BRRI ANNUAL REPORT
2013-2014

Bangladesh Rice Research Institute

BRRI ANNUAL REPORT
For July 2013-June 2014

Bangladesh Rice Research Institute (BRRI)
Gazipur 1701, Bangladesh

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 2013 to June 2014. This document consists of the significant portions of the research covering seven programme areas.

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

With a target to make Bangladesh 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 (ICM) practices, alternate wetting and drying (AWD) 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 report includes various research results out of activities that attempted to minimize yield gap between research level and farmer's fields.

In addition, readers interested to look into particulars on specific subject of this summarized version may checkout 'Proceedings of BRRI Annual Research Review for 2013-14' which is available in the website (www.brri.gov.bd).

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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BRRI

Personnel

Director General's Office
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Jiban Krishna Biswas, *PhD*
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(From 29 Dec 2013)

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Assistant Director
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Md Ashraf Ali
Assistant Engineer (Electrical)

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Dr Habiba Sultana, *MBBS****
Resident Physician

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Mahbubur Rashid Talukder, *MA (Information Sc and Lib Management)*
Librarian

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Khandakar Md Iftekharuddaula, *PhD*
Principal Scientific Officer
Partha Sarathi Biswas, *PhD*
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Mohammad Akhlasur Rahman, *PhD**
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Mohammad Amir Hossain, *PhD*
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Md Anisuzzaman, *MS*
Scientific Officer
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Scientific Officer
Tapas Kumer Hore, *MS*
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Armin Bhuiya, *MS*
Scientific Officer
Hasina Begum, *PhD*
Scientific Officer
Mohammad Zahidul Islam, *MS*+*
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F Rahman, *PhD*+*
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M M Haque, *MS*+*
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Kabita, *MSc*
Assistant Programmer

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Md Kamruzzaman, *MSc*
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Subrata Paul, *MS*
Scientific Officer
A K M Lutfar Rahman, *MS*
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Md Ashraful Alam, *MS*
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Md Kamruzzaman, *MS****
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Shamsunnaher, *MS*
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Rajesh Barua, *MS*
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Md Mahbubur Rahman Dewan, *MS*
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Md Atiqur Rahman Bhuiyan, *PhD+*
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Md Nazmul Bari, *PhD*
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Md Shafiqul Alam, *BSc Ag (Hons)*
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Md Rafiqul Islam, *PhD*
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Md Mamunur Rashid
Scientific Officer
Md Monsur Habib, *Dip-in-Ag*
Farm Manager

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Md Mosaddeque Hossain, *MS*
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Mahmuda Khatun, *PhD*
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Md Habibur Rahman Mukul, *MS*
Senior Scientific
Md Belal Hossain, *MS*
Scientific Officer
Sharif Mohammad Titumeer, *MS++*
Scientific Officer

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

Weather information

Data on different weather parameters in BRRI HQ Gazipur, Rangpur, Bhanga, Comilla and Barisal stations were recorded by WatchDog Automatic weather station.

Temperature. In the reporting period, the mean monthly maximum temperature was the lowest in January of all the stations and it was ranged from 18.7°C in Habiganj to 24.16°C in Bhanga. The highest mean monthly maximum temperature was recorded in April at Bhanga (37.96°C), Barisal (37.77°C), Comilla (35.96°C), Rangpur (33.47°C) and Habiganj (32.8°C) while 34.45°C in May at Gazipur. The mean monthly minimum temperature was the lowest in January in all the stations ranging from 11.36°C in Rangpur to 12.72°C in Gazipur. The mean minimum temperature remained below 20°C from November to March in Gazipur, Rangpur, Comilla, Habiganj and Bhanga, while it remained same from November to February in Barisal (Fig. 1).

Relative humidity. The monthly mean maximum and minimum relative humidity was in between 99.43 and 47.22% across six stations. The monthly mean maximum RH was recorded as 100% from November to January in Rangpur and Comilla while it was ranged 98-99% in December

to January at Habiganj, Gazipur, Bhanga and Barisal. However, monthly minimum humidity was the lowest in March followed by April for all the stations and it was ranged from 28.39 to 55.94%. The lowest relative humidity was recorded 28.39% in Bhanga followed by Barisal (30.03%), Gazipur (35.71%), Comilla (38.48%) and Rangpur (55.94%) (Fig. 2).

Rainfall. The highest monthly total rainfall of 442.70 mm was recorded in June at Habiganj (601 mm) followed by Comilla (450 mm), Barisal (387.90 mm) and Gazipur (204.30 mm) while it was the highest in August at Rangpur (350.90 mm) and Bhanga (184.60 mm). Dry condition prevailed from November to April at all the stations when rainfall was none to insignificant. The maximum total rainfall was recorded in Habiganj (2737 mm) followed by Comilla (1566.50 mm), Rangpur (1308.00 mm), Gazipur (1073.60 mm), Barisal (982.40 mm) and Bhanga (554.00 mm). It should be mentioned here that the lowest rainfall record of Rangpur and Barisal was mainly due to recorded period which was less compared to the other stations ie for Rangpur (18 July 2013 to 30 June 2014) and for Barisal (24 September 2013 to 30 June 2014). However, for Bhanga the lowest
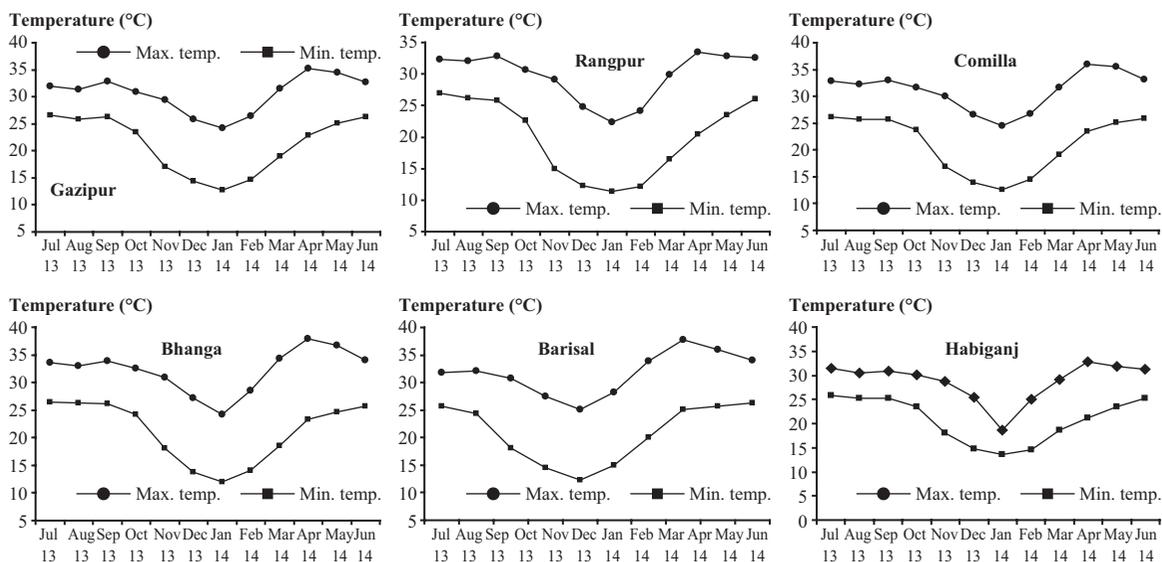
Fig. 1. Monthly mean maximum and minimum temperatures (°C) of Gazipur and five BRRI RSs in 2013-14.
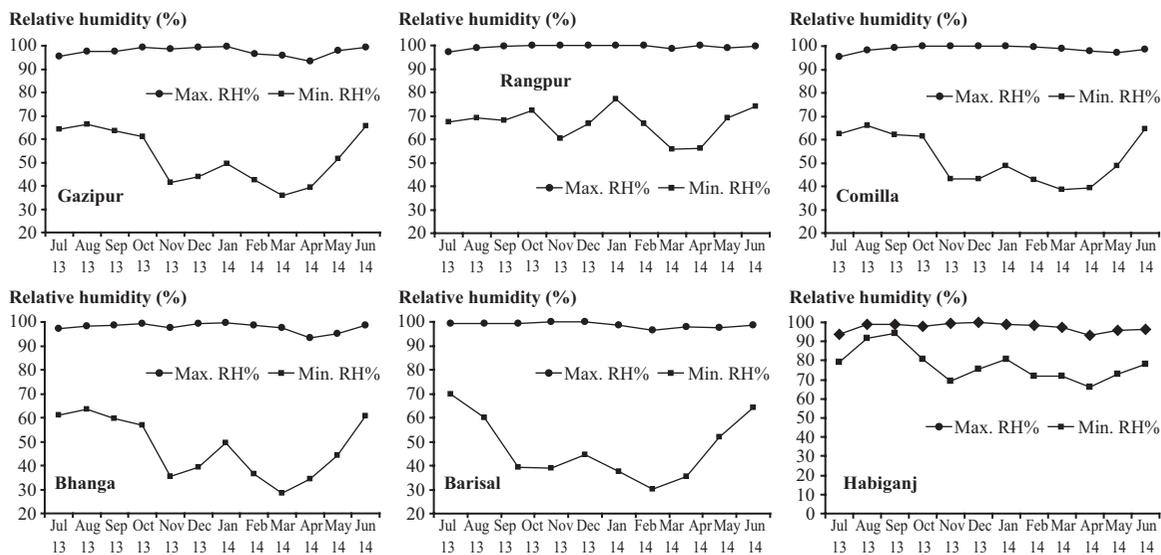
Fig. 2. Monthly mean maximum and minimum relative humidity (%) of Gazipur and five BRRI RSs in 2013-14.

rainfall record was due to technical faults of rain gauge of that station (Fig. 3).

