genotype	Location: Grain yield (t/ha)							Duration (day)	TGW (g)	Plant ht (cm)
	L1	L2	L3	L4	L5	L6	L7	Mean	Mean	Mean	Mean
BR7800-63-1-7-3	5.51	4.40	6.44	4.89	4.60	5.29	5.55	5.24	140	25.23	104
BR8245-2-1-4	5.62	5.26	6.64	5.70	6.16	5.93	5.42	5.82	145	21.27	109
HHZ23-DT16-DT1-DT1	6.15	5.53	6.72	5.57	6.62	5.43	6.31	6.04	144	22.61	96
BRRI dhan28(ck)	5.58	3.83	5.35	5.28	5.36	5.17	5.74	5.20	139	21.88	104
BRRI dhan60(ck)	5.76	4.86	6.68	5.50	6.40	5.48	6.19	5.84	144	23.77	98
LSD (0.05)				0.63				0.24	0.25	0.42	1.30

L1-Feni (Sadar), L2-Brahmonbaria (Sadar), L3-Comilla (Burichang), L4-Chandpur (Haziganj), L5-Chandpur (Kochua), L6-Comilla (Chandina), L7-Gazipur (BRRI).

g). Based on all characteristics and farmers' opinion, the advanced line HHZ23-DT16-DT1-DT1 was recommended for PVT for greater Comilla region.

Boro 2016, hybrid. Table 14 shows that none of the advanced lines gave higher yield (6.09-6.30 t/ha) than BRRI bybrid dhan3 (6.52 t/ha). Mean growth duration of the lines was found similar (149 days) to that of BRRI hybrid dhan3 (148 days). Based on grain yield, growth duration, grain size and farmers' opinion, none was found suitable for PVT.

Table 14. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (Hybrid) grown in different locations of Bangladesh during Boro 2016.

Genotype	Location: Grain yield (t/ha)													Duration (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Mean	Mean	Mean	Mean
BR1585H	5.26	4.73	6.16	7.16	6.45	6.62	7.22	5.87	6.88	6.48	7.06	3.47	6.09	149	31.21	98
BR1793H	6.13	5.60	5.65	7.18	5.80	7.68	7.37	6.16	7.01	7.04	6.51	3.71	6.30	149	30.88	104
BRRI hybrid dhan3 (ck)	6.31	6.22	6.40	7.21	6.35	6.90	7.30	6.34	7.25	7.38	7.18	3.60	6.52	148	30.01	101
BRRI dhan28 (ck)	5.90	5.67	5.27	6.10	4.14	5.68	6.01	5.06	6.15	5.64	5.91	4.22	5.48	141	22.51	100
LSD (0.05)							0.80						0.50	2.07	0.61	1.60

L1-Sherpur (Nokla), L2-Gopalganj (Sadar), L3-Comilla (Burichang), L4-Jessore (Jhikorgacha), L5-Sunamganj (Sadar), L6-Rajshahi Godagari), L7-Barisal (Sadar), L8-Gazipur (BRRI), L9-Khulna (Dumuria), L10-Satkhira (Sadar), L11-Rangpur (Sadar), L12-Habiganj (Sadar).

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 dissemination 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. In this programme, mainly BRRI varieties were demonstrated in farmers' fields.

SPDP, T. Aus 2015. SPDPs were conducted in 24 upazilas of 15 districts (Sherpur, Gazipur, Netrokona, Rajbari, Bandarban, Rangamati, Khagrachari, Barisal, Patuakhali, Rangpur, Lalmonirhat, Kushtia, Meherpur, Chuadanga and Jhinaidah) in T. Aus 2015. BRRI dhan48 and BRRI dhan55 were used. Total production through demonstrations were about 38 tons and farmers retained four tons seeds from those varieties for next year cultivation. About 3,981 farmers gained awareness about the varieties through field visits, discussion and knowledge sharing. About 969 farmers were motivated to cultivate those varieties in next year.

SPDP, B. Aus, 2015. SPDPs were conducted in six upazilas of three districts (Magura, Narail and Rajbari) using BR24 and BRRI dhan43. Total production was about five tons and farmers retained 675 kg seeds for next year cultivation. About 850 farmers gained awareness about the varieties and 350 farmers were motivated to cultivate those varieties next year.

SPDP in Jhum, Aus 2015. SPDPs were conducted in three upazilas of three hill districts (Bandarban, Rangamati, Khagrachari) in Aus 2015 using BR24, BRRI dhan27 and BRRI dhan55. Total production was about 2.75 tons and farmers retained 685 kg seeds for next year cultivation. About 350 farmers gained awareness about the varieties and 200 farmers were motivated to cultivate these varieties next year.

SPDP with USG, T. Aman 2015. SPDPs with USG were conducted in 48 upazilas of 27 districts (Satkhira, Chittagong, Cox's Bazar, Habiganj, Gaibandha, Khulna, Rajbari, Netrokona, Sherpur, Dinajpur, Barisal, Patuakhali, Jhalokathi, Barguna, Rangpur, Nilphamari, Lalmolnirhat, Kurigram, Kushtia, Meherpur, Chuadanga, Jhinaidah, Norsingdi Tangail Kishoerganj, Gazipur and Mymensingh) in T. Aman 2015. BR22, BR23, BRRI dhan37, 38, 41, 44, 49, 52, 54, 56, 57, 62 and 67 were used. Total production by those varieties was about 81 tons, from which about 13 tons were retained by the farmers for next year use. About 13,537 farmers gained awareness and knowledge about those varieties and the beneficial effect of USG and more than 4,556 farmers were motivated to cultivate those varieties and USG.

SPDP with USG, Boro 2016. SPDPs with USG were conducted in 65 upazilas of 32 districts (Gopalganj, Rajbari, Netrakona, Sherpur, Khulna, Jessore, Bagerhat, Dinajpur, Thakurgaon, Panchagor, Gaibandah, Naogaon, Bogra, Chittagong, Cox's Bazar, Moulobi Bazar, Sylhet, Sunamganj, Barisal, Patuakhali, Jhalokathi, Rangpur, Lalmolnirhat, Kushtia, Meherpur, Chuadanga, Jhinaidah, Norsingdi, Tangail, Kishoerganj, Gazipur and Mymensingh) in Boro 2016. Eight modern rice varieties (BRRI dhan47, 58, 59, 60, 61, 63, 67 and 69) were used. Total production was 163 tons and farmers retained 20 tons seeds for next year use. A total of 18,493 farmers gained awareness and knowledge and 8,692 farmers were motivated to adopt those varieties and USG.

Adaptive trials under IAPP

Adaptive trial is one of the most important trials for the farmers in which they may be able to choose the appropriate variety for their area as per local demand. In adaptive trial a combination of some varieties were cultivated together in the farmers' field with one or two local standard checks.

T. Aus 2015. Four adaptive trials were conducted in four upazilas of two southern and two northern districts under Integrated Agricultural Productivity Project (IAPP) during T. Aus 2015. In Barisal region, the districts were Barisal and Patuakhali as the non-saline coastal tidal submergence rice ecosystem while the northern districts were Rangpur and Lalmonirhat as the drought prone ecosystem. BRRI dhan27, 48, 55, 65 and local check (Munsur Irri) were used in southern districts while BRRI dhan43, 48, 55, 65 and 28 (as local check) were for northern districts. Considering overall performance and local situation, BRRI dhan27 and 48 were found suitable

for Aus season in Barisal and Rangpur region respectively.

T. Aman 2015. Eight adaptive trials were conducted in eight upazilas of four southern and four northern districts under IAPP during T. Aman 2015. The southern districts were Barisal, Jhalokathi, Patuakhali and Borguna. The northern districts were Rangpur, Kurigram, Lalmonirhat and Nilphamari. BRRI dhan41, 44, 52, 54 and local check (BR11, Dudkalam and Sadamota) were evaluated in southern districts while BRRI dhan49, 56, 57, 62 and local check (Binadhan-7, Swarna and Guti Swarna) were evaluated in northern districts. Based on grain yield and growth duration, BRRI dhan52 and 41 were found suitable to cultivate for Barisal region. BRRI dhan49 was found suitable for Rangpur region.

Boro 2016. Six adaptive trials were conducted in five districts of southern and northern regions under IAPP during Boro 2016. Southern districts were Barisal, Jhalokathi and Patuakhali. The northern districts were Rangpur and Lalmonirhat. BRRI dhan47, 61, 64, 67, 69, Bhajan, Binadhan-10 and Kajla (local check) were evaluated in southern districts while BRRI dhan50, 58, 59, 60, 63 and BRRI dhan28 (as local check) were evaluated in northern districts. Based on grain yield, growth duration and farmers' opinion, BRRI dhan67 and BRRI dhan69 were found suitable for southern region and it was BRRI dhan58 and BRRI dhan63 for northern region.

Farmers' training. During the reporting period, ARD conducted 53 Farmers' training at different locations of the country in which 1,755 trainees (1,490 farmers and 265 SAAOs of DAE) participated.

Field day/Farmers' rally. ARD conducted 66 field days at different locations of the country under different projects (IAPP, MIADP, EQSS) and GOB during Aus 2015, Aman 2015 and Boro 2016. A total of 11,550 (approx.) persons participated in those occasions. 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. Seeds of recent and promising rice varieties were produced in T. Aman and Boro seasons during the reporting period under the close supervision of ARD. A total of 7.76 tons quality seeds of different BRRI varieties were produced and were used for follow up adaptive research trials and supplied in different divisions for research purpose.

Training Division

SUMMARY

Training Division has conducted 62 training programmes in the reporting year with course duration from three day to one week. A total of 1,581 participants from different government and non-government organizations were trained through these courses. Need based course curriculum was developed for these courses. The highest number of participants was from the Department of Agricultural Extension (DAE). The average improvement of BRRI scientists in 2-month Rice Production and Communication Training (RPT) course was 411% in theory and 207% in practical evaluation. Again the overall improvement of knowledge for extension personnel in 1-week Rice Production Training (RPT) varied widely and ranged from 164 to 205%. The results indicate the significance of rice production training for scientists and extension personnel. Effectiveness of imparted trainings was determined on the basis of feedback remarks on different aspect. Most of the trainees expressed positive views about the course content and method of training. However, participants of all courses, specially the 1-week course, suggested for increasing duration of the course from 1-week to at least 2-3 weeks. Most of the BRRI's speakers' performance was very good to excellent.

TRAINING NEED ASSESSMENT

A need assessment session was conducted at the beginning of each batch of training to know the expectation of the trainees. A total of 1,332 responses on different issues were received from the trainees of which 724 from Enhancement of Quality Seed Supply Project (EQSSP), 472 from Pirojpur-Gopalganj-Bagerhat Integrated Agri-cultural Development Project (PGB), 35 from GOB funded training course and 101 from BRRI scientists (Table 1). Though the participants were different categories and from different regions and environments of the country, their expectations were very much similar. SAAOs showed high expectation about insect and disease management followed by variety related issues. On the other hand, SA and BRRI officers showed highest interest about variety and fertilizer related issues. High expectation of participants, in case of 2-month RPT course for BRRI scientists was on scientific report writing followed by variety and statistical analysis related issues.

CAPACITY BUILDING AND TECHNOLOGY TRANSFER

Two-month rice production training for BRRI scientists

The main objectives of the course were to train the new scientists so that they can:

- Plan and execute research programme on rice and rice based farming system
- Analyze, write and interpret the research findings
- Recognize and apply the major concepts principles and techniques of modern rice production activities
- Identify and solve rice related field problems and
- Conduct rice production training programme.

The course curriculum was designed as per requirement and objectives of the course. Two batches were conducted during the reporting period and 44 scientists were trained. Among the participants 31 were male and 13 were female. Table 2 presents the particulars of the participants.

Improvement of knowledge was measured on the basis of marks obtained in the benchmark and final evaluation of individual participant. Knowledge improvement through this training was very attractive. On average, it was 411% for theory and 207% for skill (Table 3). Table 4 presents the performance status of 2-month rice production training.

One-week rice production training

The main objective of the course was to train the field level extension workers of DAE. The course curriculum was designed based on the priority of field problems related to rice production and rice based technologies. A total of 424 SAAOs were trained (278 from EQSSP, 146 from PGB). Beside this, 13 Scientific Assistants (SA) and 27 BRRI officers were also trained using GOB fund. Among the participants 413 and 51 were male and female respectively (Table 5).

Table 1. Expectations of the trainees on different subjects in need during 2015-16.

Subject/issue	Expectation (%)						Subject/issue	Expectation (%)	
	SAAO				SA			Scientist	Rank
	EQSSP	PGB	All	Rank	GOB	Rank			
Disease	18	13	16	2	11	4	Report writing	14	1
Insect	18	17	18	1	13	3	Variety	13	2
Variety	10	13	12	3	18	1	Statistics	13	2
Fertilizer	7	4	6	6	14	2	Disease	10	3
Soil	3	2	3	7	6	6	Molecular science	9	4
Crop mangt.	7	11	9	5	18	1	Physiology	8	5
IWM	10	14	12	3	2	7	Soil science	8	5
Seed	12	10	11	4	9	5	Post harvest technology	5	6
Farm machinery	5	6	6	6	2	7	Irrigation	3	7
Weed	-	-	-	-	2	7	Grain quality	3	7
Others	8	9	8	-	3	-	Others	8	-
Total	100	100	100		100			100	
Response no.	724	472			35			101	

Table 2. Particulars of the 2-month rice production training in 2015-16.

Batch	Duration	No. of participants			Designation	Organization
		Total	Male	Female		
1	2-month	23	15	8	SO, SSO	BRRI
2	2-month	21	16	5	SO, SSO	BRRI
Total		44	31	13		

Table 3. Knowledge improvement through 2-month rice production training.

Category of valuation	Benchmark evaluation	Final evaluation	Improvement (%)
Theory	17	87	411
Skill	14	43	207

Table 4. Performance status of 2-month rice production training.

Category /certificate	Participant number	Percentage
Distinction (80-100% marks)	35	80
Satisfactory (60-79% marks)	9	20
Participatory (Less than 60% marks)	-	-
Total	44	100

Table 5. One week rice productiontraining conducted by BRRI in 2015-16.

Project	Batch (no.)	No. of participants			Designation	Organization
		Total	Male	Female		
EQSSP	14	278	243	35	SAAO	DAE
PGB	5	146	133	13	SAAO	DAE
GOB	2	40	37	3	SA, BRRI Officer	BRRI
Total	21	464	413	51		

Benchmark and final evaluation tool was applied to assess the knowledge improvement of individual participants. Average knowledge improvement of the participants from EQSSP, PGB and GOB funded programmes were 205, 164 and 205% respectively (Table 6). Table 7 presents the performance status of 1-week rice production for different categories of participants.

Quality rice seed production and storage

Nine 3-day training programmes on seed production, processing and storage were conducted in 2015-16. A total of 171 participants were trained through this course. Of which 151 from EQSSP and 19 form PGB funded project. The participants of these courses were Upazila Agriculture Officer (UAO), Agriculture Extension Officer (AEO), Sub-Assistant Plant Protection Officer (SAPPO) of DAE. Table 8 presents the details of the training courses.

Training on crop management skill

An international training course on crop management skill was conducted during 2015-16.

The objective of the course was to train the participants about different aspects of crop management. The participants of the course were BRRI scientists, senior agronomist and area managers of BRAC and AEO from DAE. Table 9 presents the particulars of the course.

Farmers training

BRRI Training Division also conducted some farmers training. During the reporting period 29-day- long rice production training programme were conducted in collaboration with DAE using GOB and EQSSP fund. In total 870 farmers were trained through this programmes (Table 10).

Training information of BRRI

During the reporting period, 62 training programmes have been conducted by the Training Division (Table 11).

Table 6. Knowledge gain and improvement through 1-week rice production training.

Project	Evaluation (average mark %)		Improvement (%)
	Benchmark	Final evaluation	
EQSSP	25	73	205
PGB	27	70	164
GOB	23	65	205
Average	25	69	191

Table 7. Performance status of 1-week rice production training.

Project	Category of results/ certificates		
	Distinction	Satisfactory	Participatory
EQSSP	114	149	15
PGB	48	77	21
GOB	10	23	7
Total	172	249	43

Table 8. Particulars of quality rice seed production, processing and storage training in 2015-16.

Project	Batch (no.)	Participants (no.)			Designation	Organization
		Total	Male	Female		
EQSSP	8	152	152	0	SAPPO	DAE
PGB	1	19	18	1	UAO, AEO	DAE
Total	9	171	170	1		

Table 9. Particulars of crop management skill training in 2015-16.

Project	Batch (no.)	Participant (no.)			Designation	Organization
		Total	Male	Female		
GSR	1	32	29	3	Scientist, AEO, Sr. Agronomist, Sector specialist, Area Manager	BRRI, DAE, BRAC
Total	1	32	29	3		

Table 10. Rice productiontraining courses for farmers in 2015-16.

Project	Training (no.)	Participant (no.)		
		Total	Male	Female
GOB	16	480	455	25
EQSSP	13	390	372	18
Total	29	870	827	43

Table 11. Total training conducted by Training Division in 2015-16.

Name of the training	No. of training	Duration	No. of participants			Designation
			M	F	Total	
Rice production and communication training	2	2 month	31	13	44	SO, SSO
Modern rice and quality seed production and storage (EQSSP)	14	1-week	243	35	278	SAAO
Integrated rice production training (PGB)	5	1- week	133	13	146	SAAO
Modern rice production training (GOB)	2	1-week	37	3	40	SA, BRRI officer

Table 11. Continued.

Name of the training	No. of training	Duration	No. of participants			Designation
			M	F	Total	
Rice seed production, processing and storage (EQSSP)	8	3-day	152	0	152	DAE officer
Quality rice seed production, processing and storage (PGB)	1	3-day	18	1	19	UAO, AEO
Training on crop management skill	1	2-days	29	3	32	Scientist, AEO, Sr. Agronomist, Area manager
Farmers training	29	1 day	827	43	870	Farmers
Total	62		1,470	111	1,581	

EFFECTIVENESS OF IMPARTED RICE PRODUCTION TR ꓵININ ꓶ

It is important to determine the impact of different aspects of imparted rice production training for its better planning and execution in future. This study was conducted at the end of each batch to collect the relevant information. After the completion of data collection, information was compiled and analyzed. This study reveal that both two-month and one- week RPT course are very much helpful for the trainees to build up their capacity for modern rice production activities.

Performance of BRRI speakers

Ten batches of 1- week RPT and two batches from 2-month PRT were considered for this evaluation. At first, batch wise analysis was done on the basis of five criteria for each speaker. The criteria were: a. presentation style; b. question handling; c. use of training materials; d. time management and e. quality and relevance of handout and its timely supply. Average of 5 criteria was used to determine the performance of individual speaker in each batch. The overall performances of BRRI's speakers' were very good (34.59%) to excellent (45.43%) in both long and short courses.

BANGLADESH RICE KNOWLEDGE BANK (BRKB)

Training Division is working to develop and update information on all BRRI released technologies in a digital form through BRKB. One of the objectives of this is to redesign and update the BRKB with latest rice information. During the reporting period six new fact sheets on newly released rice varieties were developed and uploaded in BRKB website.

Publications and Public Relations Division

SUMMARY

Publications and Public Relations Division (PPRD) is dedicated to documentation and dissemination of information regarding BRRI developed technologies and more so that good relations with the target people or stakeholders are maintained.

To achieve this goal in the reporting year the division has been engaged in different activities that included editorial services for publications and other communication materials, maintaining public relations through distribution of books, leaflets, folders, seasonal greeting cards, advertisements etc, attending different meetings, radio and TV programmes, providing photographic services on a regular basis, writing and disseminating press releases, articles for the social and print media, participating in workshop, seminar, fairs, training programmes.

In the reporting year, we produced 32,650 copies of 12 publications with 775 pages in Bangla and English and distributed 34,149 copies of different publications from the existing stock of 291 publications issued so far. We got 797 written requisitions for publications in the reporting year. The division supplied BRRI publications to most of the participants of government and non-government organizations of different training programmes held in BRRI HQ and BRRI regional stations. We also supplied publications to the participants to different field days, agricultural fairs and workshop programmes as well. Furthermore, we provided publications to 1,716 visitors from home and abroad in the reporting year. We issued dozens of press releases in national mass media. More than 60 news items and popular articles were published about BRRI in national dailies and periodicals in addition to radio and television coverage.

PUBLICATION

The division produced 32,650 copies of 12 categories of publications (Table 1) with 775 pages in Bangla and English. The forms of these publications include annual reports, newsletters, book, booklets, journals, diary and seasonal greeting cards. A trend change about BRRI publications can be mentioned here. From last year we started to print BRRI newsletter as a regular quarterly publication in Bangla and English. In addition, our Director General's seasonal greeting cards have been given the shape of a regular publication.

Annual Report (English, 350 copies). We published BRRI Annual Report for 2014-15, with 278 pages containing information mainly on research findings and related activities of the Institute illustrated with tables and figures on a yearly basis. BRRI Annual Report also lists working scientists and officials and put forward achievements of the Institute in a Director General's note. This publication consists of a summary of research works carried out by 19 research divisions and nine regional stations of the institute in a financial year. The document contains significant portions of the research covering eight programme areas, such as crop-soil-water management, rice farming systems, pest management, socio-economics and policy, technology transfer, farm mechanization and regional stations representing the broader conceptual frameworks of BRRI activities.

Dhan Gobeshana Samachar **(Bilingual,** 12,200 copies**).** In the reporting period, we printed four volumes of quarterly rice newsletters having 32 pages in total. In the past it was published in Bangla and primarily addressed to extension workers, educated farmers and other people who were especially interested to BRRI activities. But since January 2015 BRRI authority decided to publish it both in Bangla and English so that even our foreign partners can use it to be updated about BRRI research and other activities. It acts as an effective channel for the transfer of appropriate rice technology to farmers and extension agents who might confront manifold field problems and require instructions. It is distributed among agricultural extension officials up to the upazila level and to mass media and concerned organizations.

Adhunik Dhaner Chash **(Bangla, 19th edition, 3,000 copies).** It is one of the most important BRRI publications on BRRI developed technologies and modern rice cultivation practices. To the extension agents, farmers, agricultural scientists, students as well as policy makers, its demand is very high. Some people describe it as the bible of rice cultivation in this country. We published the 80- page booklet in four colours

Table 1. BRRI publications printed in 2015-16.

Name	Language	Target audience	No. of copies
Annual Report 2014-15	English	Scientists, Extensionists, Policy makers	350
Dhan Gobeshana Samachar, Jul- Sep 2015	Bangla/English	Scientists, Extensionists Farmers, Policy makers	12,00
Dhan Gobeshana Samachar , Oct-Dec 2015	Bangla/English	Scientists, Extensionists Farmers, Policy makers	1,000
Dhan Gobeshana Samachar, Jan-Mar 2016	Bangla/English	Scientists, Extensionists Farmers, Policy makers	5,000
Dhan Gobeshana Samachar, Jan-Mar 2016	Bangla/English	Scientists, Extensionists Farmers, Policy makers	5,000
Conservation Agriculture	English	Scientists, Extensionists, Policy makers	300
Adhunik Dhaner Chash, 19th ed. Jun 2016	Bangla	Scientists, Extensionists Farmers, Policy makers	3,000
Dhan Chasher Somosha, 5th ed. Jun 2016	Bangla	Scientists, Extensionists Farmers, Policy makers	3,000
BRRI at a Glance 2016	English	Scientists, Extensionists Policy makers	10,000
Bangladesh Rice Journal, Vol. 19, No. 1	English	Scientists	300
Bangladesh Rice Journal, Vol. 19, No. 2	English	Scientists	500
BRRI Diary 2016	Bangla	Scientists, Extensionists Farmers, Policy makers	1,000
Seasonal Greetings: Eid Card/ New Year Card	Bangla/English	Scientists, Extensionists Academics, Policy makers	2,000
Total			32650

with glossy papers. The book contains almost all the essential information about BRRI developed rice varieties along with their management practices in the field level those are suitable to the 30 agri-ecological zones of the country.

***Dhan chasher Somossa* (Bangla, 5th edition, 3,000 copies).** It is one of the popular BRRI publications on problems of modern rice cultivation practices in the country. It deals with problems of rice cultivation out of rice diseases, insect pests, weather changes and agronomic aspects. Extension agents, farmers, agricultural scientists, students as well as policy makers use it to find out and prescribe solutions of these problems. This year we published the 78- page booklet in four colours with glossy papers. The book contains almost essential information about all the major problems of rice cultivation and their management practices in field level.

BRRI at a Glance (English, 3rd edition, 10, 000 copies). PPRD published BRRI at a Glance, a 6-page brochure in June 2016. It contains a brief introduction about BRRI focusing on its past, present and future plans as well as major achievements, current programmes and projects with colourful photos and descriptions. Its intended audience is the foreign partners and the local policy makers as well as the other stakeholders.

Bangladesh Rice Journal (English, 600 copies). In the reporting period, we published two volumes (19.1 and 19.2) of the Bangladesh Rice Journal, a scientific publication of BRRI. The journal is a peer reviewed publication based on original research findings dedicated to rice science.

BRRI Diary (Bangla, 500 copies). We started to publish BRRI Diary in a comparative new form in 2015. Earlier it was published as a simple telephone directory. In the reporting year its shape and size has been changed and has been given a complete diary form. Almost all the essential information to contact BRRI has been added to it. Detailed information regarding concerned ministries and partner organizations including phone numbers and email IDs of BRRI scientists and officials is also available in it.

Seasonal Greetings (Bangla and English, 2,000 copies). In recent times BRRI Director General's seasonal greetings have been given a shape of useful publication. In an experimental approach we put in it some information as like as BRRI developed new rice varieties and detailed contact addresses of the institute along with prints of art work and colourful photographs. Similarly, it is distributed to our target audience/readers with our regular publications on the occasion of two Eid festivals and two new years-Bangla and Christian.

DISTRIBUTION OF PUBLICATIONS

PPRD distributed 34,149 copies of different publications last year against 291 requisitions. The number of our existing stock of publications issued so far stood at 291. Extension or agricultural officials constitute the major part of the target audiences of BRRI publications. They receive BRRI publications mainly through the Training and Adaptive Research Divisions. PPRD also directly supplies publications to different groups of

people on request. Most of the requests come from farmers, students, researchers, agricultural institutes, GO-NGOs, schools, colleges, universities and visitors from home and abroad.

PUBLIC RELATIONS

The division maintained contact with the mass media and government and semi-government organizations and distributed publications and contributed in organizing annual research review workshop and cooperated with the management to deal with the visitors. One of the major tusks of the PPRD people is to distribute BRRI publications to the institute's target audiences. In addition, now and then we have had to answer queries about BRRI technologies of newsmen and other stakeholders over telephone and through personal communication. We have had to write rejoinders and clarifications to newspapers to dispel misleading information about BRRI as well as rice related issues. The division supplied BRRI publications to many of the 9,489 participants of government and non-government organizations of 310 short and long training courses, field days, agricultural and ICT fairs held in BRRI and other places throughout the year. In addition, we provided publications to hundreds of visitors from home and abroad on a regular basis and issued dozens of press releases in national mass media about BRRI activities. More than one hundred news items and popular articles were published about BRRI in national dailies and periodicals in addition to regular radio and television coverages. As the voice of BRRI we also proposed about 50 titles of radio programmes for the BRRI scientists and most of them were broadcast in the *krishi bishoiok kerjokram* of the Radio Bangladesh.

Most of the receivers of our publications included extension workers, researchers, educated farmers, students and visitors. In addition to their personal use they also distributed publications to listed organizations and individuals, including libraries. We have processed and distributed some display advertisements about BRRI in the reporting year that have been published in different newspapers and periodicals.

BRRI RS, Barisal

SUMMARY

Hybridization for the development of multi-traits advanced breeding lines for tidal areas were done and ten F_1s were obtained involving parents BRRI dhan52, BR7941-41-2-2-4, BR7941-41-2-2-4, BRRI dhan41, BRRI dhan56, BRRI dhan62, Dudhkalam, EG-1 and EG-2 during T. Aman.

Three trials were conducted under RYT during Aman 2015. In these trials- six lines in RYT 1 (RLR), eight lines in RYT 2 (RLR), ten lines in RYT (PQR), and six lines in RYT (Biotech) were evaluated against standard checks. Seven trials conducted under RYT during Boro 2015-16. Out of those trials two lines in RYT-cold, six lines in RYT1 Bio (SD), seven lines under RYT 2_Bio (LD, nine lines in RYT(Insect Res), three lines in RYT 1MER, three lines in RYT 2MER, and three lines in RYT 3MER were evaluated against respective standard checks. Five PVT were conducted during T. Aman 2015. Two breeding lines, BR7941-116-1-2-1 and BR7961-41-2-2-2-4 under PVT-tidal submergence, gave around 1.5 t/ha higher yield than corresponding local checks Sadamota and Dudhkolom. Two lines, IR77092-B-2R-B-10 and BR9377-9-21-3B were evaluated under PVT salt-sub which yielded higher than standard check BRRI dhan44. In PVT (RLR, SD) NERICA-Mutant were evaluated along with standard check BRRI dhan57 but it did not produce significant yield advantage. In PVT (GSR), HUA565 was evaluated against standard check BRRI dhan33 in one location in which HUA565 gave higher yield (3.95 t/ha) than the check. In PVT (PQR), BR7697-15-4-4-2-2 gave higher yield. And in PVT (RLR), BR7611-31-5-3-2 gave around 1 t/ha higher yield than standard check BR11. One in Aus 2015, two in T. Aman 2015 and five in Boro 2015-16 were evaluated under ALART. Balam, Nakuchimota, Moulata, IM, Dudhkalam were found resistant against ufra nematode. Nativo suppressed 82.0% neck blast incidence over control. Three blast resistant multiline (IRBL-ta2, IRBLsh-T, IRBL9W) of IR49830 gave 0.7 -1.0 t/ha higher yield than local variety Sadamota. On average 2-3 irrigation were saved and fuel cost as well without compromising any yield penalty by using AWD during Boro 2015-16. A declining trend of water salinity was observed from April to May due to early monsoon. BRRI released HYVs were demonstrated under IAPP, PGB, HP and EQSS projects to disseminate to the farmers. Demonstrations, seed production and scaling up of MV rice under PGB-IADP were conducted during Aus 2015, T. Aman 2015 and Boro 2015-16. Demonstrations, seed production and scaling up of MV rice under IAPP were conducted at six blocks in Aus 2015, ten blocks in T. Aman 2015 and eleven in Boro 2015-16 having each block of 3.33 acres. Seeds of BRRI hybrid dhan3 were produced at Sagardi farm and at farmer's field. In T. Aman 2015, a total of 4,939 kg and in Boro 2015-16, a total of 10,730 kg breeder seeds were produced.

VARIETAL DEVELOPMENT

Development of tidal submergence tolerant rice

Development of multi-trait advanced breeding lines for tidal areas: Hybridization for the development of Multi-traits Advanced Breeding lines for tidal areas were done and ten F_1s were obtained involving parents BRRI dhan52, BR7941-41-2-2-4, BR7941-41-2-2-4, BRRI dhan41, BRRI dhan56, BRRI dhan62, Dudhkalam, EG-1 and EG-2 during T. Aman 2015 and Boro 2015-16 (Table 1). Also, 175 plants were selected in T. Aman 2015 and grown in Boro, 2015-16 through rapid generation advanced process. Development of varieties for tidal submergence of T. Aman rice: Four progenies from F_2, 90 progenies from F_3, 67 progenies from F_4 population, 66 fixed lines from observational trial and eight entries from secondary yield trial were selected.

Regional yield trial (RYT)

RYT Aman 2015. Six lines were evaluated against two standard checks in RYT 1 (RLR). The highest yield was obtained by BR8227-6-2-1 and BRRI dhan49 (ck) (3.21 t/ha) which is higher than the other check BRRI dhan39. In RYT 2(RLR) eight lines were evaluated against two standard checks. The highest yield was obtained by BRRI dhan49 (ck) (3.03 t/ha) which is higher than the other lines and check varieties. In case of RYT (PQR) ten lines were evaluated against two standard checks. The highest yield was obtained by BR8522-21-4-8 (4.02 t/ha) which is higher than the other lines and check varieties. Six lines were evaluated against three standard checks in RYT (Biotech). The highest yield was obtained by BR9782-BC2-132-1-3 (3.40 t/ha) and the lowest yield was obtained by BRRI dhan33 (ck) (1.67 t/ha).

Table 1. List of F_1s produced during T. Aman 2015 and Boro 2015-16.

Designation	Cross combination
BRBar001	BRRI dhan52/BRRI dhan56
BRBar002	BRRI dhan52/BRRI dhan62
BRBar003	BRRI dhan52/BRRI dhan41
BRBar004	BRRI dhan52/Dudhkalam
BRBar005	BRRI dhan76/ BRRI dhan52
BRBar006	BRRI dhan52/ EG-1
BRBar007	BRRI dhan52/ EG-2
BRBar008	BRRI dhan76/EG-1
BRBar009	BRRI dhan77/EG-1
BRBar010	BRRI dhan77/ BRRI dhan52

RYT Boro 2015-16. In case of RYT_Cold two lines were evaluated against two standard checks. The highest yield was obtained by BR7812-19-1-6-1-P4 (4.07 t/ha) which is higher than the other line and check BRRI dhan28 (3.33 t/ha) and check BRRI dhan29 (3.32 t/ha). Six lines were evaluated against a standard check in the programme of RYT 1_Bio (SD). The highest yield was obtained by BR(BIO)9787-BC2-63-2-4 (4.40 t/ha), which was higher than the other lines and check BRRI dhan28 (3.10 t/ha). Seven lines were evaluated against a standard check BRRI dhan29 under RYT 2_Bio (LD). The highest yield was obtained by BR(BIO)9787-BC2-122-1-3 (4.72 t/ha), which is higher than the other lines and check BRRI dhan29 (3.87 t/ha). In case of RYT_Insect Res, nine lines were evaluated against three standard checks. The highest yield was obtained by BR7903-16-10 (4.10 t/ha), which is higher than the other lines and checks. The lowest yield was obtained by BR8338-34-3-4 (3.30 t/ha) and BR8340-16-2-1 (3.30 t/ha). Under the experiment of RYT 1_MER three lines were evaluated against a standard check BRRI dhan28. The highest yield was obtained by BR7831-59-1-1-4-5-1-9-P1 (4.67 t/ha), which is higher than the other lines and check BRRI dhan28 (3.96 t/ha). Three lines were evaluated against two standard checks BRRI dhan63 and BRRI dhan29 under RYT 2_MER experiment. The highest yield was obtained by BR7671-37-2-2-3-7-3-P10 (3.85 t/ha), which is higher than the other lines and checks. Out of three lines under RYT#3_MER (LA) programme, IR84839-RIL118-1-1-1-1-1 gave higher yield (3.80 t/ha) than standard checks BRRI dhan58 (3.26 t/ha) and BRRI dhan29 (3.66 t/ha).

Proposed variety trial (PVT) for T. Aman rice

PVT for submergence tolerant rice. Two proposed varieties along with three checks were used in this trial. Trials were conducted in nine locations at different places of southern region of Bangladesh. Two proposed varieties BR7941-116-1-2-1 and BR7961-41-2-2-2-4 gave around 1.5 t/ha higher yield than corresponding local checks Sadamota and Dudhkolom. Seedling height of these two lines was almost similar to local checks. These two lines were recommended for two new varieties for the replacement of two local varieties Sadamota and Dudhkalom, respectively under tidal submergence condition of southern region of Bangladesh (Table 2).

PVT for salt-sub tolerant rice. Two lines were evaluated in four locations. Proposed variety IR77092-B-2R-B-10 and BR9377-9-21-3B gave higher yield than standard check BRRI dhan44.

PVT (RLR, SD). One line NERICA along with standard check BRRI dhan57 was evaluated in this trial at Barisal. NERICA Mutant gave higher yield (2.65 t/ha) than standard check BRRI dhan57 (2.40 t/ha).

PVT (GSR). Line HUA565 was evaluated against standard check BRRI dhan33 in one location. HUA565 gave higher yield (3.95 t/ha) than standard check BRRI dhan33 (3.30 t/ha) (Table 3). This line was released as BRRI dhan75 from PVT-GSR.

PVT (PQR). The proposed variety BR7697-15-4-4-2-2 gave higher yield (2.54 t/ha) than standard check BRRI dhan37 (2.31 t/ha), which was evaluated in one location.

PVT (RLR). In one location, only one line BR7611-31-5-3-2 was evaluated against standard check BR11. Proposed variety BR7611-31-5-3-2 gave around 1 t/ha higher yield than the standard check BR11.

PEST MANAGEMENT

Disease management

Screening of rice germplasms and breeding for ufra resistance. 31 local rice germplasms (collected from Barisal) with resistant check Royada were screened against ufra nematode of which Balam, Nakuchimota, Moulata, IM, Dudhkalam were resistant (score 1). Local Aman

Table 2. Performance of the lines in proposed variety trial (PVT) for the development of varieties for submergence tolerant, Aman, 2015.

Designation	Growth duration (days)	Seedling height (cm)	Plant height (cm)	Grain yield (t/ha)
BR7941-116-1-2-1	154	56	133	5.01
BR7961-41-2-2-2-4	163	54	134	5.04
Sadamota (L. ck.)	173	66	145	3.62
Dudhkolom (L. ck.)	155	66	140	3.61
BRRI dhan44 (S. ck.)	160	38	112	4.32
CV	2.06	9.56	4.17	12.42
LSD	3.1	5.3	5.1	0.5

Table 3. Performance of the line in proposed variety trial (PVT), development of varieties for Green Super Rice Aman, 2015.

Designation	Growth duration (day)	Plant height (cm)	Pacp at Mat	grain yield (t/ha)
HUA565	113	89.7	2	5.65
BRRI dhan 33(ck)	119	118	3	5.63

Komla Mota were moderately resistant (Score-3), Kachamota, Khaiya, Bhushiari Balam chikon, Montesar Mota, Kamranga, Sorbi Maloti, Sakhorkhora, Barsa and sadamota were moderately susceptible (score-5). Lal Paikka, Banshful, Chaolamatari, Chinikanai, Badshabhog, Lokma, Abdul Hai were susceptible (score 7) and Chaprash, Guti swarna were Highly susceptible (score 9).

Demonstration of blast disease management practices at farmers' field. Three local variety viz. Kalijira, Chinigura and Sakkhorkhora were used in T. Aman 2015 at three locations of Barisal and Jhalokhathi Districts. BRRI recommended practices were evaluated over farmers' practices. Yield of Kalijira, Chinigura and Sakkhorkhora were significantly increased in recommended practices (3.4, 2.9 and 3.2, respectively) over farmers' practices (2.6, 2.3 and 2.4, respectively). Disease incidence (%) decreased by 80.0%, 83.3% and 85.7% while yield increased 33.3%, 30.8% and 26.1 in Sakkhorkhora, Kalijira and Chinigura respectively over FP. Higher disease incidence (60%) and severity (scale 7) was recorded in Kalijira followed by Sakkhorkhora (DI 40% and DS 3) while lower DI was observed in Chinigura. Under blast management programme in Boro 2015-16, Nativo performed better in reducing leaf blast disease incidence, which was 78.6% over control. About 70% panicles of untreated control plot (disease) were infected by neck blast where disease severity scale varied from 5-9. Nativo suppressed 82.0% neck blast incidence over control (Table 4).

Survey and monitoring of rice diseases. Survey was conducted at Barisal Region during 2015-16. Blast, sheath blight and false smut (in later cultivated crop) were recorded as major diseases. Database would be created in order to develop forecasting models.

Performance of blast resistant multiline of IR49830 under tidal non-saline sub ecosystem. Three blast resistant multilines of IR49830 were evaluated under tidal non-saline sub ecosystem. Three checks viz Sadamota, BR22 and BRRI dhan46 were used. No blast disease in IRBL-ta2, IRBLsh-T, IRBL9W whereas higher disease incidence was recorded in Sadamota followed by BR22 and BRRI dhan46. The highest yield was recorded in BRRI dhan46 (4.6 t/ha). Three multilines of IR49830 gave 0.7 -1.0 t/ha higher yield than local variety Sadamota (2.82 t/ha).

Integrated approach on rice false smut disease management. In T. Aman 2015, there was no False Smut disease in different treatments including control irrespective of planting time and N-management hence, detail result is not presented.

Demonstration on BLB management practices. In Boro 2015-16, overall disease incidence and severity of BLB in BRRI dhan29 was less at the experimental site of Barisal.

Package for BLB demonstration. BRRI dhan29 was used as test variety. Balanced dose of fertilizers was used. Maximum tillering to boot stage; alternate wetting and drying (AWD) of field was practiced; 60 g thiovit and 60 g MOP/10 l water for five decimal land area was applied at initial disease initiation stage. Higher % DI and DS

Table 4. Efficacy of fungicide against leaf and neck blast (NB) disease on BRRI dhan47 during Boro, 2015-16 at Agailjhara, Barisal.

Treatment	Active ingredient (a.i.)	Rate g/ha	% Leaf infection	Neck blast reduction over control (%)
Nativo	Trifloxystrobin+ Tabuconazole	250	15.0 (78.6*)	82.0
Untreated control	None	None	70.0	DS scale varied from 5-9 and about 70% panicles were infected by NB

*Percent reduction of leaf area infection over untreated control.

of BLB were recorded at Nalcity, Jhalakathi followed by Babuganj, Barisal while lower % DI and DS were observed at AgayilJhara Barisal. Maximum grain yield of BRRI dhan29 was observed at AgayilJhara Barisal followed by Babuganj, Barisal and Nalcity and Jhalakathi (Table 5).

Demonstration on rice seed health management practices. BRRI dhan59 was used as test variety. Balanced dose of fertilizers was used; off type was removed (Rouging) at maximum tillering (MT), flowering and hard dough stage (3 times); disease infected panicles (especially, false smut and sheath rot infected) was removed; panicles were harvested at maturity and threshed separately, cleaned properly, sun dried at 10-12% moisture and then seeds were preserved in plastic drum along with nepthalin and neem leaf. The drum with seed was kept air-tight and preserved at corresponding farmers' home for next year use.

Insect pest management

Rice insect pests and their natural enemies were monitored by using light traps during July 2015 to June 2016 at Sagardi farm of BRRI Barisal. Total population of yellow stem borer (YSB) were higher (14,724) followed by green leafhopper (14,713), long horned cricket (LHC) (2326) and brown plant hopper (BPH) (2137). Among the natural enemies total population of green mirid bug (GMB) (4984) and carabid beetle (CBB) (1000) were most prevalent. Other natural enemies such as lady bird beetle (LBB), spider (SPD) and a number of damsel fly (DSF) were also present.

CROP-SOIL-WATER DEVELOPMENT

Adoption and demonstration of water saving technologies at farmer's fields

Eleven demonstrations on AWD to save irrigation water and cost were done during Boro 2015-16 in different Upazilas of Patuakhali, Barisal and Barguna districts. On average 2-3 irrigations were saved and fuel cost as well without compromising any yield penalty.

Assessment of suitable water resources availability for irrigation

The dynamics of surface water salinity in the dry season at different locations of Barisal region were measured to explore the source of suitable water for irrigation during April and May. A declining trend of water salinity was observed from April to May due to early monsoon.

TECHNOLOGY TRANSFER

ALART Aus 2015. One ALART was conducted at Barisal. Two advanced lines viz BR7718-55-1-3 and NERICA Mutant along with BR26 and BRRI dhan48 as checks were tested. The yield difference between BRRI dhan48 (4.00 t/ha) and BR7718-55-1-3 (3.89 t/ha) was statistically insignificant. On average, all the entries matured within 111-118 days. The growth duration of the highest yielder BRRI dhan48 was 111 days, which was the shortest regarding growth duration that was 2-7 days earlier than the tested entries BR7718-55-1-3 and NERICA Mutant respectively (Table 6).

Table 5. Disease incidence, severity and grain yield due to BLB in BRRI dhan29, Boro 2015-16.

Location	Yield (FP) t/ha	Yield (RP) t/ha	% DI in FP	DS in FP	% DI in RP	DS in RP	Farmer name and mobile no.
Babuganj, Barisal	6.0	6.5	4	4	3	3	Badal sikdar, 01723027113
AgayilJhara Barisal	6.5	7.1	3	3	2	3	Jagadish Chandra, 01740563005
Nalcity, Jhalakathi	5.1	5.8	5	4	3	3	Basjlur Rahman Hawlader 01727121838

Table 6. Data of ALART T. Aus 2015.

Genotype	Grain yield (t/ha)	Duration (day)	Plant ht (cm)	Panicle/m ^{2}	1000-grain wt	Grain/panicle	Sterility (%)
BR7718-55-1-3	3.89	113	116.7	236.7	24.9	107.8	19.6
NERICA Mutant	3.37	118	121.8	194.3	27.2	94.8	37.0
BR26 (ck)	3.15	113	114.7	239.0	28.0	82.6	20.3
BRRI dhan48 (ck)	4.00	111	110.7	216.0	26.0	109.0	17.3
CV (%)	8.50	-	2.07	9.58	0.90	7.81	11.7
LSD (0.05)	0.61	-	4.79	42.40	0.48	15.38	5.53

ALART Aman 2015. Four ALART programmes were conducted at Barisal sadar. In ALART BBR programme BRC245-4-19-2-1 gave lower (5.39 t/ha) yield than the check variety BR11 (5.68 t/ha). In ALART Hybrid programme BRRI dhan49 gave the highest yield (4.78 t/ha) than the lines and check varieties. In ALART MN programme the promising line BR8143-15-2-1 gave the highest yield (5.87 t/ha) than the other lines and check varieties. In ALART RLR programme the promising line WAS 161-B-4-B-1-TGR 51 (NERICA-L-32) gave the highest yield (5.76 t/ha) than the other lines and check varieties.

ALART Boro 2015-16. Five ALART programmes were conducted at Barisal sadar. In ALART FB-SD programme the check variety BRRI dhan28 gave the highest yield (5.85 t/ha) than the other line and check variety. In ALART ME-SD programme the promising line BR(BIO)8072-AC8-1-1-3-1-1 gave the highest yield (8.29 t/ha) than the other lines and check varieties. In ALART Hybrid programme the promising line BR1793H gave the highest yield (8.35 t/ha) than the other lines and check varieties. In ALART GSR-LD programme the promising line HHZ15-DT4-DT1-Y1 gave the highest yield (8.02 t/ha) than the other lines and check varieties. In ALART HY-SD programme the promising line BRRI dhan29-SC3-28-16-15-HR2 (Com) gave the highest yield (8.48 t/ha) than the other lines and check varieties.

Demonstration, seed production and scaling up of MV rice under PGB-IADP

In Aus 2015, BRRI dhan27, BRRI dhan48 were demonstrated and both the varieties gave similar yield. During T. Aman 2015, BRRI dhan52, BRRI dhan62 were demonstrated along with other varieties. BRRI dhan52 produced on average 4.75 tha^{-1} grain yield with growth duration of 139 days. On the other hand, BRRI dhan62 gave 4.35 tha^{-1} grain yield with much shorter growth duration of only 99 days. Farmers choosed BRRI dhan62 due to its shorter growth duration, zinc content and satisfactory grain yield. They also liked BRRI dhan52 as it survived after two weeks of tidal inundation. In Boro 2015-16, irrespective of location average grain yield of BRRI dhan60, BRRI dhan63, BRRI dhan64 and BRRI Hybrid dhan3 were 6.18, 6.14, 6.06 and 7.67 tha^{-1} respectively. Farmers were motivated with the varieties BRRI dhan48 in Aus, BRRI dhan52 and BRRI dhan62 in Aman and, BRRI dhan60, BRRI dhan64 and BRRI hybrid dhan3 in Boro due to satisfactory grain yield.

Demonstration, seed production and scaling up of MV rice under IAPP

Under IAPP six block demonstrations each of 3.3 acres in Aus 2015, ten block demonstrations each of 3.3 acres in T. Aman 2015 and eleven block demonstrations each of 3.3 acres in Boro 2015-16 were established. An average yield of BRRI dhan48 was 4.2 t/ha found over the locations in Aus season. In T. Aman 2015, average yield of BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan49 and BRRI dhan52 was 4.6, 4.8, 4.3, 4.0 and 4.7 t/ha respectively were found. In Boro 2015-16, BRRI dhan29, BRRI dhan47, BRRI dhan58, BRRI dhan59, BRRI dhan60, BRRI dhan61, BRRI dhan64 and BRRI hybrid dhan3 gave 6.67, 5.16, 5.87, 5.59, 5.31, 5.08, 4.94 & 8.04 t/ha grain yield respectively. Farmers were motivated to cultivate BRRI dhan48 in Aus, BRRI dhan44, BRRI dhan52 and BRRI dhan62 in Aman, BRRI dhan 58, BRRI dhan60 and BRRI Hybrid dhan3 in Boro.

Demonstration of Zn-rich rice under HarvestPlus project

Demonstration of BRRI dhan62 was conducted at Najirpur and Mollahat in T. Aman 2015 season. Yield of BRRI dhan62 ranged from 3.64-5.12 t/ha. A total of 300 minikit of BRRI dhan62 were distributed to Bhola sadar and Borhanuddin upazila

of Bhola district; Fakirhat and Mollahat upazilas of Bagerhat district, Najirpur upazila of Pirojpur district and Baufol upazila of Patuakhali district. Average yield of BRRI dhan62 in those upazilas were 4.02, 3.80, 3.95, 4.25, 4.60 and 4.05 t/ha respectively. In Boro 2015-16, a total of 25 demonstration trials of BRRI dhan64 were conducted at farmers field of different villages of Najirpur (Pirojpur), Mollahat and Fakirhat (Bagerhat) upazila. The yield of BRRI dhan64 was ranged from 5.41 to 6.75 t/ha. Average yield was 6.01 t/ha. Farmers were motivated to cultivate Zn-rich variety BRRI dhan62 and BRRI dhan64.

Farmer's training under different projects

BRRI RS, Barisal conducted 13 farmers' training in different locations of Barisal region during the reporting period. These training programmes were conducted at Barguna sadar, Barguna (2); Nolcity, Jhalokati (2); Babuganj, Barisal (4), Barisal sadar (1) and at Baufal, Patuakhali (1) under EQSS project; at Nazirpur, Pirojpur (2) under PGB project and one at Baufal, Patuakhali under Harvest plus project. In total 390 persons (300 males and 90 females) were trained. Awareness for adopting improved rice cultivation technologies and enhancing the dissemination of BRRI varieties was done through those trainings.

Farmers' field day under different projects

Twelve field days were conducted under IAPP, PGB-IADP and HarvestPlus Bangladesh projects. More than 2,400 (average of 200 in each field day) farmers, extension personnel, administrative peoples, public leaders participated in these programmes. Most of the farmers have chosen BRRI dhan48 for high yielding and no lodging at harvesting period in Aus season. Mollahat farmers choosed BRRI dhan62 for Aman season because of its early maturing (99 days) characteristic and higher yield (4.45 t/ha). BRRI hybrid 3 and BRRI dhan64 has been chosen in Nazirpur for Boro for higher yield. Farmers showed their interest to cultivate the demonstrated varieties in the next season.

Seed production

Hybrid seed production. Seeds of BRRI hybrid dhan3 were produced at Sagardi farm and at farmer's field. Produced seeds were provided to the farmers of this region to cultivate and disseminate.

Breeder seed production. In T. Aman 2015, a total of 4939 kg (BR23=424 kg, BRRI dhan44=218 kg, BRRI dhan52=3278 kg under EQSSP and BRRI dhan44=219 kg, BRRI dhan52=800 kg under IAPP) and in Boro 2015-16, a total of 10,730 kg (BR26=4650 kg BRRI dhan61=1080 kg, BRRI dhan67=1500 kg, BRRI dhan28=2000 kg, BRRI dhan29=1000 kg and BRRI dhan60=500 kg) breeder seed were produced. BRRI released varieties would be disseminated quickly to farmers through this programme.

BRRI RS, Bhanga

SUMMARY

For shallow flooded deepwater rice breeding, five crosses were made using seven parents and 887 F_1 seeds were produced while developing high yielding rice varieties for single Boro cropping pattern. Five crosses were made using five parents and 238 F_1 seeds were produced.

In regional yield trials (RYT), the advanced breeding lines BR8445-54-6-6 and BR7895-4-3-3-2 were promising for long slender and short bold grains respectively in T. Aman season. The advanced breeding lines, BR9892-6-2-2B, BR9392-6-2-B and BR10230-7-19-B outyielded the local check by over 1 t/ha in deepwater rice. In Boro season, the promising lines BR7988-14-1-4-4-2, BRH11-9-11-4-5B and BRRI dhan29-SC3-8-HR1(Com) were for favourable Boro; and BR7812-19-1-6-1-P4 was for cold tolerant rice. Also, BR7831-59-1-1-4-3-1-7-P2 and BR8643-6-4-4 were for micro-nutrient enriched rice while BR7372-18-2-1-HR1-HR6(Com) and BR8076-1-2-2-3 for premium quality rice.

BRRI released Aman variety BRRI dhan33 gave the highest grain yield (6.65 t/ha), while BR7 gave the highest grain yield (8.28 t/ha) among BRRI released modern rice varieties for Boro season in case of stability analysis. The highest rice yield was obtained from BRRI dhan49 that was relayed with jute before three weeks of harvesting for evaluation of Aman establishment time as relay cropping with jute in Jute-Relay Aman-Wheat cropping pattern in shallow deep water rice ecosystem.

BRRI dhan48 was found as high yielder and acceptable to the farmers of greater Faridpur region for Aus season cultivation.

In the farmers' field trials, yields of BRRI released T. Aman and Boro varieties were as follows: BRRI dhan52 gave 3.86 t/ha, BRRI dhan57 yielded 3.84 t/ha, BRRI dhan62 produced 4.33 t/ha and BRRI hybrid dhan4 gave 5.23 t/ha during T. Aman 2015 season; whereas BRRI hybrid dhan2 produced 7.15-8.45 t/ha, BRRI hybrid dhan3 gave 7.24-7.80 t/ha, BRRI dhan67 gave 6.84-7.12 t/ha, BRRI dhan58 yielded 6.38 t/ha and BRRI dhan63 gave 6.22 t/ha during Boro 2015-16 season.

BRRI RS, Bhanga farm produced about 32.1 tons of seeds of which about 16 tons were breeder seed of BRRI dhan28 and BRRI dhan29 and the rest were TLS during Boro season in 2015-16.

A total of 11.35 tons of quality seeds were produced in farmers' fields during T. Aman 2015 and Boro 2015-16 seasons to meet the local demand under EQSS project support.

Flood water entered into the farm land on 25 June 2015 and retained up to 25 October 2015 with a maximum water depth of 1.5 m.

VARIETAL DEVELOPMENT

Material development. In breeding programme for shallow flooded deepwater rice, five crosses were made using seven parents and 887 F_1 seeds were produced in collaboration with Plant Breeding Division, BRRI HQ, Gazipur (Table 1). In breeding programme for developing high yielding rice varieties in single Boro cropping pattern, five crosses were made using five parents and 238 F_1 seeds were produced (Table 2).

RYT (T. Aman). For long slender grain, the advanced breeding line like BR8445-54-6-6 produced over 1 t and 0.75 t higher grain yield than the check varieties BINA dhan7 and BRRI dhan57 respectively with five to seven days longer growth duration (Table 3). In case of short bold grain, the advanced breeding line like BR7895-4-3-3-2-3 produced over one ton higher grain yield than the standard check variety BRRI dhan32 with almost similar growth duration (Table 4). The advanced breeding lines viz BR7528-2R-HR16-12-23-P1 and

Table 1. List of crosses made, Improvement of rice for shallow flooded DWR environment, T. Aman 2015.

Cross	No. of seeds
BRRI dhan52/Bazail65	226
BRRI dhan52/Laxmidigha	140
PCR/Laxmidigha	111
BRRI dhan52/Hijoledigha	202
BR8159-20-8-5-8-2/Barshadhan	208
Total	887

Table 2. List of crosses made, Breeding for developing high yielding rice varieties for single Boro cropping pattern, Boro 2015-16.

Cross	No. of seeds
BRRI dhan58/IR35238-B-1-1-P19	40
BRRI dhan58/BR7812-19-1-6-1-P3	102
BRRI dhan63/BR7812-19-1-6-1-P3	33
BRRI dhan29/IR35238-B-1-1-P19	33
BRRI dhan29/ BR7812-19-1-6-1-P3	30
Total	238

Table 3. Grain yield and ancillary characters of RYT micronutrient enriched rice (Long Slender grain) in T. Aman, 2015 at BRRI RS, Bhanga.

Entry	Plant height (cm)	Duration (day)	Grain yield (t/ha)
BR8410-16-4-17-9-1	121	128	4.49
BR8445-54-6-6	125	123	4.65
BR7528-2R-HR16-2-24-1	119	126	4.36
BINA dhan7 (ck)	108	118	3.47
BRRI dhan57 (ck)	116	116	3.88

DS: 30 Jun 2015, DT: 28 Jul 2015.

Table 4. Grain yield and ancillary characters of RYT micronutrient enriched rice (Short bold grain) in T. Aman, 2015 at BRRI RS, Bhanga.

Entries	Plant height (cm)	Duration (days)	Grain yield (t/ha)
BR7895-4-3-3-2-3	122	139	5.23
BR8442-9-5-2-3-B1	110	140	4.27
BR5 (ck)	153	152	2.45
BRRI dhan 32 (ck)	134	136	4.09
BRRI dhan39 (ck)	109	126	4.40

D/S: 30 Jun 2015, DT: 30 Jul 2015.

IR84750-213-2-2-3-1 out-yielded the standard check variety BRRI dhan49 by over one t/ha with about one week earlier in maturity (Table 5).

RYT (Deepwater rice). The advanced breeding line, BR9892-6-2-2B had almost similar plant height with over one ton yield advantage against the local check Baila Digha in a hectare of land (Table 6). The advanced breeding lines like BR9392-6-2-B and BR10230-7-19-B yielded 1.25 t/ha higher than the local check Baila Digha while having about 38 cm shorter plant height.

RYT (Boro)-favourable Boro. The breeding lines, BR7988-14-1-4-4-2 produced the highest grain yield (8.03 t/ha) followed by BRH11-9-11-4-5B (7.75 t/ha), which were 1.25 ton and about one ton higher respectively than the check variety BRRI dhan28 but having about one week longer growth duration than the check (Table 7). Also, in RYT-FB, the advanced breeding line BRRI dhan29-SC3-8-HR1 (Com) out-yielded the standard checks BRRI dhan29 and BRRI dhan58 by about 1 t/ha having intermediate growth duration between the two checks (Table 8).

Cold tolerant rice. The advanced breeding line, BR7812-19-1-6-1-P4 having intermediate growth duration and yield between the check varieties BRRI dhan28 and BRRI dhan29.

Micronutrient enriched rice. The advanced breeding lines, BR7831-59-1-1-4-3-1-7-P2 produced 0.4 t/ha higher yield than the check variety BRRI dhan28 with a few days shorter growth duration (Table 9). Also the advanced breeding line, BR8643-6-4-4 out-yielded the checks BRRI dhan63 and BRRI dhan29 by about three tons and about 1.5 tons per hectare having similar growth duration and about a week earlier in maturity respectively.

Premium quality rice. The breeding lines, BR7372-18-2-1-HR1-HR6(Com) and BR8076-1-2-2-3 produced about 1.5 t and over 1.0 t higher yield with a few days shorter and similar growth duration respectively than the check variety BRRI dhan50 (Table 10).

Short and long duration (Biotech). None of the advanced breeding lines outyielded the check BRRI dhan28 and BRRI dhan29, with almost a few days longer and almost similar growth duration respectively.

Table 5. Grain yield and ancillary characters of RYT micronutrient enriched rice (Kataribhog type grain) in T. Aman 2015 at BRRI RS, Bhanga.

Entry	Plant height (cm)	Duration (day)	Grain yield (t/ha)
BR7528-2R-HR16-12-23-P1	122	137	6.19
BR7528-2R-HR16-12-3-P1	116	134	5.02
BR7528-2R-HR16--3-98-1	107	134	4.74
IR84750-213-2-2-3-1	121	132	5.85
Kataribhog (ck)	185	152	2.55
BRRI dhan32 (ck)	133	134	4.74
BRRI dhan39 (ck)	109	125	4.26
BRRI dhan49 (ck)	109	140	4.73

DS: 30 Jun 2015, DT: 29 Jul 15.