Solar radiation and solar hours. The monthly mean solar radiation was relatively lower during the rainy season and also in December to February as usual. The highest mean solar radiation prevailed in April at Gazipur, Rangpur, Comilla and Barisal while in May at Bhanga. The

mean maximum solar radiation varied from 207.67 to 245.98 wat/m^2 per day during March to May in all the stations, while it varied from 101.48 to 205.44 wat/m^2 per day during rest of the months of the year over all the locations. The highest mean daily solar hours prevailed in July at Gazipur, Rangpur, Comilla and Bhanga, while in May at Barisal. The lowest mean daily solar hours
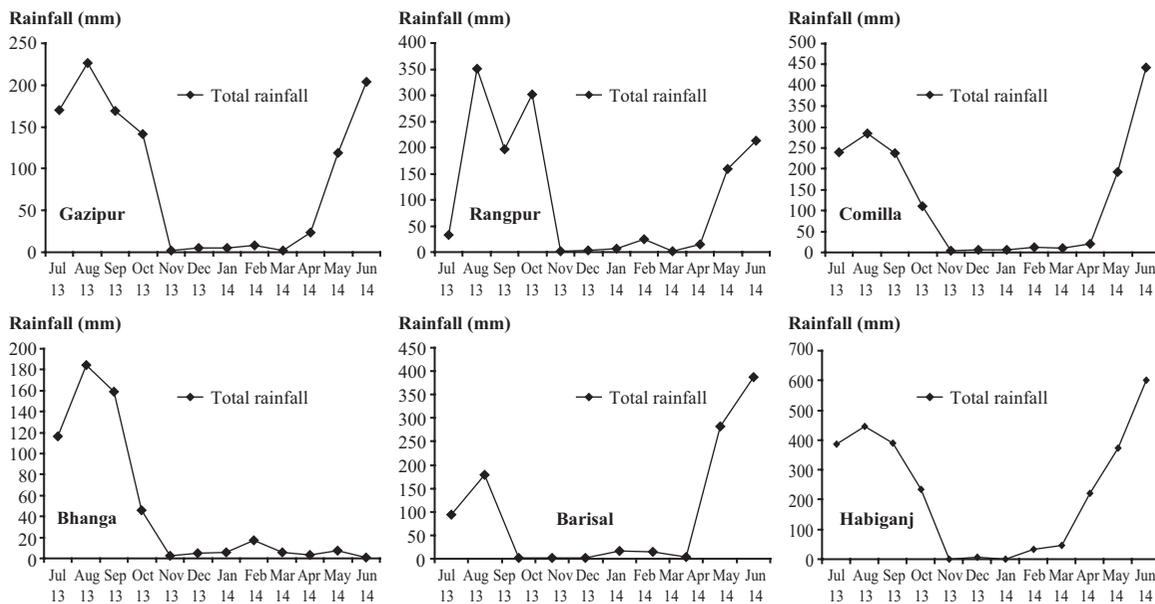
Fig. 3. Monthly total rainfall (mm) of Gazipur and five BRRI RSs in 2013-14.

prevailed in November to February for most of the stations while in September to October in Gazipur. It was ranged from 8.58 to 12.54 hr/day (Fig. 4). It should be noted that, the solar hours were considered when the solar radiation exceeding the threshold limit 21 wat/m^2.

Manual weather information of BRRI HQ, Gazipur and its different regional stations
Temperature. During the reporting period, mean monthly maximum temperature ranged from 23.87 (January) to 36.67°C (April) while the mean monthly minimum temperature ranged from 11.98 (January) to 26.23°C (July) in Joydebpur. The range of maximum temperature was 32.8 (April) to 18.7°C (January) at Habiganj and 35.93 (April) to 25.79°C (January) at Comilla. The range of minimum temperature was from 13.5 to 25.9°C at Habiganj and 12.53 to 26.3°C at Comilla.

Rainfall. The annual total rainfall was 1,387.6 mm (Joydebpur), 1,433.83 mm in Comilla and the

highest rainfall was recorded at Habiganj 2,737 mm. There was no or little rainfall during December to February in Joydevpur. Crop experienced excess rainfall during May to August.

Relative humidity. The relative humidity was the lowest in March (67.41%) and the highest in August (86.95%) at Joydebpur. More or less similar trends were observed in Comilla station. The relative humidity was comparatively higher in Habiganj than the other stations

Solar radiation and sunshine hours. The monthly mean daily solar radiation was relatively lower in December to January. The highest solar radiation 433.51 Cal/cm^2/day was observed in Joydebpur during April and the lowest was in Habiganj during December (219.125 Cal/cm^2/day). The highest mean daily hours of bright sunshine prevailed in November at Joydebpur and April at Habiganj. The lowest mean sunshine prevailed in June at both Habiganj and Joydebpur.
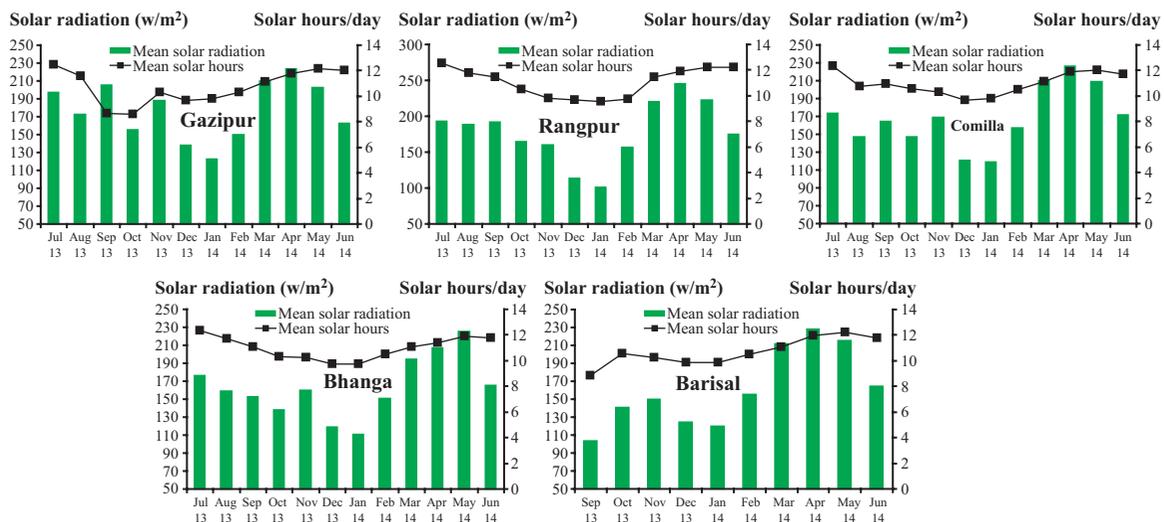
Fig. 4. Monthly mean solar radiation (wat/m^2) and solar hours/day of Gazipur and four BRRI RSs in 2013-14.

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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	=	Blast
BC	=	backcross
BCR	=	benefit-cost-ratio
BI	=	blast
BLB	=	bacterial leaf blight
BLB	=	bacterial leaf blight
BINA	=	Bangladesh Institute of Nuclear Agriculture
BMDA	=	Barind Multi Purpose Development Authority
BPH	=	brown planthopper
BR	=	Bangladesh rice
BS	=	breeder seed
BRRI	=	Bangladesh Rice Research Institute
BWDB	=	Bangladesh Water Development Board
BShB	=	bacterial sheath blight
CAB	=	Commonwealth Agriculture Bureau
ck	=	check
cm	=	centimetre
CDB	=	Carabid beetle
CMS	=	cytoplasmic male sterile
CV	=	common variance, co-efficient of variation
DAE	=	Department of Agricultural Extension (Bangladesh)
DAP	=	drought animal power
DAS	=	days after seeding
DAT	=	days after transplanting
DH	=	dead heart
DHB	=	dark-headed borer
DMRT	=	Duncan's multiple range test
DNA	=	deoxyribonucleic acid
DTF	=	days to flowering

DWSR	=	Direct wet seeded rice
DWR	=	deepwater rice
ET	=	evapotranspiration
FS	=	foundation seed
GABA	=	gamma amino buteric acid
GH	=	grasshopper
GM	=	gall midge
GMB	=	green mirid bug
GLH	=	green leafhopper
GoB	=	Government of Bangladesh
GRS	=	Genetic Resources and Seed
GSR	=	green super rice
GQN	=	Grain Quality and Nutrition
HA	=	Habiganj Aman
HAT	=	hours after treatment
HB	=	Habiganj Boro
ht	=	height
IIRON	=	International Irrigated Rice Observational Nursery
INGER	=	International Network for Genetic Evaluation of Rice
INM	=	integrated nutrient management
IPM	=	integrated pest management
IPNS	=	integrated plant nutrition system
IRRI	=	International Rice Research Institute (Philippines)
IRSSTN	=	International Rice Soil Stress Tolerance Nursery
IURON	=	International Upland Rice Observational Nursery
LCC	=	leaf colour chart
LBB	=	lady bird beetle
LHC	=	long-horned cricket
Lit/ha	=	litre per hectare
LR	=	leaf roller
LSc	=	leaf scald
LSD	=	least significant difference
LV	=	local variety
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, several crosses were made and a number of progenies and fixed lines were selected from F_2 to F_7 populations. A total of 664 crosses were made and 280 crosses were confirmed as true F_1. In total 5,493 progenies were selected from F_2 population. From segregating generations 17,833 progenies were selected and 819 fixed lines were isolated. A total of 1,026 advanced lines were selected from observational yield trials. One hundred three germplasms from different screening nurseries were selected for using in the breeding programme.