Table 6. Grain yield and ancillary characters of RYT deepwater rice at Khandarpar, Muksudpur of Gopalganj district, Aman 2015.

Designation	Plant height (cm)	Yield (t/ha)
BR9392-6-2-B	118	3.02
BR10238-5-1-B	112	2.86
BR9892-6-2-2B	149	2.74
BR10230-7-19-B	118	2.95
Barsha dhan	149	2.02
Baila Digha (L. ck)	156	1.61

DS: 10 Jun 2015.

Table 7. Grain yield and ancillary characters of RYT-1, development of rice varieties for Favourable Boro environment in Boro, 2015-16 at BRRI RS, Bhanga.

Entry	Plant height (cm)	No. of tillers/m^2	No. of panicles/m^2	Growth duration (day)	Yield (t/ha)
BR7683-30-3-3-4	93	372	327	145	6.47
BR8611-10-3-2-2	90	300	270	147	6.89
BR7988-12-5-1-1-1	86	360	303	148	7.34
BR8247-3-2-2-2	81	327	290	148	6.90
BR7988-10-4-1	86	345	283	147	7.67
BR7988-12-3-4-3-1	91	367	293	148	6.82
BRH11-9-11-4-5B	90	362	320	149	7.75
BR7988-14-1-4-4-2	103	390	323	149	8.03
BRRI dhan28(ck)	100	357	298	143	6.78

DS: 25 Nov 2015, DT: 6 Jan 2016.

Table 8. Grain yield and ancillary characters of RYT-2, Development of rice varieties for favourable Boro environment in Boro, 2015-16 at BRRI RS, Bhanga.

Entry	Plant height (cm)	No. of tillers/m^2	No. of panicles/m^2	Growth duration (day)	Yield (t/ha)
BR8626-19-4-1-1	107	240	217	150	8.10
BR8643-6-4-3	109	333	288	144	7.58
BRRI dhan29-SC3-28-16-15-HR2(Com)	105	298	272	148	8.25
BR8626-20-9-1-3	98	362	325	150	8.17
BRRI dhan29-SC3-8-HR1(Com)	103	253	228	149	9.06
BR8626-19-5-1-2	102	317	283	150	8.44
BRH10-3-12-21-4B	106	337	305	159	6.31
BRRI dhan28(ck)	110	370	310	142	7.22
BRRI dhan29(ck)	103	382	337	153	7.98
BRRI dhan58(ck)	104	317	285	146	8.08

DS: 25 Nov 2015, DT: 6 Jan 2016.

Table 9. Grain yield and ancillary characters of RYT-5, Micronutrient enriched rice (MER -2) in Boro, 2015-16 at BRRI RS, Bhanga.

Entry	Plant height (cm)	No. of tillers/m^2	No. of panicles/m^2	Growth duration	Yield (t/ha)
BR7671-37-2-2-3-7-3-P11	100	363	312	149	6.60
BR8643-6-4-4	103	263	228	144	9.64
BR7671-37-2-2-3-7-3-P10	96	325	270	148	5.92
BRRI dhan63(ck)	95	262	213	144	6.35
BRRI dhan29(ck)	102	332	278	152	8.18

DS: 25 Nov 2015, DT: 8 Jan 2016.

Table 10. Grain yield and ancillary characters of RYT-7, development of premium quality rice in Boro, 2015-16 at BRRI RS, Bhanga.

Entry	Plant height (cm)	No. of tillers/m^2	No. of panicles/m^2	Growth duration	Yield (t/ha)
BR8079-52-2-2-2	95	388	332	148	6.39
BR8076-1-2-2-3	105	312	275	147	7.11
BR7372-18-2-1-HR1-HR6(Com)	106	282	242	144	7.43
BRRI dhan50(ck)	87	385	322	147	5.99
BRRI dhan63(ck)	86	312	263	146	7.71

DS: 26 Nov 2015, DT: 8 Jan 16.

SOCIO ECONOMICS AND POLICY

Stability analysis. Among BRRI released Aman varieties, BRRI dhan33 gave the highest grain yield (6.65 t/ha) followed by BRRI dhan44 (6.10 t/ha), BRRI dhan39 (5.99 t/ha), BR3 (5.95 t/ha) and BRRI dhan41 (5.94 t/ha). In stability analysis of BRRI released modern rice varieties for Boro season, BR7 gave the highest grain yield (8.28 t/ha), which was followed by BR3 (8.11 t/ha) and BR2 (7.88 t/ha).

FARMING SYSTEMS RESEARCH

Evaluation of Aman establishment time as relay cropping with jute in Jute-Relay Aman-Wheat cropping pattern in shallow deep water rice ecosystem. The highest yield of rice was obtained from BRRI dhan49 that was relayed with jute before three weeks of harvesting. The highest REY (Rice equivalent yield) was found from Jute-Relay Aman-Onion cropping pattern followed by Jute-Relay Aman-Cumin seed cropping pattern (Table 12) and Jute-Relay Aman-Wheat cropping pattern.

BRRI RS, Comilla

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SUMMARY

Altogether 66 crosses were made and 70 crosses were confirmed during T. Aman and Boro at BRRI RS, Comilla. A total of 830, 486, 313, 875 and 108 plant progenies with desirable plant type and high yield potential were selected from F_2, F_3, F_4, F_5 and F_6 generations respectively. Eighty-eight homozygous lines were bulked under the varietal development programme. In total 132 genotypes were selected from observational trial (OT) having desirable characters and high yield potential. Twenty, 34, 10, 15, 20, 14, 13, 20, 11, 16, 30 and 17 genotypes, with diverse genetic background having earliness, good grain type, compact panicle, lodging resistance, disease and insect resistance and high yield potential, were selected from IRLON, 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), IIRON, MST-GSR and Super Yielder-GSR during T. Aman and Boro season. For making pure line three Head Rows were done during T. Aman.

Seventy-seven advanced lines were selected from different yield trials in T. Aus, T. Aman and Boro season during 2015-16.

The incidence of false smut disease (% panicle infection) was higher in 3rd planting time (15 July) than 1st and 2nd planting times (15 June and 30 June). The incidence of false smut disease was increased in late planting i.e. after June.

December 1 and 16 seeding BRRI dhan62 (7.21-7.75t/ha) yielded higher than BRRI dhan28 (6.62-6.76 t/ha). BRRI dhan62 may an alternative of BRRI dhan28 in Boro season.

Silicon @ 0.25% silicon solution resulted maximum number of productive tillers, straw yield, branches per panicle, grains per panicle, 1000 grain weight, paddy yield and grain starch applied by foliar application.

Varietal development. All the yield trials from preliminary yield trial (PYT), secondary yield trials (SYT), regional yield trial (RYT), advanced yield trials (AYT) were conducted in RCB design. Spacing was maintained 25 × 15 cm in Boro and T. Aman and 20×15 cm in T. Aus season. Replication was 2 or 3 depending on space limitation and no of seedling used.

During T. Aus, considering the yield performance (4.36-4.96 t/ha) and growth duration (108-110 days) BR7718-55-1-3 and WK1 were selected as compared with standard check BRRI dhan48 (4.4 t/ha and 110 days) from AYT# Regional (Table 1). These lines were selected for regional adaptive lines advanced research Trial (ALART) for Comilla region.

During T. Aman, in PYT#1 (Com)-RLR considering the yield performance (5.15-5.21 t/ha) BRC308-1-1-1-6, BRC312-6-1-2-1 and BRC313-6-1-1-1were selected. In PYT#2 (Com)-RLR, IR 11L433, IR 12L232, IR 12L186, IR 12L248 and IR 11F186 were selected for giving higher yield (4.57-5.89 t/ha) and showing shorter growth duration (123-129 days) for further evaluation in SYT during next T. Aman season.

During T. Aman, in SYT#1 (Com) considering the yield performance (5.02-5.12 t/ha), growth duration (129-144 days) and disease reaction IR08L181 and IR09L305 were selected as compared with standard checks. In SYT#2 (Com) BRC245-4-19-2-1 were selected for giving higher yield (5.45 t/ha) and special red tip colour. In SYT#3, BRC316-2-2-1, BRC273-3-4-4-2 and BRC273-4-2-4-3 were selected for giving higher yield (4.37-6.21 t/ha) and showing good disease reaction and agronomic characters as compared with standard checks (2.35-4.87 t/ha).

During T. Aman, in time of planting BR7358-56-2-2-1-HR7 shows no photosensitivity (1st date of flowering 12.10.2016 and 2nd date of flowering 24.10.2016) as compared with standard check BR22 (1st date of flowering 5.11.2016 and 2nd date of flowering 9.11.2016).

For T. Aman, in RYT#1 (RLR) IR70213-10-CPA 4-2-2-2 were selected for giving 0.70 t/ha higher yield than standard check BRRI dhan39 (4.48 t/ha). In RYT#2 (RLR), considering the yield performance (4.74-5.86 t/ha) and growth duration (122-135 days) BR8210-10-3-1-2, BR8198-13-4-1-3 and Inpari 11 were selected as compared with standard checks (5.04-6.05 t/ha and 124-147 days). In RYT#3 PQR BR8522-44-5-1, BR8522-46-1-1 and BR8522-30-1-2 were selected for giving higher yield (4.08-5.09 t/ha) and showing 16-23

Table1. Yield and agronomic performance of breeding materials of AYT (Regional), T. Aus 2015-16, BRRI RS, Comilla.

Genotype	Plant ht (cm)	Locations											
		On station		Chandina		Barichang		Debidwar		Sadar dhakin		Mean	
		GD	GY	GD	GY	GD	GY	GD	GY	GD	GY	GD	GY
BR7718-55-1-3	97	105	4.23	109	5.20	108	4.80	113	4.15	105	3.43	108	4.36
WKI (Selection from BR7611	98	106	4.17	111	5.61	110	5.06	115	5.20	108	4.63	110	4.93
BRRI dhan48 (ck)	96	104	4.76	109	5.24	108	4.75	113	3.90	105	3.53	108	4.44

GD=Growth duration, GY=Grain yield.

days shorter growth duration than standard checks (1.49- 3.48 t/ha and 148-153 days). In RYT#4 MN-LS BR7528-2R-HR16-2-24-1 and BR8410-16-4-17-9-1 were selected for giving higher yield (4.37-5.40 t/ha) than standard checks (3.84 t/ha). In RYT#5 MN-SB and RYT#6 MN-KB no genotypes were selected. In RYT#7-Disease Resistant (DR) considering the yield potential (4.98-6.39 t/ha), growth duration (127-147 days) and disease resistance performance BR8821-8-1 (BB), BR7959-14-2-1 (RTV), BRC171-2-1-2-2-2 (RTV) and IR73885-1-4-3-2-1 were selected as compared with standard checks (1.60-6.27 t/ha and 128-158 days). In RYT# Biotech BR9786-BC2-119-1-1 and BR9786-BC2-132-1-3 were selected for giving high yield performance (6.38-6.44 t/ha) as compared with standard checks (4.94-6.16 t/ha).

During T. Aman, in AYT#1-RLR considering the yield performance (5.24 t/ha) and growth duration (131 days) and disease reaction B10533F-KN-12-2 was selected as compared with standard checks (3.62-5.73 t/ha and 143-147 days). In AYT#2-RLR WAS 122-14-WASB-FK1(NERICA-L-8) were selected for giving satisfactory yield (5.06 t/ha) and showing shorter growth duration (129 days) as compared with standard check BRRI dhan49 (7.00 t/ha and 140 days). In AYT#3-PQR considering the yield performance (5.66- 6.55 t/ha), growth duration (145-149 days), grain size and grain tip colour BRC316-2-2-1, BRC273-3-4-4-2 and BRC273-4-2-4-3 were selected as compared with standard checks (2.71-3.43 t/ha and 145-149 days). In AYT#4-MER BR8418-1-3 were selected for giving satisfactory yield (4.19 t/ha) and showing shorter growth duration (122 days) as compared with standard checks (4.19-4.57 and 128-141 days). In AYT#5-GSR no genotypes were selected.

In AYT#6-water stagnation 14 genotypes were selected out of 54 genotypes as compared with standard check BRRI dhan44 and local checks Jira sail and Dud kalam (Table 2).

Table 2. List of selected materials for stagnant water T. Aman 2015-16, BRRI RS, Comilla.

Genotype	Plant ht (cm)	Yield (t/ha)	Remark
BR7846 -14 -1-2-1-1	131	3.84	
BR7847 -14 -1-2-1-1	129	3.52	
BR7847 -14 -1-2-1-2	128	2.63	
BR7847 -17-2-2-2-2	111	3.75	
BR7847 -17-2-2-2-2	129	1.89	RD-40%
BR7847 -17-3-3-2-3	129	-	Rat damage
BR7847 -38-1-1-3-1	123	3.71	
BR7847 -38-1-1-3-1	137	2.63	
BR7847 -38-1-1-3-1	111	3.59	
BR7847 -49-1-1-2-1	110	3.69	
BR7849 -35-2-2-1-1	123	3.84	
BR7849 -48-1-2-1-2	119	2.20	
BR7841 -34-1-1-2-2	112	3.87	
BR7841 -53-1-2-1-1	132	4.58	
BRRI dhan44 (ck)	119	3.86	

D/Soak 14 Jul 2015, D/T: 24 Aug 2015.

For Boro, in TRB-BRRI project 124 genotypes were selected among 166 genotypes from OYT based on high yield performance and other good agronomic characters.

For Boro, CT19558-2-44-5-4-M-1-M, LPD104-B-B1-8-2-1-1, IR10N230, IR11A294, IR88628-B-B-B-13, IR04A115, IR06A177, IR09N142, IR10F203, IR10N304IR and IR06A150 were selected from PYT#IRLON (Com) for giving higher yield (5.16-7.16 t/ha) as compared with standard checks (3.57-5.76 t/ha). In PYT#1 (Com) considering the yield performance (5.21-6.15 t/ha) and growth duration (139-146 days) BRC297-15-1-1-1, BRC302-1-4-4-4, BRC302-2-1-2-1and BRC269-15-1-1-3 were selected as compared with standard check BRRI dhan58 (5.21 t/ha and 142 days). In PYT#2 (Com) BRC298-18-2-3, BRC319-6-1-1 and BRE319-9-1-3 were selected for giving higher yield potential (5.15-5.57 t/ha) as compared with standard checks (5.01-5.39 t/ha). In PYT#3 (Com), BRC302-2-1-2-2 and BRC302-18-1-2-1 were selected for high yield performance (5.42-6.43 t/ha) as compared with standard checks (4.03-5.33 t/ha). In PYT#1 GSR considering the yield performance (4.99-5.59 t/ha) and growth duration

(143-146 days) GSR-IR1-9-D13-S3, GSR-IR1-11-D10-S3, HHZ-12-Y4-DT1-Y3, HHZ-12-Y4-Y1-DT1 and HHZ14-DT12-L11-L11 were selected as compared with standard checks (4.26-5.77 t/ha and 142-148 days). In PYT#2 GSR considering the yield performance (4.76-5.55 t/ha) HHZ14-Y7-Y1-DT2, HHZ15-DT4-DT1-Y1, HHZ17-Y16-Y3-Y2, HHZ25-DT8-DT1-Y1 and HHZ29-SAL9-Y3-SUB1 were selected as compared with standard checks (4.69 t/ha).

For Boro, in SYT # (Com) BRC297-15-1-1-1, BRC319-9-1-4, BRC319-9-1-5, BRC270-2-1-1-2, BRC298-2-1-2-2 were selected for giving higher yield (5.71-6.53 t/ha) than standard checks (5.15-5.69 t/ha).

For Boro, in RYT#1 (Favourable Boro) BR8247-3-2-2-2, BR7683-30-3-3-4 and BR79-88-10-4-1 were selected for giving higher yield (6.25-6.56 t/ha) than standard check BRRI dhan28 (5.64 t/ha). In RYT#2 (Favourable Boro) no genotypes were selected. From RYT#3 PQR BR8076-1-2-2-3 and BR7372-18-2-1-HR1-HR6 (Com) were selected for giving higher yield (6.08-6.09 t/ha) than standard checks (4.85-5.73 t/ha). In RYT#4-High Yield BRH11-9-11-4-5B was selected for higher yield (6.81 t/ha) and showing uniform maturity and other good agronomic characters than standard check BRRI dhan28 (4.87 t/ha). In RYT#5 Cold BR7812-19-1-6-1-P2 and BR7812-19-1-6-1-P4 were selected for high yield performance (6.68-7.84 t/ha) as compared with standard checks (5.79-7.17 t/ha). From RYT#6-insect resistant BR7987-50-1-5 and BR7987-51-1-3 were selected for giving higher yield (5.16-5.77 t/ha) and showing good resistance to insects as compared with standard checks (2.31-5.11 t/ha). From RYT#1 MER, RYT#2 MER and RYT #3 LA no genotypes were selected. In RYT # 1 Biotech BR (Bio) 9787-BC2-63-2-2 and BR (Bio) 9787-BC2-63-2-4 were selected for high yield performance (5.84-6.32 t/ha) as compared with standard check BRRI dhan28 (5.13 t/ha). In RYT # 2 Biotech BR (Bio) 9786-BC2-122-1-3 and BR (Bio)9786-BC2-49-1-2 were selected for giving high yield potential (8.21-8.27 t/ha) as compared with standard check BRRI dhan29 (7.99 t/ha).

For Boro, in AYT#GSR HHZ5-SAL10-DT1-DT1, ZHONGHUA-14 and HUANG HUAZHAN were selected for giving higher yield (6.02-6.54 t/ha) than standard checks (5.67-5.97 t/ha).

For Boro, AYT# Regional BR7833-19-2-3-5, BR8261-19-1-1-3, BR7879-17-2-4-HR3-P1, HHZ15-SAL-13-Y1, BR6158-RWBC2-2-1-1 and BR7781-10-3-2-2 were selected for giving higher yield (6.44-7.34 t/ha) than standard checks (5.88-6.36 t/ha).

For Boro, in ALART # Com BR7800-63-1-7-3, BR8245-2-1-4 and HHZ23-DT16-DT1-DT1 were selected for giving higher yield (6.01-6.31 t/ha) than standard checks (4.91-5.17 t/ha). In ALART # GSR HHZ15-DT4-DT1-Y1 was selected for giving higher yield (5.19 t/ha) and showing similar growth as compared with standard check BRRI dhan58 (4.92 t/ha and 149 days).

In T. Aman, 2,250 kg BR22, 740 kg BRRI dhan32, 350 kg BRRI dhan48, 4,174 kg BRRI dhan49 and 1,772 kg BRRI dhan62 and in Boro, 6,750 kg BRRI dhan28, 5,325 kg BRRI dhan29, 5,325 kg BRRI dhan58, 3,825 kg BRRI dhan64 and 3,300 kg BRRI dhan69 breeder seeds were produced.

Pest management. In Aman season, among the diseases false smut was the most prevalent and found in most of the varieties/lines of BRRI-Comilla farm. Incidence (21%) and severity of false smut disease was more in BRRI dhan49 compared to other varieties/ lines. Tungro disease was also found in BR11, BRRI dhan56, BRRI dhan57 and BRRI dhan62 with high severity index (DI) ranged from 7-9 as per SES. Incidence of neck blast disease was 10%, 1%, 20%, 5% and 15% in BR5, BRRI dhan30, BRRI dhan34, BRRI dhan37 and BRRI dhan38 respectively with medium to high severity index ranged from 5-7. The lower incidence and severity of sheath blight disease was also observed in BRRI dhan49, BR22, BR25, BR10, BRRI dhan32, BRRI dhan30, BRRI dhan38 and BR11. It was ranged from 5-20% incidence and 3-5 DI.

In Boro season, medium disease incidence and severity of BLB and neck blast was found in BRRI dhan28, BRRI dhan29, BRRI dhan58, BRRI dhan64 and BRRI dhan69 in BRRI RS, Comilla farm.

Outside BRRI RS, Comilla farm, the rice fields of Burichang, Debidwar and Muradnagar upazila of Comilla district were severely affected by tungro disease at maximum tillering stage T. Aman season. The varieties BR22, BRRI dhan32 and BRRI dhan46, BRRI dhan49, BRRI dhan62

and BINA 7 showed highly susceptible to tungro disease with 50-80% incidences and 5-9 severity scale. It was also observed that medium severity of sheath blight disease ranged from 3-7 as per SES.

In Boro season, a survey was conducted in Barura, Adarshaw sadar, sadar Dhakkin, Laksham, Debidwar and Muradnagar of Comilla district to investigate the disease status. The highest incidence (40-50%) of neck blast disease was recorded in BRRI dhan28 and lowest (5%) in BRRI dhan29 with 7-9 severity indexes. The BRRI dhan58 and BRRI dhan64 were infected 20-35% neck blast incidence with 7-9 severity indexes. The low incidence and medium severity of BLB was observed in BRRI dhan28, BRRI dhan29, BRRI dhan58 and BRRI dhan64 in the same area. But high incidence (80%) and severity of BLB was found in SL8/ hybrid.

The incidence of false smut disease (% panicle infection) was higher in 3rd planting time (15 July) than 1st and 2nd planting times (15 June and 30 June). The incidence of false smut disease was increased in late planting i.e. after June.

The highest level of percent panicle infection was observed in T_4 (Control) treatment of third planting. In general, among all the treatments, T_3 (Azoxystrobin + Propiconazole) showed better result in percent panicle infection and number of smut ball at all planting times (Table 3).

Tungro. The incidence and severity of rice tungro disease were higher in three T. Aman varieties under T_3 treatment compared to T_1 (insecticide spray) and T_2 (covered by net) treatments. It was observed that incidence and severity of all three BRRI varieties under T_1 and T_2 treatments showed almost same result. But three BRRI varieties under T_2 treatment showed better yield compared to T_3 (open) treatment.

Crop-Soil-Water (Cultural practices). The experiment was conducted at BRRI RS, Comilla in 2014-15 and 2015-16. Forty- to 42-day-old seedlings of BRRI dhan62 were transplanted during 1 November to 1 February at 15-days interval and compared with BRRI dhan28 (ck). In 2014-15, Both BRRI dhan28 and BRRI dhan62 produced highest yield on 1 December seeding. BRRI dhan62 yielded higher (8.22 t/ha) than BRRI dhan28 (7.34) having growth duration 140 days and 137 days respectively. In 2015-16, both the varieties gave higher yield with 1 and 16 December seeding and BRRI dhan62 (7.21-7.75t/ha) yielded higher than BRRI dhan28 (6.62-6.76 t/ha) (Table 4). So, BRRI dhan62 may be an alternative of BRRI dhan28 in Boro season.

Evaluation of BRRI varieties as Braus/Aus

The experiment was carried out in BRRI RS farm, Comilla in 2015 to find out the potential of BRRI varieties as Braus/Aus. Five BRRI varieties i) BRRI dhan28 ii) BRRI dhan29 iii) BRRI dhan48 iv) BRRI dhan58 v) BRRI dhan62 were evaluated along with standard check BINA dhan14 (ck). BRRI dhan58 (4.52 t/ha) and BRRI dhan48 (4.72 t/ha) produced highest grain yield and were statistically similar (Table 5). Variation in panicle/m^2 was non-significant. BRRI dhan58 (102) and BRRI dhan48 (103) produced higher number of grain/panicle which led to higher grain yield. The highest grain weight was found in BRRI dhan62 followed by BRRI dhan 29. Sterility in all the varieties were statistically similar.

Soil. Silicon showed no significant effect on plant height, harvest index, number of grains percentage. Silicon (1.00% silicon solution) produced maximum grain diameter and silicon (0.50% silicon solution) produced maximum grain protein while silicon @ 0.25% silicon solution resulted maximum number of productive tillers, straw yield, branches per panicle, grains per panicle, 1000 grain weight, paddy yield and grain starch applied by foliar application.

Table 3. Effect of fungicides on the incidence of false smut disease in BRRI dhan49, T. Aman, 2015.

Treatment	Concent (%)	First planting, 15 June		Second planting, 30 June		Third planting, 15 July	
		Panicle infection (%)	No. of ball	Panicle infection (%)	No. of ball	Panicle infection (%)	No. of ball
Nativo (T_1)	0.2	0.33	20.67	0.72	40.89	0.99	55.44
Azoxystrobin (T_2)	0.2	0.34	20.67	0.64	38.78	1.44	78.33
Azoxystrobin + Propiconazole (T_3)	0.2	0.24	10.67	0.62	33.56	0.94	52.22
Control (T_4)	-	1.04	22.44	1.00	59.67	1.56	137.33

Table 4. Effect of seeding time on yield, growth duration and plant height of BRRI dhan62 in Boro season BRRI RS, Comilla.

Seeding time	2014-15					
	Grain yield (t/ha)		Growth duration (day)		Plant height (cm)	
	BRRI dhan28	BRRI dhan62	BRRI dhan28	BRRI dhan62	BRRI dhan28	BRRI dhan62
1 Nov 14	4.36	3.49	151	155	89.3	80.5
16 Nov 14	4.56	4.90	145	149	99.3	85.6
1 Dec 14	7.34	8.22	137	140	108.2	98.9
16 Dec 14	6.33	6.74	132	135	94.3	88.2
1Jan 15	4.47	4.38	129	132	82.2	89.4
16 Jan 15	5.71	5.19	124	127	100.2	98.6
1 Feb 15	5.15	4.65	120	123	97.1	97.7
CV(%)	3.67				2.71	
LSD(0.05)	0.3458				4.451	
			2015-16			
01 Nov 14	2.63	2.93	155	158	90.4	84.5
16 Nov 14	2.82	3.26	146	150	100.5	88.3
1 Dec 14	6.76	7.21	135	137	107.1	100.30
16 Dec 14	6.62	7.75	129	132	95.4	94.2
1 Jan 15	4.39	4.59	128	128	85.2	85.3
16 Jan 15	3.48	3.92	121	126	98.7	94.3
1 Feb 15	2.7	3.37	117	120	99.2	96.4
CV(%)	5.11				4.34	
LSD(0.05)	0.3993				6.453	

Table 5. Yield and yield contributing characters of the varieties in Aus season.

Variety	Grain yield (t/ha)	Growth duration (day)	Panicle/m^2	Grains panicl ›	1000-grain wt	Sterility (%)
BRRI dhan28	3.60	100	275	66	20.49	23
BRRI dhan48	4.72	107	266	103	21.57	28
BRRI dhan58	4.52	108	244	102	19.86	26
BRRI dhan62	3.98	107	279	65	23.40	20
BRRI dhan29	2.45	124	242	99	19.31	26
BINA dhan14	2.57	124	262	90	25.21	30
CV (%)	7.95		8.53	14.06	8.51	12.22
LSD(0.05)	1.056		NS	22.37	3.531	5.637

In Boro season, BRRI dhan69 gave slightly higher grain yield than BRRI dhan58 and they required much lower N and K than added nutrients. However, BRRI dhan60 required higher and BRRI dhan69 required lower N than the recommended dose. BRRI dhan60 needed higher N and P and lower K than applied nutrients with similar grain yield of check variety.

Socio economic and policy. In Aman, BRRI dhan32 (6.09 t/ha) produced the highest yield followed by BR22 (5.72t/ha), BR23 (5.65t/ha), BRRI dhan31 (5.5 t/ha) and BRRI dhan53 (5.53 t/ha) and in Boro the top five varieties were BRRI dhan59 (7.18 t/ha), BRRI dhan69 (6.77 t/ha), BRRI dhan47 (6.67 t/ha), BR3 (6.62 t/ha) and BRRI dhan58 (6.58 t/ha).

Thirty T. Aman and 35 Boro rice varieties were evaluated at BRRI RS, Comilla farm to identify stability index. BRRI dhan32 (6.09 t/ha) gave the highest yield followed by BR22 (5.72

t/ha), BR23 (5.65 t/ha), BRRI dhan31 (5.5 t/ha) and BRRI dhan53 (5.53 t/ha) but they were statistically similar at the 5% level of significance. Growth duration of these varieties ranged from 124-154 days in T. Aman and Considering the yield performance the top five varieties were BRRI dhan59 (7.18 t/ha), BRRI dhan69 (6.77 t/ha), BRRI dhan47 (6.67 t/ha), BR3 (6.62 t/ha) and BRRI dhan58 (6.58 t/ha). These varieties gave yield ranged from 6.58 – 7.17 t/ha and were statistically similar at the 5% level of significance. Growth duration of these varieties ranged from 146-153 days in Boro.

BRRI RS, Habiganj

SUMMARY

Among the five tested genotypes in natural deep flooded condition, BR9892-6-2-2B gave the highest yield (4.8 t ha^{-1}) followed by BR9392-6-2-1B (4.3 t ha^{-1}) and BR10238-5-1B (4.2 t ha^{-1}) than the local check Habiganj Aman-I (156 cm tall and yield 2.5 t ha^{-1}). In PYT, among the tested entries, BR7730-1-1-2B yielded higher (3.10 t ha^{-1}) than Habiganj Aman-IV (2.85 t ha^{-1}). In AYT, BR9892-6-2-2B gave the highest yield (4.8 t ha^{-1}) followed by BR9392-6-2-1B (4.3 t ha^{-1}) and BR10238-5-1-B (4.2 t ha^{-1}) than the local check Habiganj Aman-I (156 cm tall and 2.5 t ha^{-1}). In RYT favourable Boro, BRH11-9-11-4-5B, BR7988-12-3-4-3-1 and BR7683-30-3-3-4 yielded higher (6.9, 6.5 and 6.5 t ha^{-1} respectively) than BRRI dhan28 (6.1 t ha^{-1}). BRRI dhan29-SC3-28-16-15-HR2 (Com) yielded similar (7.5 t ha^{-1}) to BRRI dhan29 (7.5 t ha^{-1}) with three days early growth duration. In RYT short duration, BR(Bio)9787-BC2-63-2-4 yielded higher (6.3 t ha^{-1}) than BRRI dhan28 (6.0 t ha^{-1}). In RYT long duration, BR(Bio)9786-BC2-124-1-1 yielded higher (7.5 t ha^{-1}) than BRRI dhan29 (7.4 t ha^{-1}) with similar growth duration. Balanced fertilization with complete treatment significantly increased the grain yield and yield parameters of rice. The grain yield increased linearly with increasing the N doses up to 130 kg/ha and beyond the dose, grain yield decreased. The lower yield in farmer's fertilizer management practices might be due to the imbalanced fertilizer management and specially the lack of S and Zn. The application of either vermicompost or cowdung with chemical fertilizer produced similar grain yield but significantly lower than recommended chemical fertilizer dose. Though similar grain yield obtained with both sole rice and rice-duck farming but higher profitability was found in rice-duck farming than sole rice farming. Normal transplanting gave higher yield (7.51 t ha^{-1}) than double transplanting (6.82 t ha^{-1}) in BRRI dhan29. But double transplanting in low lying field matured early which can escape early flash-flood during maturity stage.

VARIETAL DEVELOPMENT

Observational trial (OT), deepwater Aman 2015. Six homozygous genotypes were grown in BRRI RS, Habiganj during DWR, 2015 to evaluate yield and ancillary characters in deep flooded condition. All the six tested entries yielded higher (2.55 t ha^{-1} -2.81 t ha^{-1}) than local check Habiganj Aman-I (2.45 t ha^{-1}) **(**Table 1).

Preliminary yield trial (PYT), deepwater Aman 2015. Five advanced genotypes with check Habiganj Aman-IV were grown in BRRI RS, Habiganj during B. Aman 2015 to evaluate promising genotypes in natural deep flooded condition. Among five tested entries, BR7730-1-1-2B yielded higher (3.10 t ha^{-1}) than Habiganj Aman-IV (2.85 t ha^{-1}) (Table 2).

Advanced yield trial (AYT), deep water Aman 2015. Five advanced genotypes with check Habiganj Aman-I were grown in BRRI RS, Habiganj during B. Aman 2015 to evaluate promising genotypes in natural deep flooded condition. Among five tested entries BR9892-6-2-2B gave the highest yield (4.8 t ha^{-1}) followed by BR9392-6-2-1B (4.3 t ha^{-1}) and BR10238-5-1-B (4.2 t ha^{-1}) than the local check Habiganj Aman-I (156 cm tall and yield 2.5 t ha^{-1}) (Table 3).

Regional yield trial (RYT), high yielding rice (Biotech), T. Aman 2015. Six advanced breeding lines along with three checks were planted to evaluate specific and general adaptability of the genotypes in on station condition. Among the six advanced breeding lines BR9786-BC2-132-1-3 and BR9786-BC2-2-1-1 yielded higher (5.0 t ha^{-1} and 4.6 t ha^{-1}) than BRRI dhan33 (4.1 t ha^{-1}) and BRRI dhan39 (4.2 t ha^{-1}) with 8-11 days late growth duration. None of six entries yielded higher than BRRI dhan49 (5.1 t ha^{-1}).

Growing of F_3 generation, Boro 2015-16. A total of eight F_3 crosses were grown in BRRI RS, Habiganj in Boro 2015-16 for selection of early high yielding lines. A total of 176 plants for earliness and higher yield were selected in Boro season.

Table 1. Performance of the genotypes from OT, deep water rice, 2015.

Designation	Yield (t ha^{-1})
BR7733-2-1-2B	2.8
BR7735-1-1-2B	2.8
BR7738-2-2-2B	2.6
BR7741-2-2-3B	2.6
BR7920-1-2-3B	2.8
BR7921-1-1-3B	2.8
Habiganj Aman-I	2.5

DS: 14 May 2015.

Table 2. Performance of the genotypes from PYT, deep water rice, 2015.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR7730-1-1-2B	133	190	3.1
BR7731-1-2-2B	140	190	2.9
BR7737-1-1-2B	135	191	2.7
BR7918-1-2-3B	144	186	2.8
BR7919-1-1-3B	142	192	2.6
Habiganj Aman-IV (ck)	151	185	2.9

DS: 13 May 2015.

Table 3. Yield and agronomic performance of the advanced lines in AYT, deep water rice, 2015.

Designation	Plant height (cm)	Tiller no/m^2	Panicle length (cm)	Filled grains /panicle	Growth duration (day)	Yield (t ha^{-1})
BR9392-6-2-1B	156	310	26.2	181	158	4.3
BR10238-5-1-B	158	307	24.1	172	160	4.2
BR9892-6-2-2B	193	285	26.3	165	163	4.8
BR10230-7-19-B	152	268	25.3	150	158	3.7
BR10230-7-2	154	285	26.2	165	158	3.1
Habiganj Aman-I	156	215	21.3	110	165	2.5
LSD (5%)	2.6	3.1	1.3	4.4	1.6	0.6
CV(%)	1.4	3.6	1.9	5.8	0.9	5.4

DS: 7 May 2015.

Observational trial (OT), Boro 2015-16. Five fixed lines were grown in BRRI RS, Habiganj during Boro 2015-16 season to select early and high yielding genotypes for the development of Boro varieties for *haor* areas. All the five tested entries yielded higher (6.2 t ha^{-1} - 6.5 t ha^{-1}) than BRRI dhan28 (6.0 t ha^{-1}) (Table 4).

Table 4. Performance of the genotypes from OT, Boro, 2015-16.

Designation	Yield (t ha^{-1})
BRH5-14-4-3-2	6.5
BRH6-10-3-5-3	6.4
BRH7-13-4-3-1	6.2
BRH8-9-5-3-3	6.2
BRH9-11-6-3-2-1	6.4
BRRI dhan28 (ck)	6.0

DS: 21 Nov 2015, DT: 1 Jan 2016.

RYT, favourable Boro rice, Boro 2015-16. Two separate experiments (RYT#1 and RYT#2) were set up for the evaluation of favourable Boro rice under on station condition. In RYT#1, BRH11-9-11-4-5B, BR7988-12-3-4-3-1and BR7683-30-3-3-4 yielded higher (6.9, 6.5 and 6.5 t ha^{-1} respectively) than BRRI dhan28 (6.1 t ha^{-1}) with 2-5 days late growth duration. In RYT#2, BRRI dhan29-SC3-28-16-15-HR2 (Com) yielded similar (7.5 t ha^{-1}) to BRRI dhan29 (7.5 t ha^{-1}) with three days earlier growth duration.

RYT, short duration, Boro 2015-16. Six advanced breeding lines along with BRRI dhan28 as check were planted in a 5.4 m-10 row plot with 20 cm spacing between rows. Among them, BR (Bio) 9787-BC2-63-2-4 yielded higher (6.3 t ha^{-1}) than BRRI dhan28 (6.0 t ha^{-1}) with three days late growth duration.

RYT, long duration, Boro 2015-16. Seven advanced breeding lines along with BRRI dhan29 as check were planted in a 5.4 m-10 rows plot with 20 cm spacing between rows. Among them BR(Bio)9786-BC2-124-1-1 yielded higher (7.5 t ha^{-1}) than BRRI dhan29 (7.4 t ha^{-1}) with similar growth duration.

Multi-environment trial (MET), Boro 2015-16. A total of 100 IR lines along with BRRI dhan28 and BRRI dhan29 as checks were planted in a 5.4 m-6 row plot with 20 cm spacing between rows to isolate breeding lines with high yield potential and acceptable grain quality. The tested entries IR13A390 (7.9 t ha^{-1}), IR100008-91-B (7.5 t ha^{-1}), IR98419-B-B-7 (7.2 t ha^{-1}), IR99062-B-B-1 (7.0 t ha^{-1}), IR100740-23-B (7.0 t ha^{-1}), IR13N142 (7.0 t ha^{-1}) gave higher yield than BRRI dhan28 (6.28 t ha^{-1}) and similar or higher yield to BRRI dhan29 (7.3 t ha^{-1}) with shorter growth duration than BRRI dhan29 (Table 5).

Table 5. Yield and agronomic performance of the advanced lines, MET, Boro 2015-16.

Designation	Plant ht (cm)	Maturity (day)	Yield (t ha^{-1})
IR100008-91-B	99	141	7.5
IR13A390	104	143	7.9
IR98419-B-B-7	107	147	7.2
IR99062-B-B-1	103	141	7.0
IR100740-23-B	102	144	7.0
IR13N142	101	142	7.0
BRRI dhan28 (ck)	93	139	6.1
BRRI dhan29 (ck)	101	155	7.3
LSD (5%)	7.2	6.9	0.8
CV(%)	4.2	0.3	7.0

DS: 1Dec 2015 DT: 5 Jan 2016.

SOCIO-ECONOMICS AND POLICY

Stability analysis of BRRI released Boro varieties

Thirty-six BRRI released rice varieties were tested in a RCB design with three replications to observe the general and specific adaptability and stability of the BRRI released rice varieties at BRRI RS, Habiganj. The yield range of BRRI released Boro varieties was 5.5-7.8 t ha^{-1}. Among the inbred varieties, BRRI dhan29 (7.7 t ha^{-1}), BRRI dhan69 (7.6 t ha^{-1}), BRRI dhan58 (7.0 t ha^{-1}), and BRRI dhan47 (6.7 t ha^{-1}) yielded higher with the growth duration 160, 150, 152, 151, and 145 days respectively. BRRI hybrid dhan3 (7.8 t ha^{-1}) yielded higher than BRRI hybrid dhan2 (6.7 t ha^{-1}) with similar growth duration (Table 6).

CROP-SOIL-WATER MANAGEMENT

Long-term missing element trial for diagnosing the limiting nutrient in soil

The experiment was initiated in a permanent layout at the BRRI RS, Habiganj from 2007-08 Boro season to identify the yield limiting nutrient if any in the soils of BRRI RS, Habiganj farm. BRRI dhan29 was used as a test crop. 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). After eight years and eight crop cycles, the soil pH, organic carbon and total nitrogen remain almost similar in both control and fertilized treatment (Table 7). The soil available P decreased extremely in control plot compared to long-term fertilized plot. The exchangeable K also decreased much in control plot than fertilized plot (Table 7).

The higher grain yield was obtained in T_1 (7.56 t ha^{-1}) where complete fertilizer was used than T_3 (7.35 t ha^{-1} with P omission). The K omission treatment (T_4=6.72 t ha^{-1}) gave significantly lower yield (6.72 t ha^{-1}) than P omission treatment (7.35 t ha^{-1}). Omission of S from the complete treatment also given significantly lower yield (T_5= 6.61 t ha^{-1}) like K omission. The yield performance was very poor where N was omitted (T_2=5.19 t ha^{-1}) from complete elements and the lowest yield was found in fertilizer control treatment (T_8=3.74 t ha^{-1}). From this experimental result, it was observed that N is the most yield limiting nutrient for Boro rice followed by K and S in BRRI RS, Habiganj farm soil.

Table 6. Performance of Boro varieties for stability analysis, Boro 2015-16.

Designation	Plant ht (cm)	Maturity (day)	Yield (t ha^{-1})
BRRI dhan29	110	160	7.7
BRRI dhan47	102	145	6.7
BRRI dhan58	101	152	7.0
BRRI dhan69	101	150	7.6
BRRI hybrid dhan2	102	144	6.7
BRRI hybrid dhan3	100	143	7.8
LSD (5%)	7.2	6.9	0.8
CV(%)	3.5	0.3	7.0

DS: 17 Dec 2015 DT: 23 Jan 2016.

Table 7. Soil characters after eight years of the long-term missing element trials.

Treatment	Soil pH	OC (%)	Total N (%)	Ava. P (ppm)	Exch. K (meq/100g soil)
Control plot	4.6	3.2	0.2	0.6	0.2
Fertilized plot	4.7	3.4	0.2	13.8	0.4

Nitrogen response of advanced line BRH 11-9-11-4-5B in Rice-Fallow-Fallow cropping pattern
The experiment was conducted in BRRI RS, farm Habiganj during Boro 2015-16 to select the optimum N dose for the advanced line in the single cropped area. The treatments were: T_1=N Control, T_2=40 kg N/ha, T_3=70 kg N/ha, T_4=100 kg N/ha, T_5=130 kg N/ha, T_6=160 kg N/ha. The N control plot yielded only 4.6 t ha^{-1} grain. Application of N doses increased grain yield significantly over control. The filled grain/panicle and grain yield/ha increased linearly with increasing the N doses up to 130 kg /ha (T_5) and beyond the dose, grain yield decreased due to high sterility. The growth duration of this line was 148 days.

Potassium response of advanced line BRH 11-9-11-4-5B in Rice-Fallow-Fallow cropping pattern
Five different treatment combinations T_1=K Control, T_2=K 20 kg/ha, T_3=K 40 kg /ha, T_4=K 60 kg/ha, T_5=K 80 kg/ha were considered for the experiment in RCB design with three replications. The plant height increased significantly with increasing the K doses over control. The tiller and panicle number also increased significantly with increasing the K doses. The K control plot yielded only 6.26 t ha^{-1}. The highest grain yield (7.48 t ha^{-1}) obtained in T_5 (80 kg K/ha) followed by T_4 (7.42 t ha^{-1}). Similar results were observed for panicle/m^2 and filled grain per panicle. The growth duration of this line was 146 days.

Effect of vermicompost on Boro rice yield
The experiment was conducted at BRRI RS, Habiganj in Boro 2015-16 to increase rice yield in single cropped area through INM practices. Seven different treatment combinations i.e., T_1= Control (native nutrient), T_2= Recommended chemical fertilizer dose, T_3= Vermicompost @ 1.0 t ha^{-1}, T_4= 50% Vermicompost + 50% chemical fertilizer, T_5= Cowdung @ 5.0 t ha^{-1} (dry wt. basis), T_6= 50% Cowdung+50% chemical fertilizer and T_7=50% Cowdung+50% Vermicompost were considered for the experiment. The experiment was laid out in RCB design with three replications. The tested rice variety was an advanced breeding line BRH11-9-11-4-5B. The control plot yielded only 5.65 t ha^{-1} but grain yield increased significantly (7.41 t ha^{-1}) with applying recommended chemical fertilizer. Grain yield decreased significantly (6.12 t ha^{-1}) with applying vermicompost alone (recommended dose) than recommended fertilizer dose. The application of cowdung (recommended dose), increased grain yield over vermicompost application. The application of either vermicompost or cowdung with chemical fertilizer produced similar grain yield but significantly lower than recommended chemical fertilizer dose.

RICE FARMING SYSTEMS

System productivity increased through rice-duck farming
The experiment was conducted for the integration of rice cultivation with duck farming at BRRI RS, Habiganj farm in T. Aman 2015 and Boro 2015-16 to increase total productivity and evaluate the reduction cost of management practices (fertilizer, weeding and pesticide). There were two treatments, control (sole rice farming) and rice- duck farming. The rice variety BRRI dhan52 and BRRI dhan29 were used in Aman and Boro season respectively. The tiller and panicle number/m^2 were found higher in rice-duck farming than sole rice farming in both the seasons. On the other hand, weed infestation was higher in sole rice farming than rice-duck farming in both the seasons (Table 8). As a result, though similar grain yield obtained with both sole rice and rice-duck farming, Tk 20,000-22,000/ha productivity increased in rice-duck farming than sole rice farming (Table 8). Moreover, rice duck farming could maintain soil fertility and reduced the cost of pesticide and weed management.

Validation of double transplanting at low lying areas (*haor* areas) under Boro-Fallow-Fallow cropping systems
The study was conducted at BRRI RS, Habiganj during Boro 2015-16 with BRRI dhan29 to validate

Table 8. Comparative study of rice-duck and sole-rice culture on yield and economics in T. Aman and Boro season in 2015-16.

Treatment	Tiller/m^2	Panicle/m^2	Weed biomass (dry) (kg/ha)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Productivity increase over control (Tk/ha)
		T. Aman 2015 (BRRI dhan52)				
Rice-duck farming	267	256	3.2	6.6	6.3	22000/-
Sole rice farming	247	235	12.6	6.3	6.2	-
		Boro 2015-16 (BRRI dhan29)				
Rice-duck farming	245	234	5.3	7.5	6.7	20000/-
Sole rice farming	232	226	16.8	7.2	6.2	-

the performance of double transplanted rice at low lying areas and to maximize the farmers productivity. Normal transplanting gave higher yield (7.51 t ha^{-1}) than double transplanting (6.82 t ha^{-1}). But double transplanted BRRI dhan29 in low lying field matured early due to aged seedling and can escape early flash-flood during maturity stage.

BRRI RS, Rajshahi

SUMMARY

In RYT Aus 2015, a total of 13 breeding lines were evaluated in replicated trials of which one entry appeared promising for further evaluation. Fifty-nine breeding lines were evaluated in RYT T. Aman 2015 under replicated trials of which 11 entries appeared promising for further advancement. Considering stress (drought) and control condition data, nine genotypes (IR 93856-23-1-1-1, IR 95817-14-1-1-2, IR 93822-9-2-3-1, IR 95815-4-1-1-3, IR 93810-11-1-1-1, IR 95795-53-1-1-2, IR 93807-44-2-1-1, IR 93806-32-2-2-1 and IR 95817-5-1-1-1) were selected for PVS trial in the next T. Aman season. For proposed variety trial (PVT), proposed lines HUA 565 yielded higher against their respective check and has been released as T. Aman variety namely BRRI dhan75. In Boro 2015-16, 1, 2, 2 and 3 breeding lines appeared promising with favourable, micronutrient enriched, clod tolerant and premium quality Boro rice respectively were selected for further advancement. During T. Aman season, urea super granule (USG) performed better compared to prilled urea under drought prone ceosystem in respect to plant height, panicle/hill, yield and also growth duration. The highest natural enemies, percent parasitism by *Trichogramma chilonis* on YSB eggs were observed in rice field nearby nectar-rich flowering plants. However, least natural enemies and parasitism were found in rice field where four times (continuous/ prophylactic) insecticides were applied. Moreover, there was no yield reduction observed in rice 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. In the reporting period, the BRRI RS, Rajshahi produced 30 ton seed of recently developed BRRI varieties and also arranged 24 farmers' training and several farmers' field days.

VARIETAL DEVELOPMENT

Regional yield trial (RYT), B. Aus 2015. Five breeding lines were evaluated in RYT at BRRI RS farm, Rajshahi against standard checks of BRRI dhan43 and BRRI dhan65. Advanced line BR7587-2B-3 produced the highest yield of 3.97 t/ha against check of BRRI dhan43 and BRRI dhan65 and was selected for further evaluation.

Regional yield trial RYT, T. Aus 2015. For Plant Breeding Division, 59 breeding lines were evaluated in RYT at BRRI RS farm, Rajshahi against standard checks of BR26 and BRRI dhan48. None of the entries produced higher yield than the check variety BRRI dhan48 while genotype BR6848-3B-12 produced (3.88 t/ha) higher yield than the check variety BR26 (2.97 t/ha). In case of Biotechnology Division, three breeding lines were evaluated in RYT transplanted Aus at BRRI RS farm, Rajshahi along with standard check of BRRI dhan48. Of them, none of the breeding lines performed better over the checks.

Regional yield trial (RYT), T. Aman 2015. For Plant Breeding Division, 59 breeding lines were evaluated in eight different RYT (two for Rainfed low land rice-RLR, one for Premium quality rice-PQR, three for Micronutrient enriched-MN, one for disease resistance rice-DR and one for green super rice-GSR) at BRRI RS farm, Rajshahi against 12 different standard checks (BR5, BR 11, BRRI dhan31, BRRI dhan34, BRRI dhan39, BRRI dhan49, BRRI dhan57, BRRI dhan66, BINA dhan7, Kalizira, Kataribog and Swarna). Among them, one entry gave higher yield in RYT-RLR, three entries showed higher yield with RYT-PQR, three entries produced higher yield in RYT-MN long grain, two entries found higher yield than check varieties of BR5 and BRRI dhan39 but lower than of BRRI dhan32 with RYT-MN bold grain, the bacterial blight (BB) resistance genotypes BR8821-8-1 and BR8821-10-2 gave higher yield than BB resistance check BRRI dhan31 but gave lower yield than BB susceptible check BR11 and standard check BRRI dhan39 and were selected for further evaluation. In case of Biotechnology Division, six genotypes along with three checks; BRRI dhan33, BRRI dhan39 and BRRI dhan49 were evaluated. The genotype BR9786-BC2-132-1-3 produced higher yield and earlier growth duration (5.95 t/ha and 129 days) and was selected for advancement.

Advanced yield trial (AYT), T. Aman 2015. Nine genotypes along with three checks BR11, BRRI dhan49 and BRRI dhan66 were evaluated. The three genotypes Ranjit swarna, Suman swarna and Niranjon swarna produced higher yield (5.68-5.91 t/ha) than the check variety BR11 (5.05 t/ha)

but gave lower yield than the checks BRRI dhan66 and BRRI dhan49 (5.47-5.60 t/ha). The other genotypes Bikalpa swarna (5.30 t/ha and 109 days) and swarna-5 (5.25 t/ha and 130 days) produced similar yield but earlier growth duration than the check variety BR11 (5.05 t/ha and 136 days).

International Network for Genetic Evaluation of Rice (INGER), T. Aman 2015. Thirty-seven genotypes along with five checks IR64, Mashuri, Swarna BRRI dhan49 and BRRI dhan66 were evaluated. The tested entry IR13F402 gave similar yield with the variety BRRI dhan49 but produced higher yield than the other check varieties. The entries IR13F229, IR13F377 and IR13F692 produced higher yield but longer growth duration (4.83-4.88 t/ha and 135-152 days) than the checks Swarna, BRRI dhan56, Mashuri and IR64 (3.29-4.29 t/ha) and with growth duration of 108-135 days.

Proposed variety trial (PVT), T. Aman 2015. Four PVT; one rainfed lowland rice (RLR), one rainfed lowland rice (RLR)-short duration, one premium quality rice (PQR), and one green super rice (GSR) were conducted against their respective standard checks in farmers field of Rajshahi district. The proposed line of BR7611-31-5-3-2 did not perform better than the check variety BR11 with PVT-RLR long duration, the tested PQR line BR7697-15-4-4-2-2 produced higher yield and earlier growth duration (4.69 t/ha and 130 days) than the check BRRI dhan37 (3.73 t/ha and 145 days) in PVT-PQR. Proposed NERICA Mutant line did not give higher yield than the check BRRI dhan57 in PVT-RLR short durations. The tested GSR line HUA565 produced similar yield but with earlier growth duration (5.62 t/ha and 110 days) than the check BRRI dhan33 (5.25 t/ha and 118 days).

AYT of STRASA drought lines, T. Aman 2015. A total of 28 genotypes including four checks; MTU 1010, BINA dhan7, BRRI dhan49 and BRRI dhan56 were grown in controlled and stressed conditions at Paba site. All the genotypes except IR95785-5-2-2-2 produced more than 4 t/ha yield in controlled condition. Among those only six genotypes gave more than 4.5 t/ha yield that was higher than the yield of all the checks (4.1-4.5 t/ha). The genotype IR91810-11-1-1-1 produced the highest yield (4.8 t/ha). On the other hand, 21 genotypes including three checks produced more than 4.0 t/ha yield under stressed condition. Among them three genotypes produced more than 4.5 t/ha yield that was also higher than the yield of all the checks (3.5-4.3 t/ha). The genotype IR93856-23-1-1-1 produced the highest yield (4.6 t/ha). Considering stress and control condition data, nine genotypes (IR 93856-23-1-1-1, IR 95817-14-1-1-2, IR 93822-9-2-3-1, IR 95815-4-1-1-3, IR 93810-11-1-1-1, IR 95795-53-1-1-2, IR 93807-44-2-1-1, IR 93806-32-2-2-1 and IR 95817-5-1-1-1) were selected for PVS trial at the next season.

Participatory variety selection (PVS) of STRASA drought lines, T. Aman 2015. A total of 14 genotypes including three checks BRRI dhan56, BINA dhan7 and MTU1010 were grown in controlled and stressed conditions in four locations at Paba (Stress and Control), Godagari (Stress) and On-station (Control) sites. Actual stress was not implied in this season because of even rainfall distribution in total growth period. All the tested genotypes except IR 88839-4-1-1-3 and BINA dhan7 produced more than 4.5 kg/ha yield at Paba under controlled condition. Among them, IR677761-53-1-1 produced the highest yield (5.5 t/ha) followed by IR88869-2-1-2-2 (4.9 t/ha). Five genotypes and BINA dhan7 produced more than 4.5 t/ha yield at Paba in stressed condition. Among them IR86857-46-1-1-3 produced the highest yield (5.0 t/ha) followed by IR88903-8-1-1-3 and IR67761-53-1-1 (4.9 t/ha). All the genotypes except IR84850-B-27-2-3 and IR86857-46-1-1-3 produced more than 5.0 t/ha yield at on-station under control condition. Among them IR88965-39-1-6-4 produced the highest yield (6.30 t/ha) followed by IR67761-53-1-1 (6.20 t/ha). Eight genotypes and BINA dhan7 produced more than 4 t/ha yield at Godagari under stressed condition. Among them IR88965-39-1-6-4 produced the highest yield (4.60 t/ha). Considering all data over location and PVS function, three genotypes (IR 88965-39-1-6-4, IR 88869-2-1-2-2 and IR67761-53-1-1) were identified as promising lines for drought condition.

Observational yield trial (OYT)-Aerobic, T. Aman 2015. Fifty-six advanced breeding lines along with two standard checks viz BRRI dhan56 and BRRI dhan57 were evaluated under dry direct seeded aerobic condition following alpha lattice design with two replications. The unit plot size was 5.4 m×6 rows. Weeding and other cultural practices were done as and when necessary. Water was applied at five days after disappearing of surface

water. Thirteen genotypes produced higher yield than the checks BRRI dhan56 and BRRI dhan57. Twenty-three genotypes gave similar yield (2.55-2.90 t/ha) with the check BRRI dhan56 (2.55 t/ha). Five genotypes gave higher yield (2.33-2.54 t/ha) than the check BRRI dhan57 but eight genotypes produced similar yield (1.97-2.32 t/ha) with BRRI dhan57 (1.97 t/ha). Yield performance of the trial was not so good as the crop suffered different stresses of heavy rainfall immediately after seeding and severe drought during reproductive phase. Top ten yield performer genotypes were selected for advanced yield trial at the next T. Aman season.

RYT, Boro 2015-16. Thirty-eight breeding lines were evaluated in eight different RYT (two for favourable Boro rice-FBR, one for premium quality rice-PQR, three for micronutrient enriched-MN, one for insect resistant rice and one for cold tolerant rice) at BRRI RS farm, Rajshahi against seven different standard checks (BR3, BRRI dhan28, BRRI dhan29, BRRI dhan50, BRRI dhan58, BRRI dhan63 and T27A).

RYT#1 (FBR). Only one entry BR7988-12-3-4-3-1 gave similar yield (5.54 t/ha) with the check BRRI dhan28 (5.50 t/ha) and was selected for further advancement.

RYT#2 (FBR). The genotypes BRRI dhan29-SC3-28-28-16-15-HR2 (Com) (6.80 t/ha) and BRRI dhan29-SC3-8-HR1 (Com) (7.09 t/ha) produced the highest yield than all the checks (5.19-6.40 t/ha). The genotypes BR8626-20-9-1-3 (6.44 t/ha) and BR8626-19-4-1-1 (6.70 t/ha) produced similar yield with BRRI dhan29 (6.40 t/ha) but gave higher yield than the checks BRRI dhan28 (5.19 t/ha) and BRRI dhan58 (5.53 t/ha). The genotype BR8626-19-5-1-2 performed better yield (6.27 t/ha) than the check BRRI dhan58 (5.53 t/ha) but the genotype BRH10-3-12-21-4B gave similar yield (5.62 t/ha) with BRRI dhan58 (5.53 t/ha). The other genotype BR8643-6-4-3 produced similar yield (5.45 t/ha) growth duration (142 days) like the check BRRI dhan28 (5.19 t/ha).

RYT # 3 (MER-1). None of the genotype performed better yield than the check variety BRRI dhan28.

RYT # 4 (MER-2). The genotype BR7671-37-2-2-3-7-3-P10 produced higher yield (5.49 t/ha) than the check BRRI dhan63 (5.01 t/ha) but the other genotype BR8643-6-4-4 gave similar yield like the check BRRI dhan63 (5.01 t/ha). None of the genotypes performed better than the check of BRRI dhan29 (6.55 t/ha).

RYT#5 (MER-3). None of the genotypes performed better than the checks BRRI dhan29 and BRRI dhan58 (5.55-6.14 t/ha).

RYT#6 (Cold tolerant). Two cold tolerant materials were investigated with the checks BRRI dhan28 and BRRI dhan29. All the tested materials produced higher yield (5.96-6.88 t/ha) than the check variety BRRI dhan28 (5.79 t/ha) but none out yielded BRRI dhan29 (6.91 t/ha).

RYT#7 (Insect resistant). Nine insect resistant materials were investigated along with the susceptible checks BR3, BRRI dhan28 and resistance check T27A. The genotype BR8340-16-2-1 produced the highest yield (5.59 t/ha) than all the check varieties BR3, BRRI dhan28 and T27A (3.31-5.09 t/ha). Six genotypes BR8338-34-3-4, BR7799-51-3-13, BR7987-31-2-4, BR7987-50-1-5, BR7987-51-1-2 and BR7987-51-1-3 produced similar yield (5.09-5.33) with the check BRRI dhan28 (5.09 t/ha) but gave higher yield than the checks BR3 and T27A (3.31-4.66 t/ha). The genotype BR7987-57-1-4-2-2 performed better yield (4.99 t/ha) than the susceptible check BR3 (4.66 t/ha) and resistance check T27A (3.31 t/ha). The other genotypes BR7903-16-10 produced higher yield (4.56 t/ha) than the local resistant checks T27A (3.31 t/ha). Actually, there was no insect damage in this trial.

RYT#8 (PQR). Three PQR materials were investigated along with the checks BRRI dhan50 and BRRI dhan63. All the tested PQR materials produced higher yield (4.36-4.56 t/ha) than the check variety BRRI dhan50 (4.15 t/ha) but none out yielded BRRI dhan63 (5.10 t/ha).

RYT from Biotechnology Division, Boro 2015-16. Fourteen breeding lines were evaluated in two RYT (RYT-short duration and RYT-long duration) at BRRI RS farm, Rajshahi against standard checks of BRRI dhan28 and BRRI dhan29. In short duration RYT 4 genotypes BR(Bio)9787-BC2-63-2-2, BR(Bio)9787-BC2-63-2-4, BR(Bio)9787-BC2-119-1-6 and BR(Bio)9787-BC2-173-1-3 produced higher yield (6.11-6.33 t/ha) than the check variety BRRI dhan28 (5.68 t/ha). But in long duration RYT out of seven genotypes only one genotype BR(Bio)9786-BC2-49-1-2 gave higher yield (7.59 t/ha) than the check variety BRRI dhan29 (7.12 t/ha).