Two promising genotypes viz BR7358-30-3-1 for exporting quality rice and BR7840-54-1-2-5 for high zinc rice during Boro 2012-13 were evaluated by NSB team and have been recommended as variety. BR7358-30-3-1 (BRRI dhan63) showed 7.4 t/ha average yield with 149 days growth duration and export quality extra-long slender grain. It matured six days earlier than BRRI dhan50 with yield advantage of 0.9 t/ha. BR7840-54-1-2-5 (BRRI dhan64) showed average yield of 6 t/ha with 155 days growth duration and 7.2 mg/kg higher zinc content than BRRI dhan28. It matured six days later than the check variety BRRI dhan28 with similar yield.

National Seed Board (NSB) team evaluated and recommended OM1490 for direct seeded Aus during Aus 2013-14, IR82635-B-B-75-2 for drought prone areas during T. Aman, 2013-14 and BR7100-R-6-6 for saline prone areas, BR7830-16-1-5-3 and weed tolerant rice for favourable Boro during Boro 2013-14. OM1490 (BRRI dhan65) showed average yield of 3.4 t/ha with 99 days growth duration and long slender grain. Yield advantage of the genotype was 0.5 t/ha over the check variety BRRI dhan43 with almost similar growth duration. IR82635-B-B-75-2 (BRRI dhan66) showed 4.02 t/ha average yield with 113 days growth duration. The yield was not hampered even 80 cm perch water table depth along with less than 20% moisture content. It matured only three days later than BRRI dhan56 but yield advantage was 0.79 t/ha with medium bold grain. BR7100-R-6-6 (BRRI dhan67) showed 5.98 t/ha average yield with 143 days growth duration and long slender grain. It gave similar growth duration with BRRI dhan47 with yield advantage of 0.5 t/ha. It can tolerate 8 dS/m water salinity in its whole life cycle. BR7830-16-1-5-3 (BRRI dhan68) showed 7.3 t/ha average yield with 149 days growth duration having long bold grain. It matured five days later than BRRI dhan28 with 0.9 t/ha yield advantage. BRRI dhan69 showed 7.3 t/ha average yield with 153 days growth duration and matured five days later than BRRI dhan28 with 0.9 t/ha yield advantage having medium bold grain.

VARIETAL DEVELOPMENT

Upland rice (Aus). Major thrust has been 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, 22 crosses were made using 15 parents, 10 crosses were confirmed as true hybrid; 326 progenies and 20 fixed lines were selected from pedigree nurseries. Thirteen entries were selected from OT. Six advanced lines were selected from SYT. Three lines BR6855-3B-12, BR6855-3B-13 and BR6848-3B-12 were selected from RYT for further evaluation. The proposed line OM1490 with average growth duration of 99 days was selected and recommended as a variety (Table 1).

Transplant Aus rice. The project was aimed at developing short duration (105-115 days), high yield potential genotypes having tolerant to lodging, heat (high temperature) at reproductive phase and pre-harvest sprouting and good grain quality. Eleven crosses were made to develop high yielding rice varieties with short growth duration, tolerance to lodging, high temperature, pre-harvest sprouting tolerance and acceptable grain quality for T. Aus season. A total of 553 desirable plant progenies (F_3 families) were selected from 7 F_2. Again 1,367 individual plant progenies and 24 bulk populations were selected from F_3-F_7 generations. In observational trial, 76 entries, 27 genotypes were

Table 1. Performance of the proposed variety under direct seeded Aus 2013-14.

Designation	Plant ht (cm)*	Growth duration (day)*	Grain yield (t/ha)*	Grain characteristic					
				Head rice yield (%)	LB ratio	Size and shape	Elongation ratio	Protein (%)	Amylose (%)
OM1490 (BRRI dhan65)**	88	99	3.4	62.0	3.7	Long slender	1.2	6.5	26.8
BRRI dhan43 (ck)	105	100	2.9	60.0	2.4	Medium bold	1.6	7.5	26.7

*Mean of nine locations (Gazipur Sadar; Kapasia, Gazipur; Faridpur Sadar; Gopalganj Sadar; Sonagazi; Feni; Sitakundu, Chittagong; Biswanath, Sylhet; Golapganj, Sylhet). **NSB has released it as BRRI dhan65 on 20 November 2014.

selected on the basis of homogeneity on plant height, phenotypic acceptability at vegetative and maturity stages. In PYT, 16 entries while in SYT, three entries were selected for further evaluation based on phenotypic acceptability, grain yield and growth duration. In RYT conducted over seven locations, six entries performing better than check variety BRRI dhan48 with respect to grain yield and with more or less similar growth duration.

Improvement of rice for shallow flooded and deep water environment. The major objectives were to develop improved genotypes with slow elongation for shallow flooding condition (1.0 m flood depth) and quick elongation for deep water condition (>2.0 m flood depth). Twelve crosses were made involving eight parents and 993 F_1 seeds were obtained. Totally 23 segregating populations were bulked. In PYT, growth duration of all the entries including the checks was ranged from 224-228 days while grain yield ranged from 2.1-2.5 t/ha. Again in multi-location trials, grain yield (t/ha) of the seven entries including the checks ranged from 2.3-2.4 at on-station Gazipur and from 1.5-2.4 at Tangail. Finally, seeds of the 16 local cultivars were purified and increased.

Rainfed lowland rice (RLR). Efforts were made for development of genotypes superior to standard varieties and adaptable to rainfed lowland environment in T. Aman season. Sixteen crosses were made and two crosses were confirmed, 1,324 plant progenies and 85 fixed lines were selected from segregating population. Ninety-two genotypes were selected from OT, 22 genotypes were selected from PYT, seven genotypes were selected from SYT, three genotypes were selected from RYT and two genotypes were selected from ALART. One promising genotype (BR7611-31-5-3-2) has been suggested to retrial by NSB.

Tidal submergence tolerant rice (T. Aman). The project was aimed at developing high yielding varieties adaptable to tidal non-saline condition in the southern districts. Seventy-six and 397 progenies were selected from F_2 generation and F_6 generation respectively. In total 79 genotypes were selected from observational trial. Eleven genotypes were selected from preliminary yield trial.

Salt tolerant rice. This programme focused on the development of salt tolerant rice variety suitable for the saline prone areas of coastal districts in Aus, Aman and Boro seasons. Sixty-seven crosses for T. Aman and 48 crosses for Boro season were made. A total of 28 for T. Aman and 38 F_1s for Boro season were confirmed and selected. One hundred forty-nine progenies from 15 crosses in T. Aman and 242 progenies from seven crosses in Boro were selected from F_2 populations. Moreover, 796 progenies and 29 genetically fixed lines were selected from T. Aman while 815 progenies and 59 fixed lines were selected from pedigree nurseries of Boro season. Eleven advanced lines from T. Aman and 20 from Boro season were selected from OT, 18 entries for T. Aman and nine entries for Boro were selected from PYTs. Nine genotypes for T. Aman and eight genotypes for Boro were selected from SYTs. Two genotypes IR78761-B-SATB1-28-3-24 and IR78761-B-SATB1-28-3-26 were selected from ALART and recommended for proposed variety trial (PVT). Two genotypes BR7100-R-6-6 and IR78794-B-Sat29-1 were evaluated by National Seed Board (NSB) team and BR7100-R-6-6 released as BRRI dhan67 for salt tolerant Boro variety which produced 5.98 t/ha yield with 143 days growth duration (Table 2). Figure 1 shows water salinity levels of different experimental plots under PVT. Five genotypes IR66946-3R-149-1-1, IR78761-B-SATB2-17-1, IR73055-8-1-1-3-1,

Table 2. Performance of the proposed variety at saline prone, Boro 2013-14.

Designation	Plant ht (cm)*	Growth duration (day)*	Grain yield (t/ha)*	Grain characteristic					
				Head rice yield (%)	LB ratio	Size and shape	Elongation ratio	Protein (%)	Amylose (%)
BR7100-R-6-6 (BRRI dhan67)**	100	143	5.98	71.1	2.8	Medium slender	1.3	8.8	24.0
BRRI dhan47 (ck)	105	144	5.48	44.2	2.0	Medium bold	1.4	7.3	27.5

*Mean of 10 locations (Dakope; Paikgacha; Batiaghata, Khulna;Debhata; Tala; Ashasuni; BRRI, Satkhira; Sonagazi, Feni; Patharghata, Borguna; Nazirpur, Pirojpur). **NSB has released it as BRRI dhan67 on 20 November 2014.
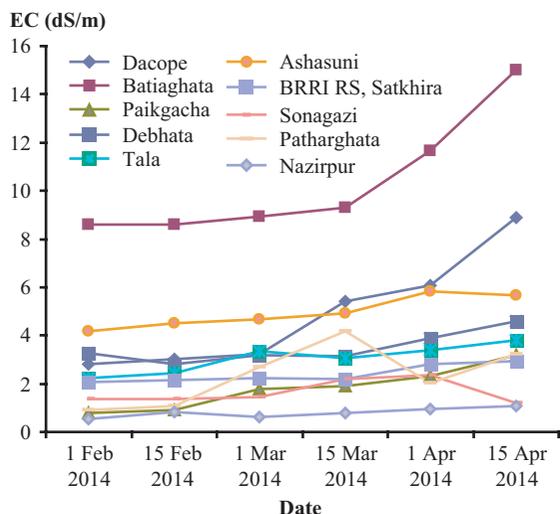
Fig. 1. Water salinity levels of different experimental plots (PVS).