Observational yield trial (OYT#1 and OYT#2-Aerobic), Boro 2015-16. Advanced evaluation of promising breeding lines for their phenotypic acceptability, adaptation under alternate wetting and drying (AWD) condition and grain yield potentials. In total, ten entries along with two checks were evaluated under AWD condition. Fifty-three-day old seedlings were transplanted at a spacing of 25×15 cm with 2-3 seedlings per hill. The unit plot size was 5.4 m×12 rows. The experimental layout was RCB design with three replications. Fertilizer was applied @ 300 kg urea, 70 kg TSP, 75 kg MoP, 45 kg gypsum and 6 kg zinc sulphate/ha. Nitrogen was applied in three splits at 20 and 35 days after transplanting and seven days before PI. Weeding and other cultural practices were done as and when necessary. Water was applied five days after disappearing of surface water.

OYT#1. Two genotypes IR97076-27-1-1-1 and IR93827-29-2-1-3 (5.78-6.03 t/ha) produced the highest yield followed by all the checks (4.51-5.15 t/ha). The genotype IR95793-5-2-2-3 gave higher yield than the check BRRI dhan58. Seventeen genotypes gave similar yield with BRRI dhan29 and BRRI dhan58 but produced higher yield than the checks BRRI dhan28. Nine genotypes (4.86-5.00 t/ha) produced higher yield but 20 genotypes (4.52-4.85 t/ha) gave similar yield with the check BRRI dhan28 (4.51 t/ha).

AYT late, Boro 2015-16. Ten entries along with two checks were evaluated under AWD condition. Fifty-three-day-old seedlings were transplanted at 25×15 cm spacing of with 2-3 seedlings per hill. The unit plot size was 5.4 m×12 rows. The experimental layout was RCB design with three replications. Fertilizer was applied @ 300 kg urea, 70 kg TSP, 75 kg MoP, 45 kg gypsum and 6 kg zinc sulphate/ha. Nitrogen was applied in three splits at 20 and 35 days after transplanting and seven days before PI. Weeding and other cultural practices were done as and when necessary. Water was applied at five days after disappearing of surface water.

Two genotypes IR93822-9-2-3-1 and IR93827-29-1-1-2 and gave the highest yield 150 days and earlier growth duration (5.48-5.50 t/ha) than the checks BRRI dhan58 and BRRI dhan29 (5.06-5.24 t/ha and 154-160 days). The genotype IR993806-19-4-3-1 gave similar yield (5.29 t/ha) with BRRI dhan29 (5.24 t/ha) but produced higher yield than BRRI dhan58 (5.06 t/ha). Four genotypes IR93856-104-1-1-4, IR93806-32-2-2-1, IR92545-24-1-1-2 and IR92545-42-2-2-1 produced similar yield (5.08-5.23 t/ha) and earlier growth duration (150-151 days) than BRRI dhan58 (5.06 t/ha and 154 days). Three genotypes (IR93822-9-2-3-1, IR93827-29-1-1-2 and IR993806-19-4-3-1) were selected for advanced generation.

CROP-SOIL-WATER MANAGEMENT

Nitrogen management in drought tolerant rice varieties at drought prone area, T. Aman 2015

The experiment was conducted with four treatments viz, prilled urea, USG, farmer's practice and N-control at Alimganj, Paba, Rajshahi. The experiment was laid out in RCB design with three replications. All the fertilizers except N were applied as basal in final land preparation. Standard crop management practices such as weeding, controlling disease and insect pests were followed as and when necessary. Data on tillering pattern at maximum tillering stage, agronomic use efficiency of nitrogen, yield and yield contributing parameters were taken.

Findings. Among the four treatments USG treated plots produced the highest plant height (128.43 cm), panicle/hill (8.7), yield (4.08 t/ha) and also growth duration (103 days) followed by prilled urea treated plots 118 cm, 8.2 and 3.80 t/ha respectively, except growth duration (Table 1). The trial should be further conducted at the next season to confirm this result.

Soil fertility scenario of BRRI RS, Rajshahi farm soil. In the reporting year soil samples were collected from 14 different blocks of BRRI RS farm, Rajshahi. Sampling was done from the depth of 0-15 cm. The samples were collected with the help of Auger from eight different point of each block and the collected samples were composite to make about 1 kg. The collected samples were brought to BRRI RS, Rajshahi laboratory air-dried, crushed and sieved through 2mm sieve prior to analysis. Soil pH Organic matter (%), total N (%), Olsen P (mg/kg), exchangeable K, Available S and Zn (mg/kg) were determined from SRDI laboratory, Rajshahi. Table 2 shows the fertility status of BRRI RS, Rajshahi farm soils.

Table 1. Yield and ancillary characters of nitrogen management materials during T. Aman 2015.

Treatment	Plant height (cm)	Growth duration (day)	Panicle/hill (no.)	Yield (t/ha)
Prilled urea	117.7	102	7.70	3.80
USG	128.4	103	8.50	4.08
Farmer's practice	115.1	102	6.57	3.46
Control (-N)	98.5	100	5.57	2.18
LSD at 5%	1.73	0.94	0.86	0.22

DS: 6 Jul 2015, DT: 29 Jul 2015.

Table 2. Fertilty status of BRRI RS, Rajshahi farm soil.

Block#	Soil pH	Soil OM (%)	Exch. K (cmol/kg)	TN (%)	Olsen P (mg/kg)	Avail. S (mg/kg)	Avail. Zn (mg/kg)
1	8.1	2.10	0.17	0.12	36.7	17.6	0.64
2	8.2	1.85	0.16	0.11	31.5	17.0	0.64
3	8.2	1.60	0.15	0.09	13.5	13.3	0.33
4	8.3	1.22	0.16	0.07	8.1	23.3	0.37
5	8.3	1.19	0.20	0.07	16.2	23.7	0.26
6	8.1	2.09	0.17	0.12	26.9	24.1	0.73
7	8.2	1.62	0.17	0.09	18.1	19.2	0.53
8	8.2	2.11	0.17	0.12	29.7	10.3	0.63
9	8.1	2.41	0.20	0.14	22.3	29.6	0.96
10	8.0	2.04	0.16	0.12	17.7	15.9	0.62
11	8.2	1.91	0.19	0.11	17.1	20.2	0.79
12	8.1	1.77	0.15	0.10	16.5	15.3	0.52
13	8.3	1.86	0.16	0.11	27.8	18.9	0.61
14	8.2	1.52	0.17	0.09	16.0	8.90	0.29
SE	0.024	0.093	0.004		2.15	1.51	0.053

Data are average of 20 replications. NS= Not significant, Value means in a column followed by a common letter in infested and control hills are not differ significantly at the 5% level of Statistix10 test.

PEST MANAGEMENT

Conservation of natural enemies through ecological engineering approaches

The experiment was conducted with BRRI dhan52 and BRRI dhan63 during T. Aman 2015 and Boro 2015-16 seasons respectively in a large field divided into three blocks and each block into four plots. Nectar-rich flowering plants (Cosmos in T. Aman and marigold in Boro) were planted on bunds of each four plots of the first block to provide food and shelter for different parasitoids. Insect pests and natural enemies counted from one and four meter away from the flowering plants of the first blocks and treated as T_1 and T_2 respectively. Prophylactic insecticide (Carbofuran 5G @ 10.0 kg/ha) was used at 15 days interval (four times) in the 2nd block after 1st top dressing of urea and treated as T_3. Normal cultivation was done in the 3rd block with no insecticide and no flowering plants and treated as T_4. Twenty complete sweeps were done in all the blocks at every 15 days interval up to flowering. Number of insect pest and natural enemies for all the sweeps from different blocks were counted and recorded separately and parasitism of YSB eggs were determined through retrieval method.

Findings. The highest natural enemies, percent parasitism by *Trichogramma chilonis* on YSB eggs were observed in rice field nearby nectar-rich flowering plants. However, least natural enemies and parasitism were found in rice field where four times (continuous/ prophylactic) insecticides were applied. 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.

Relationship between YSB damage and yield loss. The experiment was conducted at BRRI RS farm, Rajshahi during T. Aman 2015 season having natural infestation of yellow stem borer (YSB) at early tillering to panicle initiation stage. BR11, BRRI dhan34 and BRRI dhan52 were used in this experiment as test varieties. The rice fields having infested and uninfested tiller per hill were marked diagonally across the field. The 'deadheart' were counted diagonally from 20 randomly selected hills separately from each variety. In addition, 20 uninfested hills (control) were marked and counted separately. The deadheart developed on uneffective tillers during reproductive stage

were also recorded. The rice yield and yield component data from the marked hills (infested and un-infested) were recorded and analyzed statistically.

Findings. Tiller and panicle per hill in all the varieties were observed identical (Table 2). Except BRRI dhan52 reduced plant height and lower filled grain weight per hill was observed in infested hills of all the varieties. As a result yield loss occurred in YSB infested hills compared to healthy hills. Though plant height was not reduced in the infested hills of BRRI dhan52 but least filled grain observed as a result of highest yield loss occurred in BRRI dhan52 (31.97%) where 20.29% deadheart observed (ranged 7.14 to 33.33%) followed by BR11 (15.37%) where 14.66% onion shoot appeared (ranged 7.0 to 30.0%). BRRI dhan34 showed the lowest deadheart of 7.1% resulting lowest yield loss of 8.74% (Table 3).

Relationship between gall midge damage and yield loss. The experiment was conducted at BRRI RS farm, Rajshahi during T. Aman 2015 season having natural infestation of rice gall midge at vegetative (early tillering to panicle initiation) stage. BRRI dhan49 and BRRI dhan52 were used as test varieties. The rice fields having infested and uninfested tiller per hill were marked diagonally across the field. The 'onion shoot' were counted diagonally from 20 randomly selected hills separately from each variety. In addition, 20 uninfested hills (control) were marked and counted separately. The onion shoot developed on uneffective tillers during reproductive stage were also recorded. The rice yield and yield component data from the marked hills (infested and uninfested) were recorded and analyzed statistically.

Findings. Tiller and panicle per hill and in panicle lengths among the infested and healthy hills were found statistically similar (Table 4). But reduced plant height and lower filled grain weight per hill were observed in infested hills with both the varieties resulting yield loss in gall midge infested hills compared to healthy hills. BRRI dhan52 showed the highest yield loss of 24.43% while 16.62% onion shoot was observed (ranged 5.0 to 36.84%) followed by BRRI dhan49 (13.68%) where 14.15% onion shoot appeared (ranged 4.0 to 33.33%).

Table 3. Plant and yield contributing characteristics of stem borer damaged hills and control hills, BRRI RS farm, Rajshahi, T. Aman 2015.

Variety	Hill status	Tiller/hill (no.) (Mean± SE)	Panicle/hill (no.) (Mean± SE)	Plant height (Mean± SE)	Filled grain wt/hill (Mean± SE)	Percent yield loss/ hill
BR11	Infested	12.45±0.55	10.70±0.48	114.75±1.11b	20.26±1.24b	
	Control	11.80±0.78	10.65±0.65	119.45±0.65a	23.93±1.72a	15.34
LSD		*1.594*	*1.64*	*2.60*	*4.29*	
Signi.		*NS*	*NS*	*P<0.05*	*P<0.05*	
BRRI	Infested	17.85±0.68	16.65±0.8	121.25±0.1.03b	22.04±1.6b	
dhan34	Control	17.95±0.73	16.75±0.74	128.50±1.40a	24.15±1.38a	
LSD		*2.19*	*2.2*	*3.46*	*4.33*	8.74
Signi.		*NS*	*NS*	*P<0.05*	*P<0.05*	
BRRI	Infested	8.50±0.59	7.7±0.56	123.80 ±0.69a	12.79±1.17b	
dhan52	Control	9.10±0.838	8.1±0.30	123.30±0.96a	18,80±0.89a	
LSD		*1.42*	*1.28*	*2.40*	*2.98*	31.97
Signi.		*NS*	*NS*	*NS*	*P<0.05*	

Table 4. Plant and yield contributing characteristics of gall midge damaged hills and control hills, BRRI RS farm, Rajshahi, T. Aman 2015.

Variety	Hill status	Tiller/hill (no.) (Mean±SE)	Panicle/hill (no.) (Mean± SE)	Plant height (cm) (Mean± SE)	Panicle length (cm) (Mean± SE)	Filled grain wt/hill (g) (Mean± SE)	% yield loss/ hill
BRRI	Infested	19.35±0.68	12.90±2.81	104.60±4.16b	21.50±0.31	18.23±0.96b	13.68
dhan49	Control	20.40±0.80	13.95±0.54	108.90±0.67a	21.90±0.35	21.12±1.56a	
LSD		1.56	2.58	2.58	0.96	3.75	
Significance		NS	NS	P<0.05	NS	P<0.05	
BRRI	Infested	10.05±0.70	6.00±1.78b	120.10 ±0.84b	23.95±0.47	15.62±1.57b	24.43
dhan52	Control	10.90±0.62	8.05±0.37a	125.50±0.99a	24.80±0.48	20.67±1.40a	
LSD		1.89	1.10	2.65	1.37	4.26	
Significance		NS	P<0.05	P<0.05	NS	P<0.05	

BRRI RS, Rangpur

SUMMARY

In total 402 tolerant progenies with better plant type including 26 fixed lines were selected from pedigree population for flash flood submergence and water stagnation tolerance.

In PVS mother trial under rainfed condition, PVS-10 (BRRI dhan52) and PVS-6 (BR9158-19-9-6-7-50) were preferred by the farmers through PVS which was consistant in grain yield. In PVS mother trial under control submergence condition, PVS-5 (BR9158-19-9-6-7-94) and PVS-8 (BR9158-19-9-6-9-103) were selected by the farmers.

The genotype, BR8808-31-26-12-Ran1-1 produced the highest grain yield (6.0 t/ha) with good plant type in T. Aman 2015 and six entries with better plant growth and uniformity for PYT and 12 individual plants for OT were selected in Boro 2015-16 (OT-NPT)

None of the Swarna varieties produced higher yield than the check variety BR11 (AYT).

For T. Aman, in RYT#1 (RLR) two genotypes B 10533-F-KN-12-2 and BR8227-6-2-1, in RYT#3 (PQR) two genotypes BR8522-46-1-1 and BR8522-44-5-1, in RYT#4, 5 and 6 (MER, short, bold and Kataribhog grain) three genotypes BR7528-2R-HR16-2-24-1, BR7895-4-3-3-2-3 and BR7528-2R-HR16-12-3-P1 and in RYT#8 (High yielding rice-Biotechnology Division) two genotypes BR9786-BC-2-132-1-3 and BR9786-BC-2-139-2-3 performed better than the check varieties with similar growth duration.

For Boro, in RYT#2 (FBR) two entries BRRI dhan29-SC3-28-16-15-HR2(Com) and BRRI dhan29-SC3-8-HR1(Com), in RYT#3 (Cold tolerance) one genotype BR7812-19-1-6-1-P4) and in RYT#8 (Insect resistance) two entries BR8338-34-3-4 and BR7987-50-1-5 performed better than the check varieties with similar growth duration.

For Boro, in ALART#1(FBR) one entry BRRI dhan29-SC3-28-16-10-8-HR1(com) and in ALART#3 (GSR-Long duration) two entries HHZ6-SAL3-Y1-SUB2 and BR (BE)6158-RWBC2-1-2-1-1 performed better than the check varieties with similar growth duration. In ALART#4 (High yielding rice-short duration)-yield performance of tested entries was higher than the check variety BRRI dhan28 but growth duration was higher than check variety. In ALART#5 (Hybrid rice)-yield performance of tested entries was higher than the check variety BRRI dhan28 but similar to BRRI hybrid dhan3 and growth duration was higher than BRRI dhan28.

T. Aus (BRRI dhan48)-T. Aman (BRRI dhan62)-Potato (Cardinal)-Mungbean (BARI 6) and Maize (NK40)-T. Aman (BR11)-Potato (Cardinal) pattern gave higher rice equivalent yield and higher return compared to farmers' general practice. Potato based cropping pattern is most suitable and profitable in this particular area.

In nutrient management trial under control submergence condition, BRRI recommended dose (200 kg ha^{-1} Urea+46 kg ha^{-1} MoP in 2 equal splits)+75 kg ha^{-1} Urea+60 kg ha^{-1} MoP performed better than the other nutrient management options for *Sub1* genotypes.

In fertilizer management trial of Swarna varieties, all genotypes showed good performance in T_1 (Farmers practice: Urea-TSP-MP @ 180-70-90 kg ha^{-1}) than T_2 (Research practice: Urea-TSP-MP-Gyp-Zn @ 220-60-90-70-10 kg ha^{-1}).

BRRI dhan48, BRRI dhan58 or BRRI hybrid dhan3 may be an alternative of BRRI dhan28 at late planting situation (Braus) after potato harvest in Rangpur region.

BRRI dhan28 gave significantly higher grain yield (5.25 t ha^{-1}) than the BRRI dhan48 transplanted at 20 February and BRRI dhan48 gave significantly higher grain yield (4.61 t ha^{-1}) than the BRRI dhan28 transplanted at 12 March.

A total of 6,357 kg TLS and 6,550 kg breeder seed of Aus (BRRI dhan48), T. Aman (BR11, BR22, BRRI dhan34, BRRI dhan46, BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan65 and BRRI dhan66) and Boro (BRRI dhan28, BRRI dhan29, BRRI dhan58, BRRI hybrid dhan3) was produced.

VARIETAL DEVELOPMENT

Growing and screening of pedigree generations

Six F_2 and 342 progenies of 8 F_3, 2 BC_1F_4, 11 F_4, 6 F_5, 7 F_6, 9 $F_{7,4}$ F_8 and 2 F_9 populations were grown under controlled submergence condition. In total 402 tolerant progenies with better plant type and 26 fixed lines were selected from pedigree population (F_2-F_8, BC_1F_4).

Participatory variety selection (PVS) under control submergence condition

Eight submergence and medium stagnant water tolerant high yielding rice genotypes along with four standard check varieties having submergence tolerance were evaluated in the control submergence tank at BRRI RS, Rangpur. In PVS function, two genotypes viz PVS-5 as BR9158-19-9-6-7-94 (BRRI dhan44-*Sub1*) and PVS-8 as BR9158-19-9-6-9-103 (BRRI dhan44-*Sub1*) were selected by farmers. The worst two entries were PVS-9 as BRRI dhan51 (ck) and PVS-12 as BRRI dhan49 (ck).

Participatory variety selection (PVS) under rainfed condition. Eight submergence and medium stagnant water tolerant high yielding genotypes along with four standard check varieties having submergence tolerance were evaluated under rainfed condition at BRRI RS, Rangpur. In PVS function, two entries PVS-10 as BRRI dhan52 and PVS-6 as BR9158-19-9-6-7-50 (BRRI dhan44-Sub1) obtained the highest vote.

Head to head trial of the *Sub1*-varieties. Three submergence tolerant high yielding varieties along with respective original mega variety were evaluated in the on-station and farmers' field under the management practices of researchers. There was no significant difference among the tested varieties in both the locations.

Observational trial (OT-NPT)

A total of 23 advanced breeding lines (NPT) were tested under this trial in T. Aman 2015 when the check varieties were three. Among them, BR8808-31-26-12-Ran1-1 obtained the highest grain yield (6.0 t/ha) with better plant growth and uniformity. In Boro 2015-16, a total of 26 advanced breeding lines (NPT) were tested with five standard checks. Among them, six entries with better growth and uniformity for PYT and 12 individual plants for OT were selected.

Advanced yield trials (AYT). A total of Nine Swarna varieties collected from farmer's field in Rangpur and Rajshahi regions were tested under this trial in T. Aman 2015 when the check varieties were three (BR11, BRRI dhan49 and BRRI dhan66). None of the Swarna varieties produced higher yield than the check variety BR11. Mixture, irregular flowering and plant height and different grain size were observed in the Swarna varieties (Table 1).

Regional yield trial (RYT)

A total of 17 RYTs were conducted under T. Aman and Boro seasons to develop rice varieties promising for rainfed lowland (RLR), premium quality (PQR), disease and insect resistance (DR and IR), micronutrient enriched (MN), high yielding (Biotechnology) against standard check varieties. Tables 2 and 3 present the results of grain yield and other parameters.

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RLR (#1). Two genotypes (B 10533-F-KN-12-2 and BR8227-6-2-1) produced similar yield with shorter growth duration over the check varieties (Table 2).

RLR (#2). None of the tested genotypes found high yielder over the check varieties (Table 2).

PQR. Two genotypes (BR8522-46-1-1 and BR8522-44-5-1) gave higher yield over the checks with shorter growth duration (Table 2).

MER (# 1, long slender grain). One entry (BR7528-2R-HR16-2-24-1) found high yielder over the check varieties (Table 2).

MER (#2, short bold grain). One genotype (BR7895-4-3-3-2-3) found high yielder over check variety BRRI dhan39 with shorter growth duration (Table 2).

MER (#3, Kataribhog grain). One genotype (BR7528-2R-HR16-12-3-P1) found high yielder with similar growth duration over the check varieties (Table 2).

Disease resistance. None of the entries found high yielder over the check varieties (Table 2).

High yielding rice (Biotechnology). Two genotypes (BR9786-BC-2-132-1-3 and BR9786-BC-2-139-2-3) found high yielder with similar growth duration over the check varieties (Table 2).

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FBR-1. None of the tested entries found higher yield over checks BRRI dhan28 but growth duration of all the entries was higher than check (Table 3).

FBR-2. Two entries viz BRRI dhan29-SC3-28-16-15-HR2(Com) and BRRI dhan29-SC3-8-HR1(Com) performed better than the check variety BRRI dhan58 with similar growth duration but produced lower yield than BRRI dhan29 (Table 3).

Table 1. Advanced yield trial (AYT), RLR, T. Aman 2015, BRRI RS, Rangpur.

Designation	Seedling ht (cm)	Day to flowering	Duration (day)	Plant ht (cm)	Yield (t/ha)	P. Acp. at maturity
Lal Swarna (Rajshahi)	27	110	130	107	4.7	6
Sada Swarna (Rajshahi)	32	109	130	125	5.5	7
Suman Swarna (Rajshahi)	32	112	134	123	5.3	6
Ranjit Swarna (Rajshahi)	27	112	134	123	5.7	5
Bikalpa Swarna (Rajshahi)	32	80	102	111	3.7	6
Tiger Swarna (Rangpur)	26	110	134	123	5.6	5
Nepali Swarna (Rangpur)	29	111	134	119	5.8	6
Niranjon Swarna (Rangpur)	31	109	134	131	6.0	5
Swarna-5 (Rangpur)	31	111	134	125	5.6	6
BR11 (ck)	33	110	137	129	6.0	5
BRRI dhan49 (ck)	27	104	130	114	4.7	6
BRRI dhan66 (ck)	29	86	107	123	4.2	5
LSD (0.05)	-	2.0	2.1	2.8	0.9	-

DS: 4 Jul 2015, DT: 29 Jul 2015.

Table 2. Grain yield and other characters of different entries under RYT, T. Aman 2015, BRRI RS, Rangpur.

Designation	Seedling ht (cm)	Days to 50% flowering	Duration (day)	Plant ht (cm)	Yield (t/ha)	P. Acp. at maturity
		RYT#1 (RLR)				
IR70213-10-CPA4-2-2-2	36	98	123	112	5.2	5
B 10533-F-KN-12-2	38	87	110	114	4.9	3
BRRI dhan39 (ck)	32	89	112	107	4.2	4
BR8226-8-5-2-2	33	114	139	118	4.8	8
BR8226-11-4-4-3	29	110	136	104	5.4	8
BR8226-11-4-6-2	30	110	135	115	4.6	7
BR8227-6-2-1	33	107	130	122	5.1	4
BRRI dhan49 (ck)	32	104	129	105	4.9	3
LSD (0.05)	-	1.9	2.0	1.6	1.3	-
		RYT#2 (RLR)				
BR8204-50-2-2-5	34	91	111	110	4.4	6
BR8210-10-3-1-2	33	102	129	121	4.8	4
IR09F436	34	87	110	110	4.4	4
BR8198-13-4-1-3	37	99	121	121	4.6	6
BR8214-19-3-4-1	31	100	122	120	4.7	8
BR8214-23-1-3-1	32	99	124	116	4.6	8
Impari 11	33	86	103	112	4.8	4
Swarna (ck)	27	108	133	103	6.2	6
BBRI dhan39 (ck)	32	91	111	107	4.1	5
BRRI dhan49 (ck)	32	102	130	104	4.4	3
LSD (0.05)	-	2.1	1.8	1.1	0.6	-
		RYT#3 (PQR)				
BR8514-17-1-5	32	91	111	110	4.0	7
BR8522-44-5-1	29	96	117	121	4.6	5
BR8535-2-1-2	31	89	110	110	3.7	5
BR8522-21-4-1	29	101	125	126	4.2	6
BR8522-46-1-1	30	99	124	130	5.0	7
BR8522-53-1-3	31	96	118	109	4.0	7
BR8522-30-1-2	33	91	114	99	3.6	9
BR8234-1-3-7-4	29	105	129	98	2.8	7
BR8512-3-1-1	37	102	124	120	4.7	7
BR8515-23-6-3	33	98	122	114	2.8	7
BR5 (ck)	29	124	147	133	3.7	7
Kalizira (ck)	30	121	142	163	3.5	8
LSD (0.05)	-	2.0	1.8	3.4	0.7	-
		RYT#4 (MER-Long slender grain)				
BR8445-54-6-6	34	87	106	107	4.3	5
BR7528-2R-HR16-2-24-1	31	90	112	92	4.6	5

Table 2. Continued.

Designation	Seedling ht (cm)	Days to 50% flowering	Duration (day)	Plant ht (cm)	Yield (t/ha)	P. Acp. at maturity
BR8410-16-4-17-9-1	33	91	112	111	4.0	7
BRRI dhan57 (ck)	33	84	103	97	3.9	5
BINA dhan7 (ck)	32	90	112	106	4.4	6
LSD (0.05)	-	1.9	2.2	1.9	0.6	-
RYT#5 (MER-Short bold grain)						
BR7895-4-3-3-2-3	32	94	117	109	5.4	5
BR8442-9-5-2-3-B1	35	104	127	119	5.2	7
BRRI dhan32 (ck)	34	101	124	129	4.6	5
BRRI dhan39 (ck)	32	92	117	102	4.0	5
BR5 (ck)	31	116	145	136	4.0	7
LSD (0.05)	-	2.1	1.6	1.8	0.5	-
RYT#6 (MER-K. Bhog grain)						
BR7528-2R-HR16-12-23-P1	33	106	135	122	4.9	5
BR7528-2R-HR16-12-3-P1	30	105	125	117	6.8	5
BR7528-2R-HR16-3-98-P1	30	98	120	107	4.7	7
IR84750-213-2-2-3-1	34	101	126	115	5.0	5
BRRI dhan32 (ck)	34	104	125	130	5.9	5
BRRI dhan39 (ck)	31	96	115	107	5.1	5
BRRI dhan49 (ck)	34	107	136	104	4.6	4
Kataribhog (ck)	32	121	139	147	4.2	7
LSD (0.05)	-	2.1	1.7	3.4	0.8	-
RYT#7 (Disease Resistance)						
BR8821-8-1 (BB)	32	98	116	104	5.0	5
BR8821-10-2 (BB)	32	100	121	105	5.3	6
BR7959-14-2-1 (RTV)	40	109	130	124	6.0	5
BRC171-2-1-2-2-2 (RTV)	37	112	132	116	5.4	6
IR73885-1-4-3-2-1 (RTV)	36	111	131	117	5.5	5
BR7958-12-1-1-2 (RTV)	34	113	133	120	5.6	7
BR8219-12-1-2-1-1 (Blast)	30	109	130	115	6.3	7
BR11 (Sus. ck-BB, RTV)	31	118	138	115	5.8	6
BRRI dhan39 (Std ck)	32	98	118	102	5.1	5
BRRI dhan34 (Sus. ck-Blast)	33	112	133	132	3.0	5
BRRI dhan31 (Res ck-BB)	35	110	131	118	6.2	6
Local (ck) Lal Swarna	29	111	133	116	6.1	5
LSD (0.05)	-	1.8	1.7	1.0	0.9	-
RYT#8 (High yielding rice-Biotechnology)						
BR9786-BC-2-124-1-2	34	91	114	96	20.5	4.9
BR9786-BC-2-119-1-1	37	96	118	111	24.0	4.9
BR9786-BC-2-132-1-3	37	95	116	122	26.9	5.1
BR9786-BC-2-2-1-1	35	95	117	102	30.3	4.4
BR9786-BC-2-139-2-3	35	92	113	106	19.7	5.2
BR9786-BC-2-124-1-5	37	92	115	107	33.7	4.9
BRRI dhan33 (ck)	39	81	102	106	41.5	3.8
BRRI dhan39 (ck)	39	91	119	113	21.9	4.7
BRRI dhan49 (ck)	33	105	131	105	17.3	4.8
LSD (0.05)	1.2	1.5	1.6	3.4	15.0	0.7

Cold tolerance. Tested entry **(**BR7812-19-1-6-1-P4) gave 0.4 t/ha higher yield over check BRRI dhan28 with similar growth duration (Table 3).

MER-1. None of the tested entries out yielded over check BRRI dhan28 (Table 3).

MER-2. None of the tested entries out yielded over check BRRI dhan63 and BRRI dhan29 (Table 3).

MER-3 (LA). None of the tested entries out yielded over check BRRI dhan58 and BRRI dhan29 (Table 3).

PQR. None of the tested entries out yielded over check BRRI dhan50 and BRRI dhan63 (Table 3).

Insect resistance. Two entries (BR8338-34-3-4 and BR7987-50-1-5) produced higher yield than

Table 3. Performances of ALART for Boro varieties, Boro 2015-16, BRRI RS, Rangpur.