IR78761-B-SATB1-68-6 and IR83440-4-B-11-2-1-1-AJY1-B in T. Aman and four genotypes IR83484-3-B-7-1-1-1, IR86385-117-3-1-B, IR86385-117-1-1-B and IR84649-308-7-1-B-AJY1-B in Boro were preferred and selected through PVS by the farmers which showed consistency with the yield performances. PVS and validation trials were conducted under IAPP (breeding-salinity) at Borguna and Patuakhali during Aus, T. Aman and Boro seasons. Based on the farmers' preference, Mala (Local) at three locations, BRRI dhan28 at two locations, BRRI dhan47 and BRRI dhan55 at one location in Aus, BRRI dhan52 at five locations, BRRI dhna41 at three locations, BRRI dhan53 at two locations, BR11-Saltol and BRRI dhan54 in one location in T. Aman, and BRRI dhan58 at four locations, BR7100-R-6-6 at three locations, BRRI dhan29 and BINA dhan10 at two locations, BRRI dhan47

and BRRI dhan61 at one location in Boro were selected by farmers through PVS.

Premium quality rice (PQR). Efforts were made to develop aromatic and non-aromatic fine quality rice with national (Kalizira/Chinigura type) and international (Basmati/Banglamati type) standards for domestic use and export. Experiments were conducted in T. Aman and Boro season. In T. Aman, 18 crosses were made, seven crosses were confirmed, 1411 plant progenies and 202 fixed lines were selected from segregating population. Forty-three genotypes were selected from OT, 40 genotypes were selected from PYT, three genotypes were selected from SYT, four genotypes were selected from RYT and BR7357-11-2-4-1-1 performed better in ALART and this genotype was selected for proposed variety trial.

In Boro, 21 crosses were made, 19 crosses were confirmed, 1627 plant progenies and 19 fixed lines were selected from segregating population. Twenty-three genotypes were selected from OT, four genotypes were selected from PYT, five genotypes were selected from SYT, two genotypes were selected from RYT. One promising genotype, BR7358-30-3-1 with average yield 7.4 t/ha and growth duration of 149 days was selected and recommended as a variety named BRRI dhan63 (Table 3).

Favourable Boro rice. The project emphasizes for developing improved genotypes with high yield potential, earliness and acceptable grain quality for irrigated ecosystem in Bangladesh. A total of 22 crosses were made and 17 crosses were confirmed. In total 483 individual plants were selected from 11crosses of 13 F_2 population and 1,791 progenies and 51 fixed lines were selected from pedigree generations. Seven uniform advanced lines yielding from 7.03 to 9.24

Table 3. Performance of the proposed variety for exporting quality rice, Boro 2012-13.

Designation	Plant ht (cm)*	Growth duration (day)*	Grain yield (t/ha)*	Grain characteristic					
				Head rice yield (%)	LB ratio	Size and shape	Elongation ratio	Protein (%)	Amylose (%)
BR7358-30-3-1 (BRRI dhan63)**	86	149	7.4	76	3.7	Extra long slender	1.4	8.2	24.0
BRRI dhan50 (ck)	83	155	6.5	67	3.4	Long slender	1.2	8.0	24.0

*Mean of nine locations (Mymensingh, Comilla, Rajshahi, Rangpur, Habiganj, Kushtia, Satkhira, Bhanga, Sonagazi). **NSB has released it as BRRI dhan63 on 20 August 2014.

t/ha were selected from OT. Twenty- two advanced breeding lines showing significantly higher yield than the check variety coupled with similar or shorter growth duration were selected for further evaluation. BR7830-16-1-5-3 was selected from RYT based on their yield and growth duration. National Seed Board (NSB) approved the recommendation of Technical Committee to release BRRI dhan68 for Boro season that yielded 7.3 t/ha with 150 days growth duration (Table 4).

Cold tolerant rice. The major objective of the project was to develop high yielding rice varieties tolerant to cold injury by introgressing cold tolerant gene(s). Forty-four crosses were made. Twenty-four crosses were confirmed as true F_1. In total 472 individual progenies were selected from F_2 populations In total, 485 individual progenies were selected from F_4-F_8 populations. Twenty-six genotypes were selected from OT. In PYT, two genotypes BR8445-54-6-7 and BR8445-54-6-6 gave 0.6 t/ha yield advantage over BRRI dhan28 and was selected for further trial. In RYT, IR77496-31-2-1-3-1 was the highest yielder in nine locations followed by BR8245-2-1-4 and BR7812-19-1-6-1-p4. BR7813-1-1-3-1 yielded 0.5 t/ha higher than BRRI dhan28 with almost similar growth duration. Though IR77496-31-2-1-3-1 and BR7812-19-1-6-1-p4 gave similar growth duration

to BRRI dhan55 but yielded higher (0.2 to 0.4 t/ha) than the check variety (BRRI dhan55). Since all these materials were found tolerant to cold stress at seedling stage and were selected for further evaluation under on farm condition. Under IAPP cold programme, in PVS trial, BR7812-19-1-6-1-P2, BR7812-19-1-6-1-P4 and BR7813-1-1-3-1 had almost similar yield and growth duration of BRRI dhan55, which is a moderately cold tolerant rice variety. Another genotype, IR77496-31-2-1-3-1 yielded similar to BRRI dhan28 but matured five days later. In experiment of evaluation of CS1 pedigree nurseries for cold tolerance at seedling stage, 66 progenies were selected from 869 progenies. The leaf discoloration scores (LD) and % survivability of the selected progenies ranged from three to five and 6.5 to 77.27%. Importantly, F_2 mapping population were developed using one BRRI variety viz BR18 (source of cold tolerance). After screening using cold water treatment, 100 progenies (comprising most tolerant and most susceptible) were selected for genotyping based on LD scores, % survivability and % recovery after removal of cold stress.

Low amylose rice. Development of high yielding indica rice variety with low amylose content for domestic use particularly for ethnic people and export were the objectives of the

Table 4. Performance of the proposed variety at on farm trial, Boro 2013-14.

Designation	Plant ht (cm)*	Growth duration (day)*	Grain yield (t/ha)*	Grain characteristic					
				Head rice yield (%)	LB ratio	Size and shape	Elongation ratio	Protein (%)	Amylose (%)
BR7830-16-1-5-3 (BRRI dhan68)**	97.0	150	7.3	67	2.6	Long bold	2.5	7.7	25.7
BRRI dhan28 (ck)	95.0	144	6.4	84.0	3.2	Long slender	1.5	8.1	27.0

*Mean of nine locations (Gazipur, Mymensingh, Faridpur, Barisal, Sonagazi, Habiganj, Satkhira, Rangpur, Rajshahi). **NSB has released it as BRRI dhan68 on 20 November 2014.

programme. In pedigree nursery, 387 individual progeny comprising 88 from F_6 and 514 from F_7 generation and 17 bulk lines were selected. From observational trial, five genotypes were selected based on growth duration, yield, and homogeneity in morpho-agronomic traits for preliminary yield trial.

Micronutrient enriched rice (MER). The main objectives of the programme were to develop high yielding rice varieties with improved nutritional quality in term of high iron and zinc content in polished grain. Fifty-five single crosses and 14 back, top and three-way crosses in T. Aman and 111 single crosses and 13 backcrosses in Boro season were made. Total 47 and 36 crosses were confirmed as true F_1s in T. Aman and Boro season respectively. In total 2,560 progenies were selected from F_2 population. From pedigree nurseries, 1215 and 1,646 individual progenies were selected in T. Aman and Boro season respectively. Also, 122 fixed rows were bulked from advanced segregating generation. A total 38 uniform entries in T. Aman season and 43 uniform entries in Boro season were selected based on yield advantage, growth duration and zinc content in brown rice from OT for further evaluation in replicated trial. Also, 295 individual plants in T. Aman and 394 in Boro were selected from OT for further evaluation. In T. Aman season, 16 genotypes and in Boro season 36 genotypes were selected from preliminary yield trial considering yield advantage of at least 0.5 t/ha over check varieties, growth duration and zinc content; while 16 genotypes from SYT were selected for regional trial. Two lead genotypes in terms of yield advantage (0.4 to 0.8 t/ha) with more or less similar growth duration were selected from RYT in Boro season for conducting adaptive trials in farmers' field. The Zn enriched genotype BR7840-54-1-2-5 was selected and recommended as a variety named BRRI dhan64 which produced 6.0 t/ha grain yield with 155 days growth duration (Table 5).

Development of 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-eight crosses for T. Aman and 38 crosses for Boro season were made. Four and seven crosses were confirmed in T. Aman and Boro seasons, 422 progenies in T. Aman from F_2 populations, 790 progenies (521 for BPH and GM in T. Aman season and 269 for BPH in Boro season) and 30 fixed lines for BPH and GM in T. Aman season were selected from pedigree nursery. Twenty-five lines from OT, seven lines from PYT, three lines from SYT and four lines from AYT were selected showing resistance to BPH and GM in T. Aman season. Eighteen lines from OT, eight lines from PYT, six lines from SYTs and four lines from AYT were selected showing resistance to BPH in Boro season.

Disease resistant rice. Efforts were made for developing varieties resistant to bacterial leaf blight (BB), rice tungro virus (RTV) and blast diseases. Twenty-eight for BB and six crosses for blast in T. Aman and 22 crosses for BB in Boro season were made. Ten crosses for BB and six for blast during T. Aman were confirmed as true F_1. Ninety-six resistant progenies (60 for BB and 36 for blast) were selected in T. Aman season from F_2 population. Ninety-five superior progenies from F_4 generation for BB, 184 for blast from F_3 and F_4 generation and 11 for RTV from F_3 generation were selected in T. Aman, whereas 215 superior progenies from F_3-F_4 generations were selected for BB during Boro season. Seventy-nine fixed lines were isolated from F_5-F_7 generations for BB, seven fixed lines for blast and nine fixed lines from F_3 and F_6 generations for RTV during T. Aman season, while 12 fixed lines were isolated from F_7 generation for BB during Boro season. From OT, two homogenous lines for BB and single line for blast in T. Aman, while four entries for BB during Boro season showed better yield potential and agronomic performance over the check varieties. From PYT, four genotypes BR8216-14-1-2-2, BR8216-14-1-3-1, BR8216-29-1-2-2 and BRC245-4-19-2-1 yielded higher than the check varieties BRRI dhan39 and BRRI dhan49 with almost similar growth duration during T. Aman season. Three entries for BB were selected from PYT during Boro season. Three breeding lines for both BB and blast and four lines for RTV in T. Aman season were selected from SYT. Four genotypes for BB were selected from AYT during T. Aman season. Four lines such as BR7986-2-3, BR7986-29-4, BR7806-18-12 and BR7986-7-4 were selected for BB from RYT during Boro season.

Table 5. Performance of the proposed variety at on farm trial, Boro 2012-13.

Designation	Growth duration (day)*	Plant ht (cm)*	Grain yield (t/ha)*	Grain characteristic						
				Head rice yield (%)	LB ratio	Size and shape	Elongation ratio	Protein (%)	Amylose (%)	Zn content in polished rice (mg/kg)
BR7840-54-1-2-5 (BRRI dhan64)**	155	110	6.0	91.1	2.0	Medium bold	1.4	7.2	26.0	24.0
BRRI dhan28 (ck)	149	95	6.1	84.0	3.2	Long slender	1.5	8.1	27.0	16.8
LSD (0.05)	-	-	0.2							

*Mean of eight locations (Gazipur, Bhanga, Mymensingh, Rangpur, Rajshahi, Terokada, Sonagazi, Habiganj). **NSB has released it as BRRI dhan64 on 20 August 2014.

Submergence and water stagnation tolerant rice. The project was aimed at 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. In total, eight single crosses were made. Nine crosses were selected and confirmed as true F_1s. Pedigree generations were grown under controlled submergence and medium stagnant water condition of BRRI RS, Rangpur and BRRI HQ, Gazipur. A total of 286 progeny rows from F_2-F_7 and backcross generations, 19 homozygous populations from BC_2F_8 and BC_1F_9 generations were selected and preserved. In Marker-Assisted Selection, 15 BC_4F_4 plants having fixed *Sub1* QTL from the BRRI dhan33*4/BRRI dhan52, 12 BC_5F_3 plants from BRRI dhan44*5/BRRI dhan52 and 15 BC_5F_3 plants from BRRI dhan49*5/BRRI dhan52 were selected through foreground selection and depending upon yield and phenotypic acceptance. In case of producing BRRI dhan39-*Sub1*, 12 plants were selected following foreground+phenotypic selection approach and totally 746 BC_4F_1 seeds were produced while for producing BR22-*Sub1*, six backcross segregants were selected following the same approach and totally 441 BC_3F_1 seeds were produced. In total, 28 entries were selected from four observational trials depending on yield, survivability under controlled submergence and growth duration. In PYT conducted under both submergence and rainfed conditions, five genotypes were selected while in PYT conducted under stagnant water stress, five genotypes were selected based on yield and growth duration. In PVS trial conducted under controlled submergence

condition at BRRI HQ, Gazipur the genotype BR7937-28-1 got the highest votes followed by IR10F365 while BRRI dhan51 and BRRI dhan33 got the lowest votes. In submergence screening, 12 genotypes were found non-elongating type with survivability score 3. However, four genotypes namely Pathor nuti, Sada dangr boro, Jalda irri and Atshotti were found with good recovery status and might be used for further study. In validation trial, BRRI dhan52 produced the highest grain yield 5.5 t/ha

Drought tolerant rice. The project emphasizes for developing high yielding rice varieties tolerant to drought stresses in the rainfed lowland rice ecosystem in Bangladesh. Experiments were conducted in T. Aman and Boro seasons. In total, 22 crosses were made, 16 crosses were confirmed and 1976 plant progenies were selected from segregating population. In OYT 60 genotypes performed better than the local and international checks in respect to yield under stress condition at the reproductive stage. From AYT 19 genotypes were selected based on yield with 100-120 days growth duration. In PVS trial at two locations, IR82635-B-B-75-2, IR10L276 and IR82870-48 secured 1st, 2nd and 3rd positions in preference ranking score by farmers. Two genotypes selected from ALART performed better than the others. In PVT, IR82635-B-B-75-2 has been recommended as a drought tolerant variety which produced 4.02 t/ha yield with 113 days growth duration (Table 6). In validation trial, IR82635-B-B-75-2 and IR82589-B-B-84-3 produced better yield than the check variety BRRI dhan56 in the farmers' field of Rangpur.

Rice varieties using low water under irrigated ecosystem. The objective of the project

Table 6. Performance of the proposed variety under drought prone area, T. Aman, 2013-14.

Designation	Growth duration (day)*	Grain yield (t/ha)*	Grain characteristic					
			Head rice yield (%)	LB ratio	Size and shape	Elongation ratio	Protein (%)	Amylose (%)
IR82635-B-B-75-2 (BRRI dhan66)**	113	4.02	59.2	2.7	Medium bold	1.4	10.8	23.0
BRRI dhan56 (Ck)	110	3.23	57.7	2.7	Medium bold	1.3	8.4	23.0

*Mean of 10 locations (Godagari; Tanore, Rajshahi; Gomostapur, Chapainobabganj; Pursha; Neamotpur, Naogaon; Rangpur sadar; Nilphamari sadar; lalmonirhat sadar; Fulbari, Dinajpur; Gazipur sadar). **NSB has released it as BRRI dhan66 on 20 November 2014.

was to develop rice varieties suitable for low water requirement during Boro season. The growth duration of the four genotypes including standard check BRRI dhan28 was ranged from 144-154 days. All the genotypes including the check variety have similar growth duration (around 147 days). All the genotypes produced higher yield of around 7.2 tons which was more or less similar with the check variety BRRI dhan28. The genotype PSBRC82 gave 0.4 ton higher yield than the check variety which showed lodging tolerance in all the locations.

Screening and testing of improved Aus rice genotypes suitable for aerobic soil condition. Efforts were made to select improved Aus rice varieties/genotypes having high yield, shorter growth duration and deep rooting ability for growing aerobic soil condition under KGF-BRRI project. Eleven crosses were made. From OT among the tested entries, IR 87529-6-1-2-1 and IR 91051-122-1-2-3 were selected for their higher yield (4.27-4.62 t/ha) and with shorter growth duration (101-108 days) under direct seeded aerobic conditions. In PYT, among the tested entries, four top ranking varieties (IR91006-88-1-3-1, IR84788-40-3-3-1-1, IR90228-1-3-3-3-2 and IR92240-40-2-2-1) in respect to yield (3.60-4.10 t/ha), with shorter growth duration (105-109 days) under direct dry seeded conditions were selected. From SYT, among the tested entries, five top ranking varieties (BR7182-2B-1-HR4, BR7178-2B-19-10, BR6855-3B-12, BR6848-3B-12 and BI dhan-5) in respect to yield (3.55- 4.50 t/ha) with shorter growth duration (97-101 days) and better phenotypic acceptance in two locations were selected for PVS trial.

Green super rice (GSR). The project was aimed at developing high yield potential inbred rice

variety. In T Aman season, twelve genotypes were selected on the basis of yield, plant type, grain quality, homogeneity and other agronomic traits from OT. From PYT (1, 2 and 3) 21 genotypes were selected and no genotypes was selected from SYT and RYT. In PVT, HUA565 gave higher yield (4.29 t/ha) than the standard check (3.95 t/ha) and the growth duration was similar to check. So, the genotype was suggested to retrial by NSB. In Boro season, 12 fixed genotypes were selected as compared to the check variety. From PYT, six genotypes were selected and from SYT, five genotypes were selected. In RYT, the genotypes HHZ5-SAL10-DT1-DT1 (7.4 t/ha), IR83142-B-60-B (6.9 t/ha) and HUANGHUAZHAN (6.8 t/ha) were selected. In PVT, Boro 2013-14, weed tolerant rice gave higher yield (7.3 t/ha) than the standard check BRRI dhan28 (6.4 t/ha). Therefore, the genotype was selected to recommend as a new variety (BRRI dhan69) during Boro season (Table 7).

Arsenic (As) tolerant rice. Efforts were made for developing high yielding rice varieties tolerant to arsenic/reduced uptake in grain. A total of 40 crosses were made using different potential donors for arsenic phytotoxicity tolerance. In total, 440 individual progenies were selected from 4 F_2 population raised at BRRI HQ, Gazipur and BJRI Faridpur. HHZ19-DT16-DT1-DT1 was selected for further evaluation based on less reduction in grain yield at high soil and water arsenic of high arsenic site, BJRI Faridpur compared to arsenic free site at Gazipur. Also, four genotypes HHZ12-SAL8-Y1-Y2, HHZ5-Y3-SAL2-SUB1, HHZ5-SAL8-DT2-SAL1 and HHZ8-SAL9-DT2-Y2 were selected from OT for further evaluation. In a dose response validation study, 1.25 ppm arsenic in hydroponic culture was found very effective in discriminating

Table 7. Performance of the proposed variety at on farm trial, Boro 2013-14.