Designation	Plant ht (cm)	Panicle m^{-2}	Grains $panicle^{-1}$	1000-grain wt (g)	Yield (tha^{-1})	Sterility (%)	Duration (day)
			FBR				
BRRI dhan2-SC3-28-16-10-8-HR1(com)	96	270	125	20.46	5.72	20	144
BR7358-5-3-2-1-HR2(Com)	94	225	114	21.10	4.56	21	140
BRRI dhan28 (ck)	104	273	116	21.10	4.90	17	141
LSD(0.05)	5.71	21.62	14.59	1.29	0.60	2.73	0.67
			MER-short duration				
BR7831-59-1-1-4-5-1-9-P1	111	281	104	23.07	5.32	13	145
BR7831-59-1-1-4-9-1-2-P3	101	255	95	19.91	4.95	17	140
BR (BIO)8072-AC5-4-2-1-2-1	85	248	89	24.29	4.80	18	142
BR (BIO)8072-AC8-1-1-3-1-1	85	282	86	24.22	5.48	19	142
BRRI dhan28 (ck)	100	293	111	22.31	5.68	17	141
LSD(0.05)	5.42	72.15	8.71	1.01	0.77	5.93	2.43
			GSR-long duration				
HHZ15-DT4-DT1-Y1	97	243	140	24.28	6.40	18	156
HHZ6-SAL3-Y1-SUB2	100	251	158	22.29	7.25	20	155
BR(BE)6158-RWBC2-1-2-1-1	106	268	122	24.39	7.24	22	163
BRH10-3-12-21-4B	111	245	126	24.30	6.00	30	164
BRRI dhan58 (ck)	106	260	117	22.53	6.13	23	153
BRRI dhan29 (ck)	107	342	111	23.06	7.09	17	160
LSD(0.05)	4.86	31.64	27.23	2.25	0.58	10.48	2.43
			High yielding rice-short duration				
BRH11-9-11-415B	95	284	124	18.02	6.56	22	149
BRRI dhan29-SC3-8-HR1-Com	98	295	122	22.16	6.99	23	161
BRRI dhan29-SC3-28-16-15-HR2(Com)	98	398	119	20.91	7.01	32	156
BRRI dhan28 (ck)	101	323	95	22.29	5.29	20	141
LSD(0.05)	5.36	24.85	17.84	0.85	0.59	9.83	1.63
			Hybrid rice				
BR1585H	105	207	114	32.78	7.06	24	155
BR1793H	102	212	112	30.81	6.75	20	155
BRRI Hybrid dhan3	101	221	117	31.20	6.89	14	152
BRRI dhan28 (ck)	100	310	112	22.00	5.92	24	140
LSD(0.05)	5.71	21.62	17.84	1.28	0.60	2.73	1.63

the standard check BRRI dhan28 but growth duration was higher than BRRI dhan28 (Table 3).

High yielding rice (Long and short duration-Biotechnology). None of the tested entries were found out yielded over check varieties.

Advanced line adaptive research trial (ALART) for Boro varieties

Five ALARTs were conducted under Boro season to develop rice varieties promising for favorable Boro (FB)-Short duration, micronutrient enriched (MER)-short duration, green super rice (GSR)-long duration, high yielding rice-short duration (Biotechnology) and hybrid rice against standard check varieties. Table 3 presents the results of grain yield and other parameters of different ALARTs.

FBR. Yield performance of tested entry BRRI dhan29-SC3-28-16-10-8-HR1(Com) was higher than the check variety BRRI dhan28 with similar growth duration (Table 3).

MER-short duration. None of the tested entries performed better than the check variety BRRI dhan28 (Table 4).

GSR-long duration. Yield performance of tested entries was good and two entries HHZ6-SAL3-Y1-SUB2 and BR(BE)6158-RWBC2-1-2-1-1 produced higher yield than the check variety BRRI dhan29 (Table 4).

High yielding rice-short duration. Yield performance of tested entries was higher than the check variety BRRI dhan28 with higher growth duration (Table 4).

Table 4. Yield and other parameters of PVTs at Taraganj, Rangpur, T. Aman 2015.

Tested entries	Plant ht. (cm)	Days to flowering	Days to maturity	P. Accep. (At Mat.)	Lodging	Grain yield (t ha^{-1})
			RLR			
V_1=BR7611-31-5-3-2	122	122	147	Good	No	6.2
V_2= BRRI dhan11 (ck.)	103	121	146	Good	No	5.5
			RLR-short duration			
V_1=NERICA Mutant	90	93	115	Good	No	3.9
V_2= BRRI dhan57 (ck.)	95	94	117	Good	No	3.4
			GSR			
V_1=HUA565	89	96	119	Good	No	4.83
V_2= BRRI dhan33 (ck.)	107	98	122	Good	No	4.03
			PQR			
V_1=BR7697-15-4-4-2-2*	115	117	143	Good	No	4.9
V_2= BRRI dhan37 (ck)	130	121	147	Good	No	4.5

Hybrid rice. Yield of tested entries was higher than the check variety BRRI dhan28 but similar to BRRI hybrid dhan3 and growth duration was higher than BRRI dhan28 (Table 4).

Proposed variety trial (PVT). A total of four PVTs were conducted under T. Aman season to develop rice varieties Table 3 and 5 present promising for rainfed lowland rice (RLR), RLR-Short duration, GSR and premium quality (PQR) rice against standard check varieties. Table 4 presents the results of grain yield and other parameters of different PVTs.

CROP-SOIL-WATER MANAGEMENT

Introducing improved cropping pattern for increasing cropping intensity and productivity in Rice-Rice system

The treatments of the experiment were T_1=Potato (Cardinal)-Mungbean (BARI Mug 6)-T. Aus (BRRI dhan48)-T. Aman (BRRI dhan62), T_2=Mustard (BARI 14)-Mungbean (BARI Mug 6)-T. Aus (BRRI dhan48)-T. Aman (BRRI dhan62), T_3=Potato (Cardinal)-Maize (Hybrid NK40)-T. Aman (BR11)-Farmers' improved practice, T_4=Boro (BRRI dhan28)-T. Aman (BR11)-Farmers' general practice. In T. Aman season, short duration variety BRRI dhan62 was used in T_1 and T_2 (four crop system) and yield was 4.23 and 4.19 t ha^{-1}, respectively. In T_3 and T_4 (3 and 2 crop system respectively) common variety BR11 was used and grain yield was 6.45 and 6.42 t ha^{-1} respectively (Table 5). The highest rice equivalent yield (REY) was observed in T_1 (35.95 t ha^{-1}) followed by T_3 (30.32, Table 6). The lowest REY was observed in T_2 (4 crops) and T_4 (farmers practice). The lower REY T_2 was mainly due to lower yield of mustard (0.93 t ha^{-1}) and mungbean (0.71 t ha^{-1}).

Effect of nutrient management and application pattern on newly developed *Sub1* genotypes. Two *Sub-1*genotypes along with one tolerant and one susceptible check varieties were evaluated in the control submergence tank at BRRI Rangpur. Fertilizer treatments (T_1=BRRI Recommended dose (200 kg ha^{-1} Urea + 46 kg ha^{-1} MoP in two equal splits), T_2= BRRI Recommended dose + 75 kg ha^{-1} Urea + 60 kg ha^{-1} MoP and T3= BRRI Recommended dose + 60 kg ha^{-1} MoP) were used in main plot and genotypes (V_1= BR9159-8-5-40-13-52 (BRRI dhan49-Sub1), V_2= BR9159-8-5-40-14-57 (BRRI dhan49-Sub1), V_3=BRRI dhan52 (Res. ck) and V_4=BRRI dhan49 (Sus. ck) were used in sub plot. Nutrient after de-submergence and genotypes interactively affected the survival %. The highest survival (89%) was found in T_2V_1 combination while the lowest (32%) was found in T_1V_4. The interaction effect of nutrient and genotypes on grain yield was significant. The highest grain yield (5.42 t ha^{-1}) was found in T_2V_3 and the lowest (1.30 t ha^{-1}) in T_1V_4 (Table 7).

Performance evaluation of Swarna under different fertilizer combination. Three Swarna varieties along with two standard check varieties were evaluated under different fertilizer doses. Varieties (V_1=Gooty Swarna, V_2=Lal Gooty Swarna, V_3=Swarna-5, V_4=BR11 and V_5=BRRI dhan52) were used in main plot and fertilizer treatments (T_1: Farmers' practice: Urea-TSP-MoP @ 220-60-90 and T_2: Research' practice: Urea-TSP-MoP-Gypsum-Zinc sulphate @ 180-70-90-

Table 5. Grain yield and yield components of BRRI dhan62 and BR11, BRRI farm, Rangpur, T. Aman 2015.

Treatment	Plant ht (cm)	Tiller hill^{-1}	Panicle m^{-2}	Grain panicle^{-1}	1000-grain wt (g)	Yield (t ha^{-1})	Sterility (%)	Harvest index
T_1	99	12	283	52	21.57	4.23	30.3	0.43
T_2	101	11	267	57	21.43	4.19	28.9	0.42
T_3	112	16	317	78	25.60	6.45	20.4	0.50
T_4	113	16	292	97	24.77	6.42	21.3	0.48
LSD $_{0.05}$	2.54	3.83	55.52	13.27	1.05	0.26	3.94	0.068
CV %	8.67	2.79	28.34	12.70	2.00	8.17	5.65	6.46

Table 6. Rice equivalent yield (REY) under different cropping pattern, 2015-16, BRRI RS, Rangpur.

Treat.	1st crop yield (t/ha)	2nd crop yield (t/ha)	3rd crop yield (t/ha)	4th crop yield (t/ha)	REY (t/ha)
T_1	BRRI dhan62=4.23	* Potato=25.83	Mungben= 0.61	BRRI dhan48= 3.63	35.93
T_2	BRRI dhan62=4.19	**Mustard= 0.93	Mungben= 0.71	BRRI dhan48= 3.80	13.87
T_3	BR11= 6.45	Potato=26.80	Maize= 8.75	-	30.32
T_4	BR11= 6.42	Boro= 6.21	-	-	12.63

Price: Rice =14/kg (Bold grain), and 16.25/kg (Fine grain), Potato= 15/kg (early), Potato= 9.40/kg (late), Mustard= 50/kg, Mungben= 60/kg, Maize=12.5/kg; Assuming, *1 ton Potato= 0.99 ton rice (early), 0.62 ton rice (late), ** 1 ton Mustard=3.31 t rice, 1 ton Mungben= 3.97 ton rice, 1 ton Maize= 0.83 ton rice.

Table 7. Interaction effect of nutrient after de-submergence and genotypes on survival, yield and yield components in T. Aman 2015.

Treatment	Genotype	Survival (%)	Plant ht (cm)	Tillers m^{-2}	Panicle m^{-2}	Grains panicle^{-1}	1000-grain wt (g)	Yield (t ha^{-1})	Sterility (%)	Duration (day)
T_1	V_1	84	87	445	415	143	23	3.76	19	157
	V_2	81	86	373	365	115	23	3.74	23	159
	V_3	72	102	367	358	147	25	4.83	23	163
	V_4	32	81	270	190	118	20	1.30	22	160
T_2	V_1	**89**	86	453	440	151	23	4.24	11	157
	V_2	87	91	437	405	146	23	4.26	11	159
	V_3	82	102	380	373	149	24	5.42	13	163
	V_4	34	77	255	233	105	21	1.44	25	160
T_3	V_1	87	82	440	422	154	23	4.11	9	158
	V_2	85	90	392	387	142	22	3.42	10	160
	V_3	78	98	370	307	144	24	5.13	14	164
	V_4	33	78	185	172	115	21	1.41	25	161
$LSD_{0.05}$		2.47	4.42	26.29	26.68	15.82	1.17	0.34	6.73	-

D/S: 26.06.2015, D/T: 27.07.2015, D/Sub: 18.08.2015, D/de-sub: 02.09.2015.

70-10 kg ha^{-1}) were used in sub plot. The interaction effect of varieties and fertilizer combination on plant height, tillers hill^{-1}, panicle m^2, grain yield and sterility (%) was significant (Table 8). The highest grain yield was identical in V_2T_1, V_2T_2 and V_5T_1 (5.70 t/ha) and lowest yield was in V_3T_1 (4.81 t/ha). Sterility percentage was the highest in V_5T_1 (34.7) and lowest in V_2T_2 (14.6)**.**

Performance of hybrid and inbred rice at late planting situation under T. Aman-Potato- Braus cropping pattern in Rangpur region. The experiment was conducted at BRRI RS, Rangpur farm during February-June, 2016 to evaluate hybrid and inbred rice varieties as Braus after potato harvest using split plot design with three replications. BRRI dhan28, BRRI dhan48, BRRI dhan58, BINA dhan14, BRRI hybrid dhan3, SL8-H and Hira2 were used in the experiment. All hybrid varieties gave higher grain yield than inbred at 1 March planting but BRRI hybrid dhan3 produced higher grain yield up to 15 March. At 30 March planting, Hira2 produced higher yield than other hybrid and inbred varieties. BRRI dhan28 gave higher yield at 1 March planting but produced similar yield from 15 to 30 March. BRRI dhan48 and BRRI dhan58 gave higher yield at 15 March planting. BINA dhan14 gave higher yield at 30 March. Irrespective of planting date, BRRI dhan48 gave higher yield than other inbred varieties. BRRI

Table 8. Interaction effect between treatment and Swarna varieties on yield components, grain yield and other parameters, T. Aman 2015.

Variety	Treatment	Plant ht (cm)	Tillerhill^{-1}	Panicle m^{-2}	Grains panicle^{-1}	1000-grain wt (g)	Yield (t ha^{-1})	Sterility (%)	Duration (day)
V_1	T_1	131	9	225	144	23.7	5.40	19.28	139
	T_2	131	10	252	91	23.8	5.00	26.24	140
V_2	T_1	132	9	225	100	24.1	5.70	24.48	138
	T_2	133	9	218	121	24.0	5.70	14.64	140
V_3	T_1	131	10	247	113	22.3	4.81	21.28	140
	T_2	131	9	213	150	22.2	4.70	18.24	142
V_4	T_1	116	9	228	111	24.2	5.30	27.92	142
	T_2	118	10	247	76	24.1	4.91	27.68	140
V_5	T_1	125	8	200	90	25.9	5.70	34.72	141
	T_2	128	8	193	92	26.0	5.10	33.92	140
$LSD_{0.05}$		3.06	1.69	40.84	41.83	0.45	0.51	15.42	NS

dhan28, BRRI dhan58 and BINA dhan14 gave statistically similar yield. Similarly, BRRI hybrid dhan3 and Hira2 gave statistically similar grain yield (>5.82 t/ha, Table 9).

RICE FARMING SYSTEMS

Long-term effect of three cropped cropping patterns on the agro-economic productivity. The tested cropping patterns were, Potato-Boro-T. Aman, Maize-Mungbean-T. Aman, Boro- T. Aus-T. Aman and Boro-Fallow-T. Aman (check). The yield of each crop was converted to rice equivalent yield (REY) for comparing the system productivity. The Potato yield was 24.33 t/ha and maize yield was 7.43 t/ha. Mungbean plants damaged due to heavy rainfall. Grain yield of Boro rice was 5.80, 3.36 and 3.55 t/ha under Boro-Fallow-T. Aman, Boro-T. Aus-T. Aman and Potato-Boro-T. Aman cropping patterns. Average grain yield of T. Aman rice was 4.2 t ha^{-1} under Boro-Fallow-T. Aman, Boro-T. Aus-T. Aman, Potato-Boro-T. Aman and Maize-Mungbean-T. Aman cropping patterns. Grain yield of T. Aus rice was 2.63 t/ha. The highest REY (22.75 t ha^{-1}) was obtained from Potato-Boro-T. Aman cropping pattern followed by Boro-T. Aus-T. Aman (10.39 t ha^{-1}), Boro-Fallow-T. Aman cropping pattern (10.00 t ha^{-1}) and the lowest REY (9.57 t ha^{-1}) was found from Maize-Mungbean-T. Aman cropping pattern.

Evaluation of BRRI dhan48 as early Aus rice in Potato-Boro-T. Aman cropping pattern in medium highland irrigated ecosystem

The experiment was conducted at BRRI RS farm to find out suitability of BRRI dhan48 as early Aus and appropriate seedling age of rice after potato. The treatments were, Factor A: Transplanting date (20 February, 2 March and 12 March) and Factor B: Variety and seedling age (V_1S_1=BRRI dhan28 with 40 days and V_1S_2= BRRI dhan28 with 30 days old seedling, V_2S_1=BRRI dhan48 with 30 days and V_2S_2=BRRI dhan48 with 20-day-old seedling). The results show that plant height, tillers m^{-2}, grains panicle^{-1}, 1000 grains weight and grain yield varied significantly due to the interaction effect of variety and variable planting with different seedling age. The highest grain yield (5.36 t ha^{-1}) was recorded from $T_1V_1S_1$ and the lowest in $T_3V_1S_1$ (4.16 t ha^{-1}). Based on the results, it is concluded that BRRI dhan28 with 30-day-old seedling planting at 20 February and BRRI dhan48 with 30-day-old

Table 9. Yield performance of inbred and hybrid rice as Braus, Rangpur, Braus 2016.

Tested variety	Mean grain yield (tha^{-1})			Mean of variety
	1 March	15 March	30 March	
BRRI dhan28	5.11 (113 d)	4.96 (111 d)	4.92 (108 d)	5.00
BRRI dhan48	5.07 (116 d)	5.48 (114 d)	5.30 (104 d)	5.28
BRRI dhan58	4.97 (117 d)	5.18 (115 d)	5.14 (104 d)	5.10
BINA dhan14	4.96 (111 d)	4.89 (109 d)	5.03 (104 d)	4.96
BRRI hybrid dhan3	6.53 (125 d)	6.12 (122 d)	4.93 (121 d)	5.86
SL8-H	6.84 (126 d)	5.74 (124 d)	4.20 (124 d)	5.60
Hira2	6.85 (122 d)	5.23 (120 d)	5.37 (119 d)	5.82
SE		0.1920		0.1109
$LSD_{(0.05)}$		0.3894		0.2248

Within parenthesis: Total growth duration (day).

seedling planting at 2 March may be suitable for early Aus rice after potato harvest.

Technology transfer

Demonstration of BRRI dhan48 in Braus season in potato and tobacco growing areas in Rangpur region (IAPP). Fifteen farmer field trials were conducted in three locations under Rangpur and Lalmonirhat districts. BRRI dhan48 were used as test variety. The data demonstrated that Taraganj of tobacco growing area gave the highest grain yield followed by Pirgacha of potato growing area and Aditmari of tobacco growing area. The farmers of those locations had chosen BRRI dhan48 because of satisfactory grain yield.

Demonstration of newly BRRI released Aus varieties for Aus season in Rangpur region (IAPP). Four Aus varieties (BRRI dhan48, BRRI dhan55, BRRI dhan65 and local Parija) were used in this demonstration. The data demonstrated that BRRI dhan48 gave the highest grain yield followed by BRRI dhan65, BRRI dhan55 and Parija. The farmers have chosen BRRI dhan48 because of grain yield but another choice was BRRI dhan65 because of grain type and yield.

Performance evaluation of different short duration Aman varieties for timely sowing of potato in Potato-Rice system (IAPP). Three farmers were selected in different three locations. Four short duration variety of BRRI dhan33, BRRI dhan56, BRRI dhan57 and BRRI dhan62 were used in this trial. The results show that BRRI dhan56 gave the highest grain yield followed by BRRI dhan33, BRRI dhan57 and BRRI dhan62 in maximum locations. Farmer's reaction about these varieties in all locations was highly positive for BRRI dhan56 because of plant type, low insect and disease infestation, good grain quality and yield.

Validation of newly released BRRI varieties for Boro season in Rangpur region (IAPP). Validation trial was conducted in farmers' field during Boro 2015-16 in four locations of Rangpur, Nilphamari, Lalmonirhat and Kurigram. Four varieties (BRRI dhan58, BRRI dhan60, BRRI dhan63 and BRRI dhan69) were used. The results showed that BRRI dhan69 produced the highest grain yield in all locations followed by BRRI dhan60, BRRI dhan63 and BRRI dhan58. BRRI dhan58 gave the highest grain yield in Mithpukur, Rangpur and sadar, Nilphamari.

Demonstration of BRRI dhan58 in Rangpur region (IAPP)

Four field trials were conducted in farmers' field during Boro 2015-16 in two locations of Rangpur (Badarganj) and Kurigram (Dashiyer Chara) under IAPP project using BRRI dhan58. The data demonstrated that higher grain yield was found at Dashiyer Chara, Fulbarai, Kurigram compared to Badarganj, Rangpur and the lowest grain yield was found at one location of Dashiyer Chara, Fulbari, because of neck blast infestation. In all locations, farmers have chosen BRRI dhan58 because of higher yield and grain quality.

Seed distribution under IAPP

To disseminate modern T. Aman rice varieties in target areas of Rangpur, a total of 1500 kg seeds were distributed. A total of 15 groups were formed with the help of DAE and local SAAO and CF while 30 farmers were in each group. Fifteen knowledge sharing workshop was held in the selected areas. A short briefing was given by the expert scientists about the varieties and production technologies. The farmers gave their opinion from their experiences. Finally, each farmer took 5 kg seeds according their choice and land type.

Seed production and dissemination in 2015-16. A total of 6357 kg TLS and 12161 kg breeder seed of Aus (BRRI dhan48), T. Aman (BR11, BR22, BRRI dhan34, BRRI dhan46, BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan65 and BRRI dhan66) and Boro (BRRI dhan28, BRRI dhan29, BRRI dhan58 and BRRI hybrid dhan3) was produced.

Weather information. The monthly mean maximum temperature recorded in BRRI RS, Rangpur was the highest (32.4°C) in October 2015. The lowest monthly mean temperature (10.8°C) was recorded in January 2016.

The monthly total rainfall varied from 0 to 676 mm. Monthly rainfall was not uniformly distributed. The highest monthly total rainfall (676 mm) was recorded in August 2016.

BRRI RS, Shatkhira

SUMMARY

A total of 841 progenies each were selected from 102 and 88 crossing populations in Aman and Boro season respectively. Ten to 18 lines were selected from OT against salinity. IR12T157 and BR8980-4-6-5 performed better in PYT. IR64683-87-2-2-3-3, HHZ5-SAL14-SAL2-Y1, IR83484-3-B-7-1-1-1, WANXIAN7777-P10 and WANXIAN7777-P12 yielded better against check in SYT.

From RYT in Aman season, BR9786-BC2-132-1-3 and BR9786-BC2-119-1-1 could be promising genotypes for favorable T. Aman. In RYTs for MER, BR8445-54-6-6 and BR7528-2R-HR16-2-24-1 lines could be selected for long and slender grain type. In RYTs for RLR, yield of IR70213-10-CPA4-2-2-2, BR8226-8-5-2-2 and BR8227-6-2-1 found better in RYT-1 and BR8214-23-1-3-1 was in RYT-2. Seven better yielder entries were identified in RYT-PQR. BR7959-14-2-1 (RTV) showed better performance under RYT-DR. In Boro season, BR8626-20-9-1-3, BR8626-19-5-1-2 and BR8626-19-4-1-1 could be promising genotype in RYT-FBR where BR8076-1-2-2-3 showed good yielder in RYT-PQR.

A new variety named BRRI dhan75 has released in PVT of HUA565. BR7697-15-4-4-2-2 produced higher yield against BRRI dhan37 with an advantage of 21 days growth duration in PVT. IR77092-B-2R-B-10 would be also a good genotype for saline condition tested in PVT. Based on the result of missing element trial, balanced fertilizer application is needed for high yield in saline *gher* and N is the most critical nutrient element. BRRI dhan67, BRRI hybrid dhan2, BRRI hybrid dhan3 was found better for saline *gher* and BRRI dhan50 in non-saline *gher*. BR11, BRRI dhan52 and BR10 was found higher yielder in stability analysis in Aman season where BRRI dhan69, BRRI dhan47 yielded better during Boro 2015-16.

A total of 25.35 ton breeder seed and 6.91 ton of TLS was produced during the reporting period. A total of 455 SPDP of different varieties, 13 field day and 32 farmer's training were conducted during the reporting year.

VARIETAL DEVELOPMENT

Selection from pedigree nursery (F_2-F_7)

A total of 841 progenies each were selected from 102 and 88 crossing populations in Aman and Boro season respectively. Number of progenies of 241, 207, 85, 300 and 8 were selected from $19F_2$, $24F_3$, $14F_4$, $43F_5$ and $2F_6$ populations in Aman season and 221, 271, 92 and 204 progenies were selected from $25F_2$, $31F_3$, $7F_4$ and $25F_5$ populations in Boro season. Forty-three and 10 lines were bulked from F_6 and F_7 populations, respectively.

Observational trial (OT)

Twelve and 18 lines were selected from 34 and 56 genotypes respectively against BRRI dhan53 and BRRI dhan54 in saline area of Noyapara (Assasuni), Satkhira during Aman 2015. Out of 66 lines, 15 and 10 lines were selected against BRRI dhan28, BRRI dhan61 and BRRI dhan67 at Kulia (Debhata) and Noyapara (Assasuni), Satkhira respectively as well as 18 genotypes suitable for saline prone areas were selected form 47 lines against BRRI dhan28, BRRI dhan67 and BINA dhan10 at Kulia, Debhata, Satkhira during Boro 2015-16.

Preliminary yield trial (PYT)

Twenty-two salinity tolerant lines were evaluated against BRRI dhan53 and BRRI dhan54 in two PYTs at Kulia (Debhata), Satkhira. BR8718-B-2-2-1 yielded (4.67 t ha^{-1}) better than the checks in PYT-1 where IR12T157 (5.00 t ha^{-1}), IR11T174 (4.88 t ha^{-1}) and IR89609-8-2-B (4.70 t ha^{-1}) yielded better than the checks in PYT-2 during Aman 2015. HHZ5-Y4-SAL1-Y1, HHZ12-SAL8-Y1-Y2 and HHZ6-SAL3-Y1-SUB2 yielded better in all three locations of Debhata, Assasuni and Kaliganj in Aman season. Figures 1 and 2 present the salinity level of these tested sites during the crop growth period.

In Boro 2015-16, a total of 3 PYTs were conducted at Kulia (Debhata) and Chiladanga (Assasuni), Satkhira compared with BRRI dhan28, BRRI dhan61, BRRI dhan67 and BINA dhan10. All tested entries along with checks were died due to high salinilty at Chiladanga site. In PYT1, eleven lines were evaluated and no entry could beat the yield of all the checks. Among ten lines in PYT 2, BR8980-4-6-5 yielded (6.11 t ha^{-1}) significantly higher. In PYT3, no entry could beat the yield against the checks.

Secondary yield trial (SYT)

Thirteen and eight lines were evaluated in two SYT compared with BRRI dhan53 and BRRI dhan54;

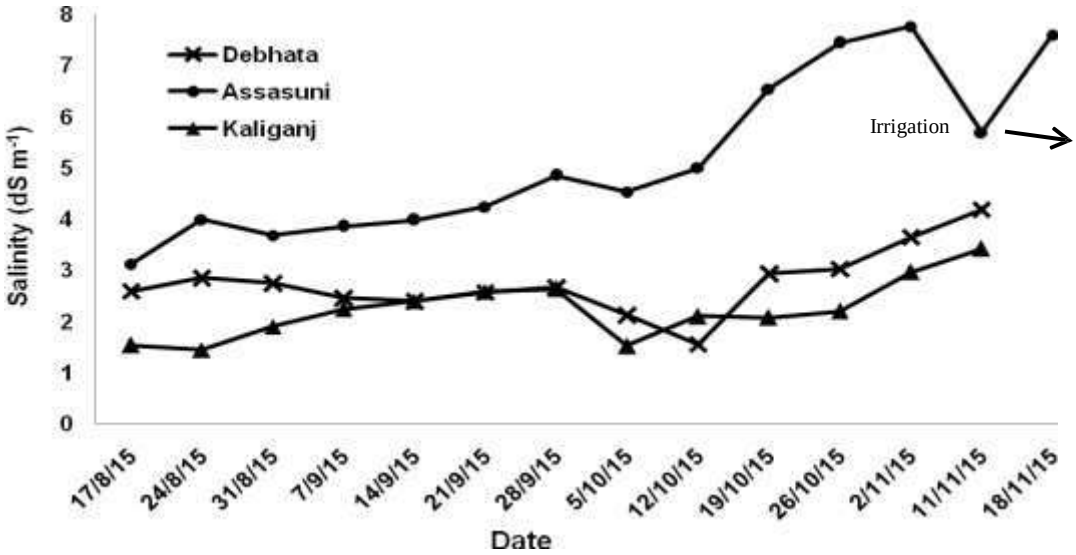

Fig. 1. Water salinity of experimental plots at Debhata, Assasuni and Kaliganj during T. Aman 2015.

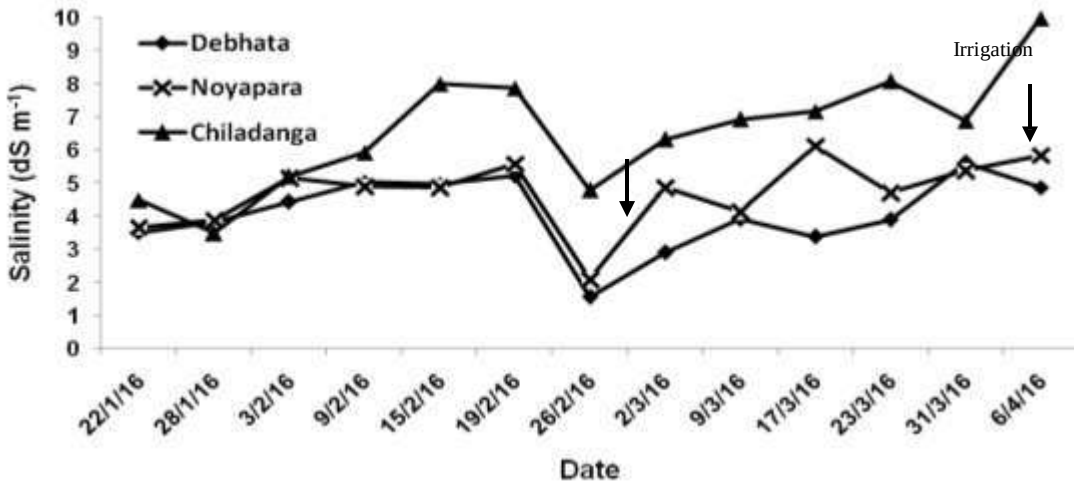

Fig. 2. Water salinity of experimental plots at Debhata and Assasuni (Noyapara and Chiladanga) during Boro 2015-16.

BRRI dhan53 and BRRI dhan66, respectively at Kulia (Debhata) during Aman 2015. No significant difference was found on grain yield in SYT with 13 lines. IR64683-87-2-2-3-3 (5.87 t ha^{-1}) and HHZ5-SAL14-SAL2-Y1 (5.79 t ha^{-1}) yielded significantly higher except BRRI dhan53 (5.78 t ha^{-1}).

Eleven and seven entries were evaluated in SYT against BRRI dhan28, BRRI dhan61, BRRI dhan67 and BINA dhan10 at Kulia (Debhata) and Tarali (Kaliganj) during Boro 2015-16. IR83484-3-B-7-1-1-1 yielded (6.26 t ha^{-1}) significantly higher than other entries including all checks in SYT with 11 lines. WANXIAN7777-P10 produced the highest yield (4.95 t ha^{-1}) at Kulia (Debhata) and WANXIAN7777-P12 (5.00 t ha^{-1}) at Tarali (Kaliganj) against BRRI dhan28.

Regional yield trial (RYT) for Aman 2015

Eight RYTs for favourable Aman, micronutrient enriched rice (MER), rainfed lowland rice (RLR), premium quality rice (PQR), disease resistance rice (DR) against respective check varieties were conducted at BRRI RS, Satkhira during T. Aman 2015 following RCB design with three replications.

Respective recommended size of plots were transplanted using 2-3 seedlings hill^{-1} maintaining of 15 cm x 20 cm spacing. Fertilizer and pest management, cultural practices were done as per recommendation. Table 1 presents the results.

In RYT from Biotechnology Division, BR9786-BC2-132-1-3 yielded (6.26 t ha^{-1}) significantly higher with an advantage of plant height over the check varieties. BR8445-54-6-6 (4.66 t ha^{-1}) and BR7895-4-3-3-2-3 (6.00 t ha^{-1}) performed better in grain yield under RYT-1 and RYT-2 of MER whereas none of the tested line in RYT-3 did better than the checks. In RYT-2 under RLR, BR8214-23-1-3-1 yielded (6.14 t ha^{-1}) higher than checks. All of the entries except BR8515-23-6-3, BR8514-17-1-5 and BR8234-1-2-7-4 showed better yield with lower growth duration and shorter plant height compared to the checks under PQR trial. BR7959-14-2-1 (RTV) under DR trial showed higher yield (5.99 t ha^{-1}) than the check varieties.

Table 1. Performance of different entries under RYT during Aman 2015, BRRI RS, Satkhira.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
	RYT (Biotechnology)		
BR9786-BC2-124-1-2	111	126	4.76
BR9786-BC2-119-1-1	121	129	5.57
BR9786-BC2-132-1-3	123	128	6.26
BR9786-BC2-2-1-1	109	128	4.67
BR9786-BC2-139-2-3	112	126	4.85
BR9786-BC2-124-1-5	110	126	4.24
BRRI dhan33 (ck)	104	120	4.91
BRRI dhan39 (ck)	110	122	4.64
BRRI dhan49 (ck)	100	130	5.81
$LSD_{0.05}$	5.5	1.7	0.48
	RYT-1 (MER)		
BR8445-54-6-6	118	115	4.66
BR7528-2R-HR16-2-24-1	117	121	4.50
BR8410-16-4-17-9-1	118	117	4.38
BRRI dhan57 (ck)	99	109	3.53
BINA dhan7 (ck)	98	115	4.47
$LSD_{0.05}$	4.1	0.8	0.53
	RYT-2 (MER)		
BR7895-4-3-3-2-3	119	147	6.00
BR8442-9-5-2-3-B1	119	142	4.23
BRRI dhan32 (ck)	120	139	5.96
BRRI dhan39 (ck)	109	130	4.63
BR5 (ck)	125	149	4.16
$LSD_{0.05}$	4.2	2.8	0.61
	RYT-3 (MER)		
BR7528-2R-HR16-12-23-P1	125	140	4.17
BR7528-2R-HR16-12-3-P1	124	144	3.90
BR7528-2R-HR16-3-98-1	115	138	5.16
IR 84750-213-2-2-3-1	116	134	3.86
BRRI dhan32 (ck)	123	133	5.95
BRRI dhan39 (ck)	109	127	4.25
BRRI dhan49 (ck)	105	137	5.39
Kataribhog (ck)	116	147	3.36
$LSD_{0.05}$	4.2	2.8	0.61
	RYT-1 (RLR)		
IR70213-10-CPA4-2-2-2	117	137	5.51
B 10533 F-KN-12-2	112	131	4.42
BRRI dhan39 (ck)	107	153	4.91
BR8226-8-5-2-2	114	150	5.46
BR8226-11-4-4-3	104	147	4.84
BR8226-11-4-6-2	114	144	5.02
BR8227-6-2-1	118	145	5.56

Table 1. Continned.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRRI dhan49 (ck)	104	137	5.44
$LSD_{0.05}$	3.0	2.5	0.65
	RYT-2 (RLR)		
BR8204-50-2-2-2-5	110	130	3.67
BR8210-10-3-1-2	116	136	5.51
IR09F436	113	126	3.81
BR8198-13-4-1-3	116	139	5.54
BR8214-19-3-4-1	122	137	5.70
BR8214-23-1-3-1	124	136	6.14
Inpari 11	111	125	4.04
Swarna (ck)	96	146	5.99
BRRI dhan39 (ck)	105	126	4.38
BRRI dhan49 (ck)	100	139	5.22
$LSD_{0.05}$	2.4	1.8	0.78
	RYT (PQR)		
BR8514-17-1-5	119	129	3.26
BR8422-44-5-1	114	137	4.25
BR8535-2-1-2	103	122	4.17
BR8522-21-4-8	133	138	5.10
BR8522-46-1-1	132	136	4.87
BR8522-53-1-3	117	134	4.51
BR8522-30-1-2	107	137	4.21
BR8234-1-2-7-4	98	142	2.15
BR8512-3-1-1	106	136	4.66
BR8515-23-6-3	124	141	3.25
BRRI dhan34 (ck)	139	142	3.41
Kalizira (ck)	157	145	2.71
$LSD_{0.05}$	2.0	1.8	0.71
	RYT (DR)		
BR8821-8-1 (BB)	100	128	4.84
BR8821-10-2 (BB)	102	139	4.38
BR7959-14-2-1 (RTV)	122	134	5.99
BRC171-2-1-2-2-2 (RTV)	110	138	4.56
IR73885-1-4-3-2-1 (RTV)	114	138	4.92
BR7958-12-1-1-2 (RTV)	113	139	5.29
BR8219-12-1-2-1-1 (Blast)	108	137	5.39
BR11 (Sus ck-BB & RTV)	116	147	5.47
BRRI dhan39 (std ck)	101	130	4.85
BRRI dhan34 (Sus ck-Blast)	138	139	3.17
BRRI dhan31 (Res ck-BB ck)	111	139	4.67
$LSD_{0.05}$	5.5	1.8	0.69

Proposed variety trial (PVT) for Aman 2015

A total of six proposed variety trials (PVT) for short duration (SD), rainfed lowland rice (RLR), green super rice (GSR), premium quality rice (PQR) and for salinity tolerant rice were conducted in Satkhira, Bagerhat and Khulna district. Transplanting was done using 25-day-old seedlings of SD, RLR, GSR, PQR and 30-35-day-old seedlings for PVT of salinity tolerant trial by 2-3 seedlings hill^{-1} maintaining the spacing of 15 cm×20 cm in plots of 5.0 m×5.0 m. All the recommended management practices were followed during the whole crop growth period. HUA565 produced higher yield (6.87 t ha^{-1}) with one week growth duration advantage and this entry has already released as a new variety named BRRI dhan75. For premium quality rice, the line BR7697-15-4-4-2-2 produced higher yield (4.74 t ha^{-1}) compared to check BRRI dhan37 (3.87 t ha^{-1}) with an advantage of 21 days growth duration. PVT for salinity tolerant were conducted at six different upazilas of Khulna, Bagerhat and Satkhira districts (Table 2). Entry IR77092-B-2R-B-10 performed better with shorter growth duration than the check BRRI dhan41 relatively in high saline area (Fig. 3).

Table 2. Performance of proposed variety trial tested in saline environment during Aman 2015 in Satkhira, Khulna and Bagerhat district.

Location	Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
Dumuria, Khulna	IR77092-B-2R-B-10	133	130	4.59
	BR9377-9-21-3B	145	140	4.60
	BRRI dhan41(ck)	146	138	4.70
Kaligonj Satkhira	IR77092-B-2R-B-10	108	131	4.64
	BR9377-9-21-3B	118	139	4.68
	BRRI dhan41(ck)	114	136	4.99
Noyapara Assasuni	IR77092-B-2R-B-10	98	130	4.42
	BR9377-9-21-3B	104	143	4.31
	BRRI dhan41(ck)	101	142	3.90
Debhata Satkhira	IR77092-B-2R-B-10	-	139	5.36
	BR9377-9-21-3B	-	150	3.63
	BRRI dhan41(ck)	-	143	4.16
Paikgachha, Khulna	IR77092-B-2R-B-10	109	144	4.05
	BR9377-9-21-3B	100	153	3.46
	BRRI dhan41(ck)	104	149	3.69
Rampal, Bagerhaat	IR77092-B-2R-B-10	106	148	4.13
	BR9377-9-21-3B	97	154	3.33
	BRRI dhan41(ck)	93	151	3.34

DS: 10-15 Jul 2015, DT: 13-20 Aug 2015.

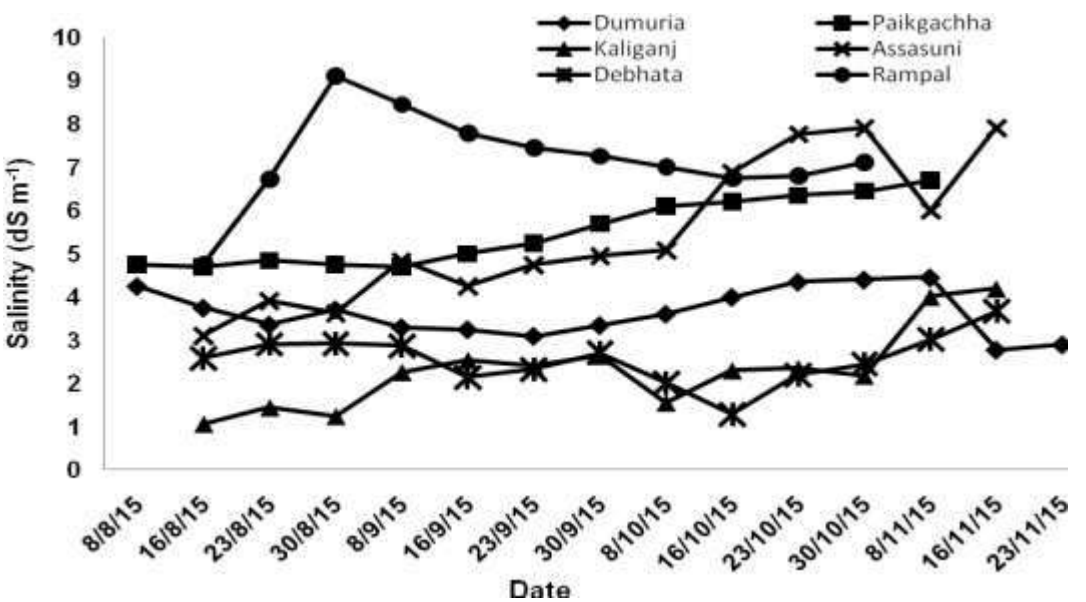

Fig. 3. Water salinity of PVT plots at different locations of Satkhira, Bagerhat and Khulna districts.

Regional yield trial for Boro 2015-16. Nine RYTs for short duration (SD), long duration (LD), favourable Boro rice (FBR), micronutrient enriched rice (MER), cold tolerant rice (CTR), premium quality rice (PQR) were conducted with respective check varieties at BRRI RS, Satkhira farm during Boro 2015-16 following RCB design with three replications. Each unit plot of 3.0 m×2.0 m was transplanted using 2-3 seedlings hill^{-1} maintaining of 20 cm×20 cm spacing. Fertilizer and pest management, cultural practices were done as per recommendation. Table 3 presents the results.

Table 3. Performance of different entries under RYT during Boro 2015-16, BRRI RS, Satkhira.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
	RYT-SD		
BR(Bio)9787-BC2-63-2-2	95	133	6.00
BR(Bio)9787-BC2-63-2-4	94	134	6.40
BR(Bio)9787-BC2-119-1-6	128	147	6.49
BR(Bio)9787-BC2-127-1-5	94	139	6.83
BR(Bio)9787-BC2-173-1-3	95	139	6.48
BR(Bio)9787-BC2-16-3-1	98	137	6.39
BRRI dhan28 (ck)	101	132	6.76
$LSD_{0.05}$	5.5	1.6	0.68
	RYT-LD		
BR(Bio)9786-BC2-122-1-3	103	143	7.54
BR(Bio)9786-BC2-15-2-2	104	146	7.17
BR(Bio)9786-BC2-15-2-3	101	141	7.56
BR(Bio)9786-BC2-49-1-2	103	142	7.38
BR(Bio)9786-BC2-59-1-2	103	143	7.40
BR(Bio)9786-BC2-124-1-1	102	140	7.70
BR(Bio)9786-BC2-142-1-1	105	147	7.58
BRRI dhan29 (ck)	105	149	7.11
$LSD_{0.05}$	3.3	1.7	0.73
	RYT-1 for FBR		
BR7988-12-5-1-1-1	85	138	6.35
BR7988-12-3-4-3-1	86	139	5.75
BR7988-14-1-4-4-2	107	146	6.52
BR8611-10-3-2-2	-	-	-
BR8247-3-2-2-2	88	135	6.81
BRH11-9-11-4-5B	94	140	6.61
BR7683-30-3-3-4	99	135	6.48
BR7988-10-4-1	93	135	6.25
BRRI dhan28(ck)	104	134	6.38
$LSD_{0.05}$	5.2	2.0	NS
	RYT-2 for FBR		
BR8643-6-4-3	101	142	7.07
BR8626-20-9-1-3	96	137	7.96
BR8626-19-5-1-2	101	139	7.93
BR8626-19-4-1-1	105	140	7.67
BRRI dhan29-SC3-28-16-15-HR2(Com)	100	143	6.35
BRRI dhan29-SC3-8-HR1(Com)	98	142	7.41
BRH10-3-12-21-4B	109	145	6.19
BRRI dhan28 (ck)	104	134	6.86
BRRI dhan29 (ck)	102	144	7.11
BRRI dhan58 (ck)	96	139	6.74
$LSD_{0.05}$	2.6	1.3	0.56
	RYT-1 for MER		
BR7831-59-1-1-4-9-1-2-P3	102	128	5.40
BR7831-59-1-1-4-3-1-7-P2	97	133	5.67
BR7831-59-1-1-4-5-1-9-P1	108	129	6.59
BRRI dhan28 (ck)	102	131	6.51
$LSD_{0.05}$	NS	2.0	NS
	RYT-2 for MER		
BR7671-37-2-2-3-7-3-P10	103	148	5.75
BR7671-37-2-2-3-7-3-P11	101	146	6.42
BR8643-6-4-4	101	134	6.83
BRRI dhan63 (ck)	94	131	5.46
BRRI dhan29 (ck)	101	145	7.21
$LSD_{0.05}$	3.1	3.0	0.81

Table 3. Continued.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
	RYT-3 for MER		
IR84839-R1L118-1-1-1-1-1	95	138	7.46
IR85849-33-1-2-1-2-2	92	136	6.11
BR8640-9-7-3	99	133	6.13
BRRI dhan29 (ck)	101	142	7.70
BRRI dhan58 (ck)	90	133	6.60
$LSD_{0.05}$	3.5	2.2	0.52
	RYT-CTR		
BR7812-19-1-6-1-P2	100	135	7.06
BR7812-19-1-6-1-P4	101	136	7.06
BRRI dhan28 (ck)	103	134	6.89
BRRI dhan29 (ck)	101	146	7.06
$LSD_{0.05}$	NS	1.3	NS
	RYT-PQR		
BR8079-52-2-2-2	89	137	6.13
BR8076-1-2-2-3	99	135	6.74
BR7372-18-2-1HR1-HR6 (Com)	99	137	6.67
BRRI dhan50 (ck)	82	142	5.89
BRRI dhan63 (ck)	89	137	6.67
$LSD_{0.05}$	6.9	2.1	0.63

All the entries showed very similar in yield ranging between 6.00 and 6.83 t ha^{-1} with check BRRI dhan28 (6.76 t ha^{-1}) in RYT-SD. Almost similar result like RYT-SD was found in RYT-LD where BR(Bio)9786-BC2-124-1-1 showed better yield with nine days earlier than BRRI dhan29. There was no significant difference among the nine entries of RYT-1 for FBR. The entries BR8626-20-9-1-3 (7.96 t ha^{-1}), BR8626-19-5-1-2 (7.93 t ha^{-1}) and BR8626-19-4-1-1 (7.67 t ha^{-1}) yielded significantly higher than all the three checks of RYT-2 for FBR. More or less similar yield level was observed in RYT-1, RYT-2 and RYT-3 for MER as well as RYT-CTR compared to the respective checks. BR8076-1-2-2-3 performed better in yield and growth duration in RYT-PQR.

Participatory varietal selection (PVS) in Aman and Boro seasons during 2015-16

Nine entries compared with BR11, BRRI dhan53 and BRRI dhan54 in Aman season and the same number of entries compared with BRRI dhan28, BRRI dhan61, BRRI dhan67 and BINA dhan10 in Boro season were evaluated in a PVS during 2015-16. PVS preference analysis was done by a team consisting of 20 male and 10 female farmers along with 2 plant breeders. IR78761-B-SATB1-68-6, BR8371-18-20-52-55, BRRI dhan54 and IR78761-B-SATB1-68-6 ranked first choice whereas BRRI dhan53, BR11, IR78761-B-SATB1-68-6 and BRRI dhan54 ranked in second choice in PVS at BRRI farm, Tarali (Kaliganj), Kulia (Debhata) and Noyapara (Assasuni) Satkhira, respectively in Aman 2015. BRRI dhan61, IR86385-117-1-1-B and IR58443-6B-10-3 ranked first choice where IR86385-117-1-1-B, IR86385-183-1-1-B and IR86385-117-1-1-B ranked in second choice in PVS at BRRI farm, Kulia (Debhata) and Tarali (Kaliganj) Satkhira, respectively in Boro 2015-16.

CROP-SOIL-WATER MANAGEMENT

Determination of nutrient requirements for Boro rice in saline *gher.* A missing element trial was set using six treatments in RCB design with three replications at Benerpota. NPKSZn was applied at a rate of 100-15-60-10-1 kg ha^{-1}, respectively. Recommended establishment methods and management practices were followed. About 63% lower grain yield was found in N omitted plot (3.09 t ha^{-1}). And N is the most limiting factor followed by K, S, Zn and P (Table 4). Figure 4 presents the salinity levels of the tested sites.

Table 4. Effect of missing element on grain yield and panicle m^{-2} of BRRI dhan67 at saline *gher* during Boro 2015-16.

Treatment	Panicle m^{-2}	Yield (t ha^{-1})	Yield decrease (%) due to missing nutrient from NPKSZn
PKSZn (-N)	216	3.09	63.43
NKSZn (-P)	255	4.52	11.73
NPSZn (-K)	255	3.98	26.88
NPKZn (-S)	251	4.02	25.62
NPKS (-Zn)	258	4.11	22.87
NPKSZn	295	5.05	-
$LSD_{0.05}$	27.1	0.34	-

DS: 10 Dec 2015, DT: 21 Jan 2016.

SOCIO-ECONOMIC

Stability analysis of BRRI varieties at BRRI RS, Satkhira in Aman and Boro season during 2015-16. Thirty and 36 BRRI developed modern T. Aman and Boro varieties, respectively were tested at BRRI RS farm, Satkhira during 2015-16 following RCB design with three replications. All the management practices were followed as per BRRI recommendation. The highest grain yield was found in BR11 (6.23 t ha^{-1}) which was statistically similar with BRRI dhan52 (5.70 t ha^{-1}) but significantly higher than the other varieties. BR4, BR10, BRRI dhan31, BRRI dhan33, BRRI dhan39 and BRRI dhan40 yielded more than 5.00 t ha^{-1} in Aman season. BRRI hybrid dhan3 produced the highest yield (7.18 t ha^{-1}) followed by BRRI dhan69 (6.95 t ha^{-1}), BRRI dhan47 (6.92 t ha^{-1}), BRRI hybrid dhan2 (6.89 t ha^{-1}), BRRI dhan59 (6.83 t ha^{-1}) and BRRI dhan74 (6.72 t ha^{-1}) in Boro season. The yield of 21 varieties was over six tons per hectare.

TECHNOLOGY TRANSFER

Validation of Boro rice varieties for saline and non-saline *gher*. The experiment was done in a saline *gher* of Benerpota and a non saline *gher* in Khejurdanga to validate suitable variety following RCB design with three replications. Among the seven tested varieties, BRRI hybrid dhan3 yielded the highest (5.13 t ha^{-1}) followed by BRRI hybrid dhan2 (4.76 t ha^{-1}), BRRI dhan47 (4.59 t ha^{-1}) and BRRI dhan67 (4.40 t ha^{-1}) in saline *gher* as well as BRRI dhan59 yielded the highest (7.27 t ha^{-1}) followed by BRRI dhan74 (7.20 t ha^{-1}) and BRRI dhan50 (6.64 t ha^{-1}) in non-saline *gher* (Fig. 4).

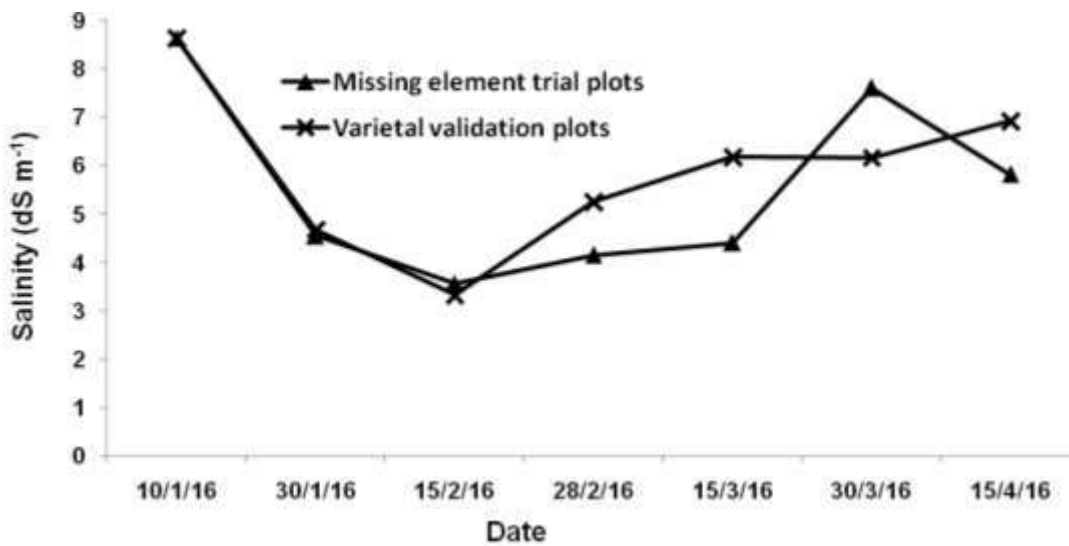

Fig. 4. Water salinity of experimental plots in saline gher during Boro 2015-16.

Breeder seed and truthfully labelled seed (TLS) production. A total of 9.33 tons and 16.02 tons of breeder seed were produced in Aman and Boro season, respectively during 2015-16. And 1.01 tons and 5.90 tons of TLS were produced in Aman and Boro season respectively during the reporting year.

Activity of seed production and dissemination programme (SPDP). A total of 455 SPDP was conducted in the farmer's field of different upazila in Satkhira, Jessore, Bagerhat and Khulna districts. In T. Aman, 345 demonstrations were conducted. The grain yield of the varieties (BRRI dhan62, BRRI dhan49, BRRI dhan30 and BRRI dhan57) varied from 3.60-5.65 t ha^{-1} with an average yield of 4.96 t ha^{-1}. Another 110 demonstrations were conducted during Boro 2015-16. Average yield of BRRI dhan50, BRRI dhan58, BRRI dhan63, BRRI dhan64, BRRI dhan67 and BRRI dhan69 ranged from 5.55-6.47 t ha^{-1}.

Farmer's training and field day. Thirty-two farmer's training (11 in Aman and 21 in Boro season) on rice production technology was conducted to train up 950 farmers' (male-728, female-222) of Satkhira, Khulna, Bagerhat and Jessore districts under GoB, EQSS and HarvestPlus project. A total of seven field day programmes were arranged during Aman and Boro seasons on BRRI dhan49, BRRI dhan62, BRRI dhan64 and BRRI dhan50.

BRRI RS, Sonagazi

SUMMARY

During the reporting period 16 regional yield trials and five proposed variety trials were conducted in BRRI RS, Sonagazi. Seven Aus, 59 Aman and 31 Boro breeding lines from Plant Breeding Division, 15 Boro genotypes from Biotechnology Divisions were evaluated in replicated regional yield trials. Among the tested genotypes; two rain-fed lowland rice, 10 premium quality rice and five micronutrient enriched rice in Aman, four favourable Boro rice of Plant Breeding Division appeared promising. On the other hand, one Aman and two Boro genotypes of Biotechnology Division appeared promising. The promising genotypes were selected for further evaluation.

In proposed variety trials, proposed genotypes; BR9377-9-21-3B, IR77092-B-2R-B-10 for tidal submergence and salinity, BR7611-31-5-3-2 for rain-fed lowland rice, BR7697-15-4-4-2-2 for premium quality rice, HUA 565 for green super rice and NERICA Mutant, produced better yield than their respective checks.

A survey results showed that traditional methods are applied in different mills to produce puffed and flattened rice. Usually double parboiled milled rice is supplied by the auto rice millers from different places of the country for producing puffed rice. BR11, BR16, BRRI dhan28, hybrid and Indian Swarna were more popular varieties and BR16 was the dominant followed by Swarna. On the other hand, rough bold rice was collected from different rice traders to produce flattened rice. BR11, BR16, BRRI dhan28, BRRI dhan29, BRRI dhan46 and hybrid rice were used in the mills.

For Boro rice, nitrogen was the most limiting element. Soil test based fertilizer dose along with 25% higher NPK was the most profitable fertilizer package in saline charland ecosystem. Cultivation of *khesari* as relay crop in T. Aman season suppressed the soil salinity than fallow land in Sonagazi areas. In Sonagazi farm, BRRI dhan46 and BRRI dhan29 performed better in T. Aman and Boro seasons respectively. Survey results showed that Zn enriched variety BRRI dhan64 was severely infested by panicle blast.

In the reporting period, the station produced seven tons breeder seed of BR11, BRRI dhan33 and BRRI dhan34 in Aman season. It also produced five tons breeder seed of BRRI dhan28 and BRRI dhan29 in Boro season. All the breeder seeds of different varieties were sent to Genetic Resources and Seed Division, BRRI, Gazipur. It further produced 25.4 tons truthfully labeled seed of different T. Aman varieties for local farmers' need. It arranged 22 training programme for 650 farmers and several farmers' field days of Chittagong and Chittagong Hill Tracts regions.

VARIETY DEVELOPMENT

Regional yield trial (RYT) in Aus 2015

A total of 11 breeding lines including standard checks BRRI dhan43, BRRI dhan48 and BRRI dhan65 were evaluated in two different regional yield trials from Plant Breeding and Biotechnology Divisions. The tested genotypes did not perform better than their respective checks and therefore, no selection was done.

RYT in T. Aman 2015

For Plant Breeding Division 59 breeding lines including standard checks BR5, BR11 (S. ck. BB and RTV), BRRI dhan31 (R. ck. Blast), BRRI dhan32, BRRI dhan34 (S. ck. Blast), BRRI dhan39 (Std. ck.), BRRI dhan49 and BRRI dhan57, Kataribhog, Kalizira, Swarna and BINA dhan7 were evaluated in seven regional yield trials. Among the tested genotypes, IR70213-10-CPA4-2-2-2 gave comparable yield (6.26 t/ha) to BRRI dhan49 (5.88 t/ha) in rain-fed lowland rice (RLR) 1 whereas BR8198-13-4-1-3 gave higher yield (6.21 t/ha) than Swarna (5.34 t/ha), BRRI dhan39 (5.18 t/ha) and BRRI dhan49 (5.40 t/ha) in RLR 2. Two genotypes; BR8445-54-6-6 (5.70 t/ha) and BR7528-2R-HR16-2-24-1 (5.33 t/ha) gave comparable yield to BINA dhan7 (4.93 t/ha) but higher than BRRI dhan57 (2.25 t/ha) in mcrnutrient enriched rice for long grain.

For Biotechnology Division nine genotypes including standard checks; BRRI dhan33, BRRI dhan39 and BRRI dhan49 were evaluated in one regional yield trial for high yielding rice. Among the tested genotypes, only BR9786-BC2-124-1-3 gave comparable yield (5.03 t/ha) than BRRI dhan33 and BRRI dhan39 (4.12-4.93 t/ha) but lower than BRRI dhan49 (6.36 t/ha).

RYT in Boro 2015-16

For Plant Breeding Division, 31 breeding lines including standard checks; BRRI dhan28, BRRI dhan29, BRRI dhan58 and BRRI dhan63 were evaluated in three regional yield trials for favourable Boro rice, micronutrient enriched rice and cold tolerant rice. Among the tested genotypes, four gave higher yield (5.24-5.80 t/ha) in favourable Boro than their respective checks (3.51-4.66 t/ha) and were selected for further evaluation.