Designation	Plant ht (cm)*	Growth duration (day)*	Grain yield (t/ha)*	Grain characteristic					
				Head rice yield (%)	LB ratio	Size and shape	Elongation ratio	Protein (%)	Amylose (%)
Weed tolerant rice (BRRI dhan69)	105	153	7.3	87.9	2.4	Medium bold	1.3	7.8	17.0
BRRI dhan28 (ck)	95	144	6.4	84.0	3.2	Long slender	1.5	8.1	27.0
LSD (0.05)	5.1	7.5	0.7						

*Mean of nine locations (Gazipur, Mymensingh, Faridpur, Barisal, Sonagazi, Habiganj, Satkhira, Rangpur, Rajshahi). **NSB has released as BRRI dhan69 on 20 November 2014.

varieties for their response to arsenic phyto-toxicity in terms of root length reduction, shoot length reduction and root-shoot biomass reduction. Four F_5 mapping population comprising 1,369 progenies were developed conferring arsenic phyto-toxicity tolerance. Around 54% polymorphism was found from a parental survey with a subset of 175 SSR markers that were intended to be used in mapping QTLs from a $F_{2:3}$ mapping population of BRRI dhan45 × BRRI dha47.

High beta-carotene rice (Golden Rice). The main objective of the programme was development, introgression and evaluation of transgenic golden rice enriched with beta-carotene, the precursor of vitamin A. Twenty-two BC_3F_8 and BC_4F_3 backcross introgression lines of BRRI dhan29 Golden Rice (event GR2-R) along with transgenic control (GR2-R) and wild type control (BRRI dhan29) were evaluated at Gazipur. The introgression lines showed a wide range of variation in grain yield and other ancillary traits. The grain yield ranged from 3.4 t/ha to 6.5 t/ha with an average value of 5.4 t/ha. Growth duration differed from 138 days to 149 days. However, BRRI dhan29 yielded 5.8 t/ha and growth duration at 149 days. Seven lines were selected considering similar or higher yield than the non-transgenic control, BRRI dhan29. These lines showed up to 12 % yield advantage over BRRI dhan29. Total carotenoid (ug/g) at three months after harvest in the selected lines ranged from 8.1 to15.5 ug/g. No unusual disease infection was observed in the transgenic plots. However BLB was 1 to 5% BLB was observed in all the entries including non-transgenic BRRI dhan29. Among the major insects pest, only leaf folder and stem borer infestation was observed. However, level of infestation was below the economic threshold level (ETL) both in

vegetative and reproductive stage of the test entries including BRRI dhan29. Soil analysis at pre-planting and post harvest showed no significant difference in the microbial population in the transgenic plots indicating no detrimental or harmful effect on soil microbes as well as soil fertility for wetland rice cultivation. Regular monitoring for unusual or abnormal plant development, survivability of volunteers or ratoons did not show any aggressiveness or weediness of the transgenic golden rice.

Pyramiding salinity and submergence tolerant genes (NATP)
The objective of the project was introgression of *SUB1* and *Saltol* QTL into the genetic background of BRRI dhan49 through marker-assisted backcrossing. Out of 403 microsatellite (SSR) markers, 96 markers (24%) were found polymorphic between BRRI dhan49 and FL478. Five BC_2F_1 best plants were selected possessing *Saltol* QTL using RM493 as foreground marker over 56 background markers covering whole genome. Recurrent parent genome recovery of the selected plants ranged from 48 to 89.6%. Selected 5 BC_2F_1 best plants were self-pollinated to produce BC_2F_2 seeds with the background of BRRI dhan49.

International Network for Genetic Evaluation of Rice (INGER)
This programme focused on sharing germplasm and breeding lines through international platform for the acceleration of rice improvement. In total 87 germplasms were selected from ten INGER nursery sets for using in the breeding programme either as parents or for directly using in the yield trials.

Biotechnology Division

SUMMARY

Biotechnology Division conducted 11 experiments under four projects in the reporting period. To make BRRI dhan29 drought and salt tolerant, *TPSP* gene was transferred in it through *Agrobacterium*-mediated transformation. Using PCR analysis we confirmed three putative transformants in T_1 generation and harvested T_2 seeds for further evaluation. In another study, *GlyI* and *GlyII* genes were introduced into BRRI dhan29 to make it salt tolerant through *Agrobacterium*-mediated genetic transformation. Four putative transformants were confirmed in T_2 generation by PCR analysis and T_3 seeds were harvested for further evaluation. For developing modern rice variety through anther culture 28 different crosses were made and 3,433 F_1 seeds were harvested from those crosses. In total, 31 green plantlets were regenerated from the hybrid anthers of three crosses. Genotyping of mapping population of BRRI dhan28/*Oryza rufipogon* (Ac. no. 105890) has been completed for QTL analysis. We evaluated some backcrossed materials developed through high yield enhancing QTL study as OTs and selected 56 promising advanced materials from them on the basis of phenotypic appearance and yield performance. Three bacterial blight pyramided lines were evaluated as OT and two lines were selected after both molecular analysis and bacterial inoculation with BXo9. Twenty-six homozygous advanced lines having *SUB1* QTLs were evaluated as OT with standard checks. Among them, 13 lines were selected for further evaluation. Fifty-two anther culture derived advanced breeding materials were evaluated in three OTs with standards checks in T. Aman 2013. Sixteen materials from them were selected for further evaluation. On the other hand, 122 anther culture derived advanced breeding materials were evaluated in five OTs during Boro 2013-14 with standard checks and 47 materials were selected for further evaluation. Sixteen anther culture derived advanced lines were evaluated as PYT with standard checks. Among them 10 entries were selected for further evaluations. A total of 99 homozygous lines were bulked from 383 pedigree lines during T. Aman 2013. On the other hand, in Boro 2013-14 season, 225 plants were selected and 25 homozygous lines were bulked from 178 pedigree lines.

DEVELOPMENT OF RICE VARIETY THROUGH TISSUE CULTURE

Development of rice variety through anther culture
Twenty-two F_1 populations (Table 1) were grown in the net house under optimum management. A total of 60,339 hybrid anthers of 22 F_1 crosses were plated in KE medium for callus induction. A total of 330 calli were obtained from all the crosses. The highest (73) and the lowest (2) numbers of calli were obtained from hybrid anthers of BRRI dhan29/MR219 and BR6157-R1-1/BRRI dhan29 respectively (Table 1). Calli obtained from induction medium were transferred into the regeneration medium. Two, 26 and three green plantlets were regenerated from the hybrid anther of BRRI dhan29/MR219, BRRI dhan29/FL478 and MR219/IRBB60 respectively (Fig. 1). After hardening, green plantlets were transferred into the earthen pots and kept until maturity.

FIELD PERFORMANCE OF TISSUE CULTURE DERIVED LINES

Hybridization
Hybridization was done to generate F_1s for anther culture. Twenty-eight crosses were made for aromatic fine grain, high yield potential, salinity tolerance, cold tolerance, low GI and short duration. In total 3,433 F_1 seeds were harvested from 28 different crosses (Table 2).

Progeny selection
Progeny selection was carried out to select the best progenies with high yield and salinity tolerance. A total of 383 and 178 pedigree lines were grown during T. Aman 2013 and Boro 2013-14 seasons respectively. During T. Aman 2013 a total of 99 homozygous lines were bulked from 383 pedigree lines. A total of 225 plants were selected and 25 homozygous lines were bulked from 178 pedigree lines for further evaluation in 2013-14.

Table 1. Callus induction and regeneration of hybrid anther of 22 crosses.

Designation	No. of anther plated	No. of calli obtained	No. of plant regenerated
BRRI dhan29/MR219	5043	73	2 green plants
BRRI dhan29/IRBB60	3057	6	
BRRI dhan29/IRBB65	255	10	
BRRI dhan29/FL478	4508	50	26 green plants
MR219/FL478	3326	13	1 albino plant
MR219/IRBB60	249	15	3 green plants
BRRI dhan29/Lalmota//BR11*2	439	10	1 albino
BR11/Lalzarmota//BRRI dhan29*2	7101	9	1 albino
MR219/ BRRI dhan29	1481	4	
BR11/FL378	1607	5	
BR16/Kanaklata	3537	31	1 albino
Kanaklata/BR16	2629	12	
BRRI dhan29/BRRI dhan40	3990	10	
MR219/Kanaklata	1062	33	
O.nivara/BR11	1648	9	
BR4909-R1-R2/BRRI dhan40	10454	4	
BRRI dhan29/kanaklata	4948	13	
BRRI dhan29/BR16	2602	7	
BR6157-R1-1/BR6158RWBC$_2$-1-2-1-1-1	692	8	
BRRI dhan29/BRRI dhan49	218	3	
BR6157-R1-1/BRRI dhan29	390	2	2 albino
BR4909-R1-1/BRRI dhan47	1103	3	
Total	60339	330	31 green plants

Table 2. List of crosses for anther culture.

Cross	No. of F_1 seeds	Remark
BR11×Biroi	40	Aromatic and fine grain with high yield
Biroi ×BR11	150	
BRRI dhan50/Bashful	63	
BRRI dhan50/Tepi boro	133	
BRRI dhan28/Tepi boro	36	
Chinigura/BRRI dhan28	21	
BRRI dhan29/Tepi boro	375	
BRRI dhan28/BRRI dhan61	267	Salt tolerant and high yield
BRRI dhan28/FL478	168	
BRRI dhan29/FL478	161	
BRRI dhan29/BRRI dhan61	228	
BRRI dhan61/FA\L478	151	
MR219/BR17	72	Cold tolerant and high yield
BRRI dhan28/BR17	32	
BRRI dhan29/BR17	71	
BR17/MR219	201	
BR17/BRRI dhan29	95	
BR17/BRRI dhan28	4	
MR219/BR16	277	Low GI and high yield
BRRI dhan29/BR16	169	
BR16/MR219	163	
BRRI dhan28/Kanaklata	83	
MR219/Kanaklata	93	
BR16/Kanaklata	185	
BRRI dhan29/Kanaklata	89	
NERICA7/BRRI dhan55	37	Short duration and high yielding Aus
BRRI dhan55/NERICA7	26	
NERICA7/BRRI dhan48	43	
Total	3433	

Fig 1. Anther culture derived green plants from BRRI dhan29/FL478 in net house.

Observational trials (OT)

Fifty-two anther culture derived advanced breeding materials were grown in three OTs with standards checks to select agronomically desirable and high yield potential materials in T. Aman 2013. Further more 16 advanced breeding lines were selected depending on the duration and comparable yield with checks (Tables 3, 4 and 5 and Figs. 2 and 3). During Boro 2013-14, 122 advanced breeding materials were grown in five OTs with standard checks and 58 advanced breeding lines were selected depending on the duration and comparable yield with checks (Tables 6, 7, 8, 9 and 10).

Preliminary yield trial (PYT)

Preliminary yield trial was carried out to initial evaluation of agronomically desirable and high yield potential anther culture derived lines. During Boro 2013-14 season seven and eight anther

Table 3. Agronomic characteristics of anther culture derived materials during T. Aman 2013 (OT-1).

Designation	Plant ht (cm)	Growth duration (day)	Yield (t/ha)
BR8018-AC2-2-2-1	115	126	5.16*
BR8019-AC3-1-1-1	116	129	5.18*
BR8019-AC4-1-1-3	123	129	5.67*
BR8019-AC5-1-2-1	97	126	5.32*
BR8019-AC8-1-2-2	99	125	5.20*
BR8019-AC9-3-3-1	97	124	5.41*
BRRI dhan40 (ck)	126	140	5.44
BRRI dhan41 (ck)	127	141	5.65
BRRI dhan54 (ck)	118	129	5.95

Sixteen entries were evaluated and six entries were selected. *=Selected.

Table 4. Agronomic characteristics of anther culture derived materials during T. Aman 2013 (OT-2).

Designation	Plant ht (cm)	Growth duration (day)	Yield (t/ha)
BR8032-AC3-4-1-3	101	123	4.58*
BR8032-AC4-1-2-2	101	120	4.65*
BR8033-AC1-1-2-1	123	127	4.76*
BR8033-AC3-3-2-3	134	133	5.15*
BR8033-AC7-3-1-3	120	126	4.77*
BRRI dhan40 (ck)	127	147	5.23
BRRI dhan41 (ck)	132	149	4.47
BRRI dhan54 (ck)	122	130	5.52

Twenty-nine entries were evaluated and five entries were selected.*=Selected.

Table 5. Agronomic characteristics of anther culture derived materials during T. Aman 2013 (OT-3).

Designation	Plant ht (cm)	Growth duration (day)	Yield (t/ha)
BR8017-AC4-2-1-2	117	132	5.47*
BR8036-AC2-2-2-2	132	131	5.35*
BR8036-AC3-2-2-3	129	125	5.04*
BR8036-AC2-1-2-1	126	127	5.46*
BR8036-AC6-2-2-1	103	127	4.96*
BRRI dhan40 (ck)	118	149	5.35
BRRI dhan41 (ck)	121	140	5.25
BRRI dhan54 (ck)	116	128	4.90

Seven entries were evaluated and five entries were selected. *=Selected.

Fig. 2. Selected material from OT-2; BRRI dhan28 × *O. rufipogon* (Acc no. 105890); yield-7.29 t/ha and growth duration-148 days.

Fig. 3. Selected material from OT-3; BRRI dhan29 × *O. rufipogon* (Acc no. 103404); yield- 8.67 t/ha and growth duration-157 days.

Table 6. Agronomic characteristics of wide crossed materials during Boro 2013-14 (OT-4).

Designation	Plant ht (cm)	Growth duration (day)	Yield (t/ha)
BR9787-BC2-3-6-2	99	149	7.28*
BR9787-BC2-8-7-1	101	149	6.78*
BR9787-BC2-16-3-1	92	147	6.56*
BR9787-BC2-35-4-2	94	153	6.91*
BR9787-BC2-41-3-2	94	149	7.17*
BR9787-BC2-41-8-2	98	146	6.45*
BR9787-BC2-43-6-1	99	145	6.91*
BR9787-BC2-44-7-1	98	149	7.06*
BR9787-BC2-48-4-1	99	150	6.81*
BR9787-BC2-51-9-1	98	151	6.87*
BR9787-BC2-53-4-1	102	151	7.19*
BRRI dhan28 (ck)	95	145	6.12
BRRI dhan29 (ck)	100	157	7.20

Twenty-one entries were evaluated and eleven entries were selected. *=Selected.

Table 7. Agronomic characteristics of wide crossed materials during Boro 2013-14 (OT-5).

Designation	Plant ht (cm)	Growth duration (day)	Yield (t/ha)
BR9787-BC2-63-2-2	100	149	7.20*
BR9787-BC2-63-2-4	98	148	7.29*
BR9787-BC2-102-1-4	96	153	7.28*
BR9787-BC2-119-1-6	115	148	6.47*
BR9787-BC2-127-1-5	98	148	6.55*
BR9787-BC2-173-1-3	98	147	7.39*
BR9787-BC2-203-1-3	89	149	6.69*
BRRI dhan28 (ck)	98	146	6.31
BRRI dhan29 (ck)	102	158	7.27

Fourteen entries were evaluated and seven entries were selected. *=Selected.

Table 8. Agronomic characteristics of wide crossed materials during Boro 2013-14 (OT-6).

Designation	Plant ht (cm)	Growth duration (day)	Yield (t/ha)
BR9786-BC2-2-1-1	93	159	8.70*
BR9786-BC2-9-1-2	102	157	8.11*
BR9786-BC2-15-2-2	99	156	7.74*
BR9786-BC2-15-2-3	100	156	7.94*
BR9786-BC2-16-1-1	104	157	8.14*
BR9786-BC2-16-1-2	105	157	7.92*
BR9786-BC2-49-1-2	102	157	8.16*
BR9786-BC2-59-1-2	103	157	7.84*
BR9786-BC2-98-1-1	102	145	6.78*
BR9786-BC2-98-1-2	101	148	7.01*
BR9786-BC2-115-2-1	97	159	8.03*
BR9786-BC2-119-1-1	105	157	8.67*
BR9786-BC2-122-1-3	102	157	7.76*
BR9786-BC2-124-1-1	101	156	7.99*
BR9786-BC2-124-1-2	94	158	8.20*

Table 8. Continued.

Designation	Plant ht (cm)	Growth duration (day)	Yield (t/ha)
BR9786-BC2-124-1-5	98	158	8.25*
BR9786-BC2-127-2-3	98	158	8.14*
BR9786-BC2-132-1-3	106	155	8.17*
BR9786-BC2-135-4-1	96	156	8.44*
BR9786-BC2-135-4-3	95	158	8.17*
BR9786-BC2-139-2-3	98	157	8.54*
BR9786-BC2-139-3-2	97	157	8.20*
BR9786-BC2-142-1-1	102	158	8.08*
BRRI dhan28 (ck)	92	142	6.60
BRRI dhan29 (ck)	101	159	7.99
BRRI dhan55 (ck)	98	147	7.21

Fifty-two entries were evaluated and twenty three entries were selected. *=Selected.

Table 9. Agronomic characteristics of wide crossed materials during Boro 2013-14 (OT-7).

Designation	Plant ht (cm)	Growth duration (day)	Yield (t/ha)
BR9785-BC2-9-2-3	113	143	7.01*
BR9785-BC2-6-2-2	105	141	6.98*
BR9785-BC2-19-3-1	118	144	7.45*
BR9785-BC2-20-1-3	104	140*	7.65*
BR9785-BC2-6-2-1	103	141	7.15*
BR9785-BC2-27-1-1	99	141*	7.52*
BR9785-BC2-27-1-2	100	140	6.86*
BR9785-BC2-27-1-3	103	142	7.99*
BR9785-BC2-27-1-4	100	141	7.17*
BR9785-BC2-19-3-5	102	143	7.38*
BR9785-BC2-62-2-2	102	143	8.25*
BR9785-BC2-76-2-1	109	145	7.41*
BR9785-BC2-110-1-2	114	146	7.28*
BR9785-BC2-110-1-3	118	147	7.65*
BR9785-BC2-147-3-1	111	147	7.10*
BRRI dhan28 (ck)	100	141	6.40
BRRI dhan29 (ck)	99	161	7.04
BRRI dhan55 (ck)	102	146	6.74

Thirty-two entries were evaluated and fifteen entries were selected. *=Selected.

Table 10. Agronomic characteristics of bacterial blight pyramided lines during Boro 2013-14 (OT-8).