In case of Biotechnology Division, 15 genotypes including standard checks BRRI dhan28 and BRRI dhan29 were evaluated in two different regional yield trials. Among the tested genotypes; BR (Bio) 9787-BC2-173-1-3 produced better yield (5.94 t/ha) than BRRI dhan28 (5.60 t/ha) in RYT 1 whereas BR(Bio)9787-BC2-122-1-3 and BR(Bio)9787-BC2-124-1-1 gave higher yield (7.00-7.07 t/ha) than BRRI dhan29 (6.62 t/ha) in RYT 2.

Proposed variety trial (PVT) for tidal submergence and salinity

Two salt tolerant genotypes; BR9377-9-21-3B and IR77092-B-2R-B-10 in proposed variety trial were evaluated in farmers' field of Chokhoria (Cox's Bazar) and Subarnachar (Noakhali) along with standard check, BRRI dhan41. The salt tolerant genotype, BR9377-9-21-3B gave better yield (4.50 and 5.95 t/ha) than the check (4.01 and 5.20 t/ha) in both the locations. Whereas the proposed genotype IR77092-B-2R-B-10 gave higher yield (4.42 t/ha) than the check (4.01 t/ha) in Noakhali but lower (2.51 t/ha) than that of the check (5.20 t/ha) due to severe bacterial blight infestation in Cox's Bazar.

PVT for RLR

One genotype BR7611-31-5-3-2 in proposed variety trial for rainfed low land rice was evaluated in farmers' field of Sonagazi, Feni along with the standard check BR11. The proposed genotype gave higher yield (4.61 t/ha) than the check (3.57 t/ha).

PVT for RLR-short duration

NERICA Mutant in proposed variety trial was evaluated in farmers' field of Sonagazi, Feni along with the standard check, BRRI dhan57. NERICA Mutant gave higher yield (3.88 t/ha) than the check (3.15 t/ha).

PVT for PQR

One genotype; BR7697-15-4-4-2-2 in proposed variety trial for premium quality rice was evaluated in farmers' field of Sonagazi against standard check BRRI dhan37. The proposed genotype gave higher yield (4.82 t/ha) than the check (4.35 t/ha).

PVT for GSR

One proposed genotype; HUA565 in proposed variety trial for green super rice was evaluated in farmers' field of Sonagazi against standard check BRRI dhan33. The proposed genotype gave better yield (5.42 t/ha) than the check (4.68 t/ha).

Survey on indigenous rice products of BRRI varieties

Puffed and flattened rice are important food items especially for rural people of this country. A survey was conducted in Feni and Chittagong districts to find out the popular BRRI varieties and to identify the traditional methodologies used in mills to produce puffed and flattened rice.

The survey result showed that traditional methods are applied in different mills to produce puffed and flattened rice. The result also showed that double parboiled milled rice was supplied by the auto rice millers from different places of the country for producing puffed rice. The varieties BR11, BR16, BRRI dhan28, hybrid and Indian Swarna were more popular varieties and BR16 was the dominant followed by Swarna. The results further showed that rough bold rice was collected from different rice traders to produce flattened rice. The varieties; BR11, BR16, BRRI dhan28, BRRI dhan29, BRRI dhan46 and hybrid rice were used in the mills.

CROP-SOIL-WATER MANAGEMENT

Long-term missing elements trial

Two experiments were initiated on a permanent layout at BRRI RS farm, Sonagazi in T. Aman 2015 and Boro 2015-16 in viewing missing element effect on yield. The experiment was laid out using seven treatments in randomized block design with three replications. The results showed that incomplete fertilizer treatment (NKSZn) that missing P gave the highest grain yield (6.36 t/ha) but statistically similar to incomplete fertilizer treatment (NPKS) that missing Zn, complete

fertilizer treatment (NPKSZn) and incomplete fertilizer treatment (NPSZn) that missing K in T. Aman 2015 (Table 1). On the other hand, complete fertilizer treatment (NPKSZn) gave the highest grain yield (4.56 t/ha) but statistically similar to other treatments except all missing and N missing treatments (Table 2). It can be concluded that N is the most limiting nutrient element in T. Aman and Boro rice for saline charland ecosystem.

Evaluation of soil management packages for rice production in char land ecosystems

The experiment was initiated at the BRRI RS farm, Sonagazi during T. Aman and Boro 2015-16 to identify the proper soil management packages through organic and inorganic amendments in char land ecosystems. A total of six different fertilizer combinations were imposed. Soil test based (STB) fertilizer (NPKSZn @ 140-20-30-15-4 kg/ha) was used. Twenty-five percent more NPK over the control (T_3) gave the highest yield (5.15 t/ha) but did not differ statistically with other treatments except local farmers' practice (Table 3) in T. Aman 2015. On the other hand, local farmers' practice (T_3) produced higher yield (4.25 t/ha) but did not differ with other treatments except control in Boro 2015-16 (Table 4). It can be noted that the farm usually submerges with tidal flash flood 3-4 times in T. Aman season that carries silt/clay and for siltation fertility increases that's why its effect hardly differs.

Table 1. Effect of long-term missing element on grain yield of BRRI dhan41 BRRI RS farm, Sonagazi, T. Aman 2015.

Treatment	Grain yield (t/ha)
All missing	5.02
NPKSZn (@ 100-20-30-15-4)	5.83
- N	4.36
- P	6.36
- K	5.72
- S	5.47
- Zn	6.07
$LSD_{0.05}$	0.73

Table 2. Effect of long-term missing element on grain yield of BRRI dhan29, BRRI RS farm, Sonagazi, Boro 2015-16.

Treatment	Grain yield (t/ha)
All missing	1.33
NPKSZn (@ 140-20-30-15-4)	4.56
- N	1.64
- P	4.45
- K	4.16
- S	4.06
- Zn	4.22
$LSD_{0.05}$	0.75

Table 3. Effect of different fertilizer combinations on grain yield of BRRI dhan41, BRRI RS farm, Sonagazi, T. Aman 2015.

Treatment	Grain yield (t/ha)
T_1=Control	4.22
T_2=STB fertilizer (NPKSZn @ 97-12-7-10-3 kg/ha)	4.79
T_3= T_1 + 25% over NPK	5.15
T_4 = T_1 + 25% over NPKSZn	4.65
T_5 = T_1 + Rice straw @ 3.0 t/ha (oven dry basis)	4.18
T_6 = Local farmers practice	3.70
$LSD_{0.05}$	1.03

Table 4. Effect of different fertilizer combinations on grain yield of BRRI dhan29, BRRI RS farm, Sonagazi, Boro 2015-16.

Treatment	Grain yield (t/ha)
T_1 = Control	1.51
T_2=STB fertilizer (NPKSZn @ 140-20-30-15-4 kg/ha)	4.15
T_3= T_1 + 25% over NPK	4.24
T_4 = T_1 + 25% over NPKSZn	4.17
T_5 = T_1 + Rice straw @ 3.0 t/ha (oven dry basis)	4.28
T_6 = Local farmers practice (NPK @ 120-10-30 kg/ha)	4.35
$LSD_{0.05}$	0.49

Soil salinity scenario of BRRI RS farm, Sonagazi soil

In the dry period, out side the coast embankment of the Bangladesh Water Development Board (BWDB), most of the char land remains fallow due to soil salinity and drought. But some farmers grow *kheshari* as a relay crop with Aman rice. From a study at Sonagazi farm soil, it was found that the salinity level (1:5 soil water ratios) of *kheshari* covered land was lower than fallow land. Soil salinity of fallow land was high until March and declined sharply after first shower in April. It may be due to increase of soil moisture content.

Evaluation of different T. Aman varieties at direct wet seeded condition

The station brought about 18 hectares of land under cultivation during T. Aman 2015 to evaluate the yield performance of rice under direct wet seeded conditions. The varieties BR23, BRRI dhan32, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46 and BRRI dhan49 were used. Sprouted seeds @ 45 kg/ha were broadcast uniformly on well-prepared puddle field on last week of June. The results showed that BRRI dhan46 produced the highest yield (3.70 t/ha) followed by BRRI dhan49 (3.3 t/ha) (Fig. 1).

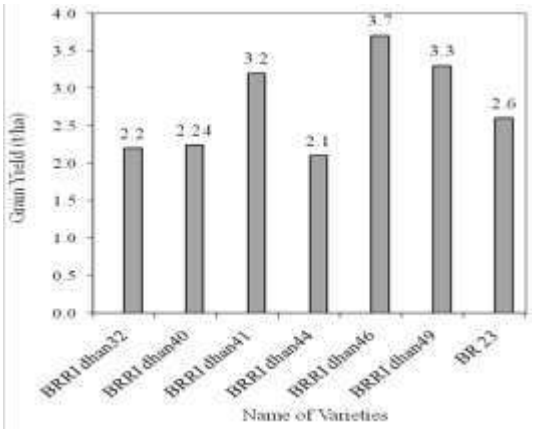

Fig. 1. Grain yield of different varieties at direct wet seeded condition, T. Aman 2015.

PEST MANAGEMENT

Survey and monitoring of rice diseases

Survey and monitoring of rice disease incidence was done during Boro 2015-16 to know the status of disease incidence and how farmers' address the disease. This was done mainly at Sonagazi and Dagonbhuiyan of Feni, Laxmipur sadar and Lama upazilas of Cox's Bazar. Farmers' interview during the visit was taken to know the knowledge status regarding rice disease. Sheath blight and blast incidence was more irrespective of variety. BRRI dhan64, a Zn enriched variety, was severely infested by panicle blast. Farmers' statement indicated that they knew the disease with few control measures. Survey and monitoring results suggested the need of farmers' skill development on rice disease orientation and management through training programme.

SOCIO-ECONOMICS AND POLICY

Stability analysis of BRRI varieties

Different BRRI released varieties were grown in T. Aman and Boro seasons at BRRI RS, Sonagazi farm to find out the suitable rice cultivars in this region. Three replications with randomized complete block design was followed. Crop management practices were adopted as per BRRI recommendation. In T. Aman, BR23 (4.98 t/ha) while in Boro BRRI Hybrid dhan3 (6.98 t/ha) gave the highest yield.

TECHNOLOGY TRANSFER

Demonstration of Boro varieties

Field demonstrations were carried out at different locations of Chittagong and Chittagong Hill Tracts regions during Boro 2015-16. BRRI dhan58, BRRI dhan64 and BRRI dhan69 were demonstrated in 10 locations of Sonagazi, Daganbhuiyan, Raipur and Lama upazilas. The farmers of demonstrated areas showed very much interest about these Boro varieties. The DAE personnel can take initiative for rapid dissemination of the varieties.

BRRI RS, Kushtia

SUMMARY

In RYT (Upland Aus 2015) five lines were tested and the line BR7698-2B1-9-2 gave the highest yield (4.41 t/ha) than both the checks. In RYT-1 (T. Aus 2015) seven lines were tested and none of the lines gave higher yield than the check variety BRRI dhan48. In PVT (RLR), (T. Aman 2015) the line BR7911-31-5-3-2 with BR11 as check were tested and the proposed material BR7911-31-5-3-2 gave higher yield (5.58 t/ha) than the check variety BR11 (5.04 t/ha).

In PVT (RLR-SD), (T. Aman 2015) the proposed variety trial was performed with NERICA (Mutant) and BRRI dhan57 (Std. check). Yield of the line NERICA (Mutant) (5.01 t/ha) was higher than the check variety BRRI dhan57 (4.47 t/ha). In PVT (PQR), (T. Aman, 2015) the line BR7697-15-4-4-2-2 with BRRI dhan37 as check were tested and the proposed material BR7697-15-4-4-2-2 gave higher yield (4.87 t/ha) than the check (2.22 t/ha). In PVT (GSR, T. Aman 2015) the proposed line HUA565 was tested and gave higher yield (6.49 t/ha) than the check variety BRRI dhan33 (5.07 t/ha). Therefore, the material HUA565 could be proposed as a variety.

In RYT (RLR-1, T. Aman 2015) six entries were tested and the yield of the tested lines ranged from 4.44 to 5.42 t/ha. None of the lines gave higher yield than the check variety BRRI dhan49 (5.58 t/ha). In RYT (RLR-2, T. Aman 2015) seven entries were tested and the yield of the tested lines ranged from 5.25 to 6.47 t/ha. None of the lines gave higher yield than the check variety Swarna (6.54 t/ha). In RYT (PQR, T. Aman 2015) ten materials were tested and the yield of the tested lines ranged from 3.65 to 5.84 t/ha. Most of the lines gave higher grain yield than the check varieties (BRRI dhan34). In RYT (MER-LS grain, T. Aman 2015) three materials were tested and the yield of the tested lines ranged from 4.18 to 5.20 t/ha. Most of the lines gave more or less similar grain yield with the check varieties BRRI dhan57 and BINA dhan7. In RYT (MER-SB grain, T. Aman, 2015) two materials were tested and the yield of the tested line BR7895-4-3-3-2-3 gave higher yield (6.12 t/ha) than the check varieties. In RYT (MER-K.b grain, T. Aman 2015) four materials were tested and the yield of the tested lines ranged from 5.87 to 6.42 t/ha. The highest yield was observed in the line IR84750-213-2-2-3-1 (6.42 t/ha) than all checks. In RYT (DR, T. Aman 2015) seven materials were tested and the yield of the tested lines ranged from 4.52 to 6.45 t/ha. The highest yield was observed in the line BRC171-2-1-2-2-2(RTV) (6.45 t/ha) and it was resistant to RTV. In RYT (Bio-tech., T. Aman 2015) six materials were tested and the yield of the tested lines ranged from 5.08 to 5.71 t/ha. The highest yield was observed in the line BR9786-BC2-124-1-5 (5.71 t/ha) compared to checks. In RYT FBR-1, Boro 2015-16 seven materials were tested and among the tested lines only BR7988-14-1-4-4-2 line gave higher grain yield (6.95 t/ha) than the check variety BRRI dhan28 (6.75 t/ha). In RYT (FBR-2, Boro, 2015-16) seven materials were tested and none of the lines gave higher yield than the check BRRI dhan29 (7.71 t/ha). In RYT (IRR), Boro 2015-16) nine materials were tested and most of the lines gave higher yield than all the check varieties. The highest yield was found from the line BR8340-16-2-1 (7.41 t/ha) followed by line BR7987-51-1-2 (7.34). In RYT (Cold tolerant), (Boro 2015-16) two materials were tested and the yield of the tested lines gave higher than the check variety BRRI dhan28 (6.68 t/ha) but lower than check variety BRRI dhan29 (7.91 t/ha). In RYT (Bio-tech. SD), (Boro 2015-16) six materials were tested and the highest yield was observed in the line BR(Bio)9787-BC2-127-1-5 (7.38 t/ha) than the check BRRI dhan28. In RYT (Biotech. LD, (Boro 2015-16) seven materials were tested and the line BR (Bio)9786-BC2-122-1-3 gave higher yield (8.09 t/ha) than the check BRRI dhan29 (7.76 t/ha).

In T. Aman 2015 a long duration variety (BR11) and a short duration variety (BRRI dhan33) were tested to determine effect of drought for different transplanting dates and drought severity. BRRI dhan33 suffered comparatively less drought than BR11 due to its shorter growth duration. But in reproductive and ripening phases higher drought occurred in case of transplanting after 22 July. BRRI dhan33 yielded the highest (5.4 t/ha) when it was transplanted on 22 July and the lowest yield was found (4.1 t/ha) in case of transplanting on 19 August. For BR11, the highest yield (5.5 t/ha) was found when it was transplanted on the 22 July and the lowest yield was observed in case of 19 August (4.2 t/ha). Yield decreased for both short and long duration variety after transplanting on 22 July.

In T. Aman 2015 the experiment was conducted to find out suitable time for application of supplemental irrigation with three treatments. Four, three and two numbers of irrigation was applied when water level went down at 15, 20 and 25 cm below ground surface respectively. There were no considerable yield differences among the treatments. The highest yield was found in T_1 (5.63 t/ha) and the lowest in T_3 (5.58 t/ha). Further trial is needed to draw a conclusion and recommendation for actual depth of perched water table for applying supplemental irrigation.

Stability analysis of 30 BRRI varieties in T. Aman 2015, the highest yield was obtained from BRRI dhan66 (6.69 t/ha) and the lowest from the BRRI dhan37 (3.88 t/ha). Lodging at different magnitudes (25%-50%) was observed in case of six test varieties viz BR5, BR25, BRRI dhan32, BRRI dhan34, BRRI dhan37 and BRRI dhan38.

Stability analysis of 36 BRRI varieties in Boro 2015-16 the highest yield was obtained from the BRRI hybrid dhan3 (7.83 t/ha) and the lowest from the BR6 (5.99 t/ha. lodging tendency was not found in the BRRI varieties during Boro season.

In total, 21 batches farmers' training and 22 field days were organized with the cooperation of the Department of Agricultural Extension (DAE) at different upazilas of Kushtia, Magura, Jhenaidah, Meherpur and Rajbari districts. About 625 and 1400 farmers participated in the training programmes and field days. Modern rice varieties and relevant technologies were disseminated to the farmers. We also participated in an 'agricultural fair' arranged by DAE, Kushtia district where BRRI developed technologies were demonstrated.

VARIETAL DEVELOPMENT

Regional yield trial (RYT), upland Aus 2015

Five lines and two standard checks BRRI dhan43 and BRRI dhan65 were evaluated under this experiment to evaluate the lines for yield potential and adaptability in Kushtia region. The line BR7698-2B1-9-2 gave the highest yield (4.41 t/ha) than both the check varieties (Table 1).

Regional yield trial (RYT-1), T. Aus 2015

Seven genotypes and two standard checks BRRI dhan48 and BR26 were evaluated under this experiment to evaluate the lines for yield potential and adaptability in Kushtia region. None of the lines gave higher yield than the check variety BRRI dhan48 (Table 2).

Proposed variety trial (PVT), RLR, T. Aman 2015

One genotype and one standard check BR11 was evaluated under this experiment to evaluate of proposed genotype by the NSB team for recommendation to release as a new variety. The proposed material BR7911-31-5-3-2 gave higher yield (5.58 t/ha) than the check variety BR11 (Table 3).

Proposed variety trial (PVT), RLR-SD, T. Aman 2015

One genotype and one standard check BRRI dhan57 was evaluated under this experiment to evaluate proposed genotype by the NSB team for recommendation to release as a new variety. The proposed material NERICA (Mutant) gave higher yield (5.01 t/ha) than the check variety BRRI dhan57 (4.47 t/ha).

Table 1. Performance of some RYT lines, Upland Aus, 2015.

Designation	Growth duration (day)	Plant height (cm)	No. of panicles/m^2	TGW (gm)	Yield (t/ha)
BR7698-2B1-9-2	104	100.2	348	26.37	4.41
BR7992-2B-5-2	104	116.7	251	29.77	2.53
BR7383-2B-23	104	117.5	288	26.47	3.90
BR7587-2B-3	109	128.53	254	29.37	3.09
BR6855-3B-13	106	109.9	305	26.33	3.24
BRRI dhan43 (ck)	103	108.3	275	25.17	3.31
BRRI dhan65 (ck)	105	89.2	335	24.13	3.54
$LSD_{0.05}$		11.44	65.11	2.36	0.83
CV (%)		5.8	12.3	4.9	13.6

TGW=1000 grain weight.

Table 2. Performance of some BRRI developed RYT lines, T. Aus 2015.

Designation	Growth duration (day)	Plant height (cm)	No of panicles/m^2	TGW (gm)	Yield (t/ha)
BRRI dhan29-SC3-28-16-10-8-HR1(Com)	100	100.9	269	23.16	3.99
BRRI dhan29-SC3-28-16-10-6-HR6(Com)	98	109.9	215	21.33	4.54
BRRI dhan29-SC3-28-16-10-2-HR3-HR9 (Com)	98	111.6	237	22.30	4.32
BRRI dhan29-SC3-8-HR1(Com)	117	115.5	260	21.40	4.22
BRRI dhan29-SC3-28-16-15-HR2 (Com)	117	115.5	248	21.47	3.93
BR6848-3B-12	108	113.1	223	25.43	4.40
NERICA Mutant	100	111.7	254	26.43	4.47
BRRI dhan48 (ck)	101	108.1	260	25.57	4.89
BR26 (ck)	100	109.3	271	26.03	4.53
$LSD_{0.05}$		7.50	34.17	1.03	0.48
CV (%)		3.9	7.9	2.5	6.4

Table 3. Performance of proposed variety trial (PVT) lines, RLR, T. Aman 2015.

Designation	Growth duration (day)	Plant height (cm)	No. of Panicles/m^2	Yield (t/ha)
BR7911-31-5-3-2	142	149.8	222	5.58
BR11 (ck)	135	128.1	271	5.04
$LSD_{0.05}$		3.48	96.96	1.87
CV (%)		0.7	10.6	10.2

Proposed variety trial (PVT), premium quality rice (PQR), T. Aman 2015

One genotype and one standard check BRRI dhan37 was evaluated under this experiment to evaluate proposed genotype by the NSB team for recommendation to release as a new variety. The proposed material BR7697-15-4-4-2-2 gave higher yield (4.87 t/ha) than the check variety BRRI dhan37 (2.22 t/ha) (Table 3).

Proposed variety trial (PVT), GSR, T. Aman 2015

One genotype and one standard check BRRI dhan33 was evaluated under this experiment to evaluate of proposed genotype by the NSB team for recommendation to release as a new variety. The proposed line HUA565gave gave higher yield (6.49 t/ha) than the check variety BRRI dhan33 (5.07 t/ha).

Regional yield trial (RYT), RLR-1, T. Aman 2015

Six genotypes and two standard checks BRRI dhan39 and BRRI dhan49 were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. None of the lines gave higher yield than the check variety BRRI dhan49 (5.58 t/ha) (Table 4).

Regional yield trial (RYT) RLR-2, T. Aman 2015

Seven genotypes and three standard checks BRRI dhan39, BRRI dhan49 and Swarna were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. None of the lines gave higher yield than the check variety Swarna (6.54 t/ha) but only three lines gave higher yield over cheek varieties BRRI dhan39 and BRRI dhan49 (Table 5).

Regional yield trial (RYT), PQR, T. Aman 2015

Ten genotypes and one standard check BRRI dhan34 were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. Most of the lines gave higher yield than the check BRRI dhan34 except line BR8234-1-3-7-4 and BR5815-23-6-3.

Regional yield trial (RYT), MER (LS grain), T. Aman 2015

Three genotypes and two standard checks BRRI dhan57 and BINA dhan7 were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. Most of the lines gave more or less similar grain yield with the check varieties BRRI dhan57 and BINA dhan7.

Table 4. Performance of some rainfed low land rice (RLR) lines, T. Aman 2015.

Designation	Growth duration (day)	Plant height (cm)	No. of panicles/m^2	TGW (gm)	Yield (t/ha)
IR70213-10-CPA4-2-2-2	119	110.8	219	29.89	5.14
BR10533F-KN-12-2	112	114.2	235	22.72	4.44
BRRI dhan39 (ck)	114	110.7	238	24.39	4.42
BR8226-8-5-2-2	143	120.0	265	19.84	4.89
BR8226-11-4-4-3	143	111.6	259	20.24	5.07
BR8226-11-4-6-2	143	118.3	242	17.25	5.05
BR8226-6-2-1	133	123.8	230	23.30	5.42
BRRI dhan49 (ck)	131	109.6	252	19.18	5.58
$LSD_{0.05}$		4.01	38.89	1.03	0.43
CV (%)		2.0	9.1	2.7	4.9

Table 5. Performance of some Rainfed Low Land Rice (RLR) lines, T. Aman, 2015.

Designation	Growth duration (day)	Plant height (cm)	No. of panicles/m^2	TGW (gm)	Yield (t/ha)
BR8204-50-2-2-5	123	110.7	226	26.17	6.18
BR8210-10-3-1-2	134	122.2	265	21.47	6.43
IR09F436	118	108.7	265	26.19	5.37
BR8198-13-4-1-3	130	127.1	259	26.05	6.23
BR8214-19-3-4-1	130	133.7	251	25.59	6.44
BR8214-23-1-3-1	130	128.1	226	26.18	6.47
Inpari11	118	109.7	287	24.95	5.25
Swarna (ck)	143	100.2	290	20.07	6.54
BRRI Dhan39 (ck)	118	106.3	233	24.45	6.23
BRRI Dhan49 (ck)	134	110.2	284	18.95	6.00
$LSD_{0.05}$		4.27	40.27	112	1.07
CV (%)		1.6	6.9	2.1	7.7

Regional yield trial (RYT), MER (SB grain), T. Aman 2015

Two genotypes and three standard checks BRRI dhan32, BRRI dhan39 and BR5 were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. The highest yield and 1000-grain wt were observed in the line BR7895-4-3-3-2-3 (6.12 t/ha) than the checks varieties.

Regional yield trial (RYT), MER, (K. b grain), T. Aman 2015

Four genotypes and four standard checks BRRI dhan32, BRRI dhan39, BRRI dhan49 and Kataribhog were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. The highest yield was observed in the line IR84750-213-2-2-3-1 (6.42 t/ha) followed by the line BR7528-2R-HR16-12-23-PI (6.25 t/ha) than all checks.

Regional yield trial (RYT), disease resistance (DR), T. Aman 2015

Seven genotypes and five standard checks BR11 (Sus ck-BB and RTV), BRRI dhan39 (Std ck), BRRI dhan34 (Sus ck-Blast), BRRI dhan31 (Res ck-BB) and Locally adaptive variety (ck) Kataribhog were evaluated under this experiment to evaluate the lines for yield potential and adaptability in Kushtia region. The highest yield was observed in the line BRC171-2-1-2-2-2(RTV) (6.45 t/ha) and it was resistant to RTV.

Regional yield trial (RYT), (Biotech.), T. Aman 2015

Six genotypes and three standard checks BRRI dhan33, BRRI dhan39 and BRRI dhan49 were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. Most of the lines gave more grain yield over the check varieties BRRI dhan33 and BRRI dhan39 except BRRI dhan49.

Regional yield trial (RYT), (FBR-1), Boro 2015-16

Seven genotypes and one standard check BRRI dhan28 were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. Among the tested lines one line BR7988-14-1-4-4-2 (6.95 t/ha) gave

higher grain yield than the check variety BRRI dhan28 (6.75 t/ha).

Regional yield trial (RYT), (FBR-2), Boro 2015-16

Seven genotypes and three standard checks BRRI dhan28, BRRI dhan29 and BRRI dhan58 were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. The lines BRRI dhan29-SC3-28-16-15-HR2 (com) and BRRI dhan29-SC3-8-HR1 (com) gave 7.44 t/ha grain yield, which were lower than the check variety BRRI dhan29 (7.71 t/ha) but higher than the checks BRRI dhan28 (6.34 t/ha) and BRRI dhan58 (7.33 t/ha).

Regional yield trial (RYT), (IRR) Boro 2015-16

Nine genotypes and three standard checks BR3 and BRRI dhan28, while T27A was used as resistant check, were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. All the tested lines gave higher grain yield than the checks.

Regional yield trial (RYT, cold), Boro 2015-16

Two genotypes and two standard checks BRRI dhan28 and BRRI dhan29 were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. The yield of the tested lines were higher than the check variety BRRI dhan28 (6.68 t/ha) but lower than check variety BRRI dhan29 (7.91 t/ha).

Regional yield trial (RYT), (Biotech. SD), Boro 2015-16

Six genotypes and one standard check BRRI dhan28 were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. Highest yield was observed in the line BR(Bio)9787-BC2-127-1-5 (7.38 t/ha) than the check BRRI dhan28.

Regional yield trial (RYT), (Biotech. LD), Boro 2015-16

Seven genotypes and one standard check BRRI dhan29 were evaluated under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. The line BR(Bio)9786-BC2-122-1-3 gave higher yield (8.09 t/ha) than the check BRRI dhan29 (7.76 t/ha).

CROPS-SOIL-WATER MANAGEMENT

Terminal drought mitigation adopting transplanting dates in T. Aman 2015

In T. Aman 2015 a long duration variety (BR11) and a short duration variety (BRRI dhan33) were tested to determine drought effect for different transplanting dates and drought severity. BRRI dhan33 suffered comparatively less drought than BR11 due to its shorter growth duration. But in reproductive and ripening phases higher drought occurred in case of transplanting after 22 July Figures 1 and 2. BRRI dhan33 yielded the highest (5.4 t/ha) when it was transplanted on 22 July and the lowest yield was found 4.1 t/ha in case of transplanting on 19 August. For BR11, the highest yield (5.5 t/ha) was found when it was transplanted on 22 July and the lowest yield was observed in case of 19 August (4.2 t/ha). Yield decreased for both short and long duration variety after transplanting on 22 July.

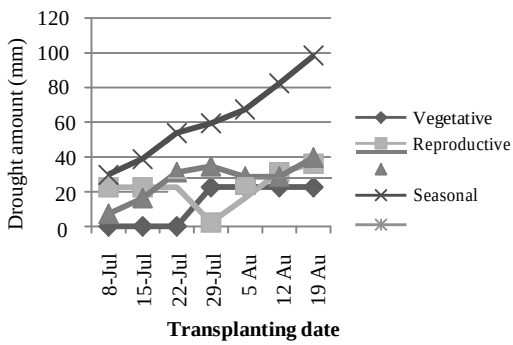

Fig. 1. Drought pattern in 2015 for BR11.

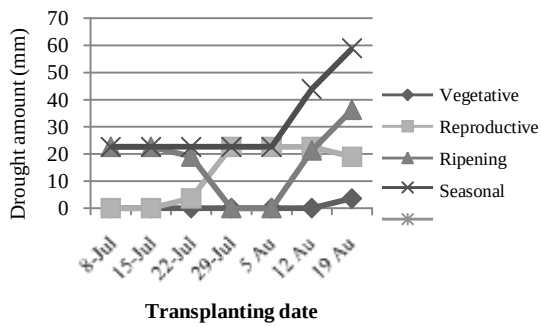

Fig. 2. Drought pattern in 2015 for BRRI dhan33.

Determination of suitable time for application of supplemental irrigation in T. Aman 2015

In T. Aman 2015 the experiment was conducted to find out suitable time for application of supplemental irrigation with three treatments. Four, three and two number of irrigation was applied when water level went down at 15, 20 and 25 cm below ground surface respectively. There were no considerable yield differences among the treatments. The highest yield was found in T_1 (5.63 t/ha) and the lowest in T_3 (5.58 t/ha). Further trial is needed to draw a conclusion and recommendation for actual depth of perched water table for applying supplemental irrigation.