Designation	Plant ht (cm)	Growth duration (day)	Yield (t/ha)
BR8333-BC5-1-1	90	152	6.46*
BR8333-BC5-3-8	94	153	6.69*
BR8333-BC5-5-11	96	155	6.57
BRRI dhan29	98	157	6.68
IRBB60	74	151	5.08
Purbachi	88	146	5.70

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

culture derived advanced breeding lines along with two standard checks were evaluated as PYT-1 and PYT-2 respectively. On the basis of early maturity and high yield potential four and five entries were selected from PYT-1 (Table 11, Fig. 4) and PYT-2 (Table 12) respectively. Physicochemical properties of these materials were determined by GQN Division, BRRI. Based on the agronomic and physicochemical properties five lines were selected as promising materials (Table 13).

Table 11. Agronomic characteristics of anther culture derived lines (PYT-1).

Designation	Plant ht (cm)	Growth duration (day)	Yield (t/ha)
BR8072-AC1-2-3-2-1-1	93	137	6.24
BR8072-AC4-2-1-2-2-1	93	137	6.39
BR8072-AC5-4-2-1-2-1	92	137	6.57*
BR7082-AC6-3-1-2-4-1	89	141	6.21
BR8072-AC7-4-1-2-2-4	94	141	6.64*
BR8072-AC8-1-1-3-1-1	95	137	6.36*
BR8072-AC9-1-1-2-1-1	92	137	6.60
BR8072-AC11-1-1-3-1-1	95	138	6.50*
BRRI dhan28 (ck)	100	143	6.61
CV(%)	2.1	2.14	2.26
LSD	3.4	1.32	0.33

Eight entries were evaluated and four entries were selected. *=Selected.

Fig. 4. Selected material from PYT-1 (yield- 6.57 t/ha; growth duration- 137 days; protein- 9.6%; amylose- 26%).

Table 12. Agronomic characteristics of anther culture derived lines (PYT-2).

Designation	Plant ht (cm)	Growth duration (day)	Yield (t/ha)
BR10384-AC10-2-1-3	97	137	7.03*
BR9782-AC3-2-3-3	92	134	6.12*
BR9783-AC3-1-3-1	93	149	6.47
BR9783-AC3-1-3-2	99	149	6.65*

Table 12. Continued.

Designation	Plant ht (cm)	Growth duration (day)	Yield (t/ha)
BR9783-AC5-1-5-2	100	151	6.60*
BR9783-AC6-2-2-2	98	148	7.09*
BR9783-AC8-1-4-1	99	148	6.87*
BR9783-AC9-1-2-1	96	148	6.44
BRRI dhan29	102	151	6.96
CV(%)	1.16	0.79	3.03
LSD	1.9	2.01	2.10

Eight entries were evaluated and six entries were selected. *=Selected.

DNA MARKERS APPLICATION

Introgression of submergence tolerance QTL, *SUB1* into BRRI dhan44 through marker assisted backcross breeding

To make the BRRI dhan44 submergence tolerant for about two weeks through marker assisted backcross breeding, BRRI dhan52 was used as the donor parent for *sub1* gene and the BRRI dhan44 was used as the recurrent parent. Foreground selection was done in the BC_1F_1 and BC_2F_1 populations to select the plants possessing the target gene. The best plants within the backcross populations were selected phenotypically. In this way BC_3F_1 population was generated and then background selection was done. On the basis of background selection, five homozygous plants of BC_4F_1 were selected for further backcrossing. Foreground selection was done in BC_4F_1 and BC_5F_1 generations and heterozygous plants were selected with SUB1C173 primer. In BC_5F_2 generation, foreground selection was done again with SUB1C173 primer to confirm homozygous plants for *SUB1* QTL in BRRI dhan44. Forty-four plants were detected for further evaluation. In T. Aman 2013 season, Plant Breeding Division grew 26 homozygous plants having *SUB1* QTLs as OT with standard checks (Fig. 5) and 13 lines were selected. Plant Breeding Division also screened the selected lines under submergence condition in Boro 2013-14.

Gene pyramiding for resistance to bacterial blight

IRBB60 was used as donors of two bacterial blight (BB) resistance genes, *Xa21* and *xa13* for

Table 13. Physicochemical properties of anther culture derived lines.

Variety/Line	Milling outturn (%)	Head rice yield (%)	Appea-rance	Chalki-ness	Length (L) mm	Breadth (B) mm	L/B ratio	Size and shape	Alkali spreading value	Amylose (%)	Protein (%)	Cooking time (min)	ER	IR
BR8072-AC1-2-3-2-1-1	72	52	V. good	Tr	6.4	2.1	3.1	LS	5.0	25.3	8.7	18.3	1.3	2.6
BR8072-AC4-2-1-2-2-1	70	46	V. good	Tr	6.8	2.0	3.4	LS	3.5	19.3	8.3	16.0	1.2	2.3
*BR8072-AC5-4-2-1-2-1	72	52	V. good	Tr	6.5	2.0	3.2	LS	5.0	26.0	9.5	17.0	1.2	2.6
BR8072-AC6-3-1-2-4-1	70	65	Good	Tr	6.4	1.9	3.3	LS	3.2	13.7	9.3	16.3	1.3	2.6
*BR8072-AC7-4-1-2-2-4	74	64	Good	Wc10-20	6.5	2.1	3.1	LS	5.0	23.2	9.8	19.3	1.2	2.6
*BR8072-AC8-1-1-2-1-1	74	67	Good	Wb 10-20	6.6	2.1	3.2	LS	5.0	25.0	9.2	18.3	1.2	2.6
BR8072-AC9-1-1-2-1-1	71	60	Good	Wb10-20	6.5	1.9	3.4	LS	3.0	14.0	8.1	16.0	1.2	2.3
*BR9782-AC3-1-3-2-3-3	72	45	Good	Wb>20	6.0	2.1	2.8	LS	5.0	25.6	8.9	17.0	1.4	2.6
*BR10384-AC10-2-1-3-1	70	64	Good	Wb 10-20	6.4	2.2	3.0	LS	5.0	25.0	8.6	18.0	1.3	2.6
BR802-78-2-1-1(CK)	70	55	Good	Opaque/Tr	6.0	2.0	3.0	LS	4.1	23.1	8.2	17.0	1.2	2.9
BRRI dhan28 (ck)	72	66	good	Wb10-20	6.0	1.6	3.8	LS	5.0	26.0	8.9	19.0	1.3	4.1
Niamat (ck)	72	57	good	Wb>20	7.7	2.0	3.8	LS	7.0	25.7	9.5	15.0	1.4	3.4

Nine entries were evaluated and five entries were selected. Tr=Translucent, Wb=White belly, Wc=White centred, LS=Long slender, LB=Long bold, ER=Elongation ratio, IR=Imbibitions ratio.

Fig. 5. Phenotypic appearance of *SUB1* BRRI dhan44 at primary yield trial.

pyramiding the BB resistance genes into BRRI dhan29. After molecular confirmation, BB screening was carried out on BC_5F_1 progenies and three resistant lines were selected. In Boro 2013-14, three selected lines were evaluated as OT (Table 10). Selected plants were reconfirmed by further molecular analysis as well as bacterial inoculation with BXo9 isolate and finally two BB pyramided lines were selected (Table 14, Fig. 6).

Identification of yield enhancement QTLs

Three crosses were made to identify and introgress high yield QTLs for enhancing grain yield of elite Bangladeshi rice varieties where BRRI dhan28 and BRRI dhan29 were used as recurrent parent and *Oryza rufipogon* (Ac. no. 103404 and 105890) were used as donor parents. A total of 430 simple

Table 14. Lesion length and percent damage area of three pyramided lines of BRRI dhan29 fourteen days after inoculation with BXo9 isolate.

Designation	Leaf length (cm)	14 days after inoculation	
		Lesion length (cm)	Average damage area (%)
BR8333-BC5-1-1	20.6	2.8	3.9*
BR8333-BC5-3-8	23.0	1.8	2.34*
BR8333-BC5-5-11	23.3	3.1	4.6
BRRI dhan29 (ck)	27.2	5.3	7.7
IRBB60 (Resistant ck)	22.0	0.7	0.6
Purbachi (Susceptible ck)	24.3	12.6	35.3

Three entries were evaluated and two entries were selected. *=Selected.
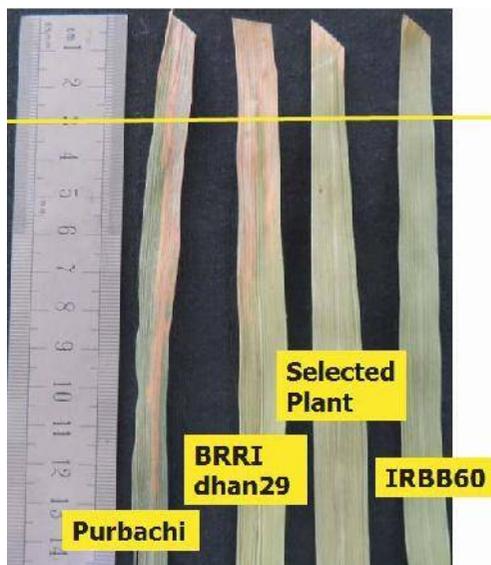
Fig. 6. Disease reaction of bacterial blight 14 days after inoculation BXo9 isolate.

sequence repeat (SSR) markers were used to identify polymorphism between the parents. Among them 102, 108, and 89 primers were identified to use for genotyping of BRRI dhan28/*Oryza rufipogon* (Ac. no. 105890), BRRI dhan28/*Oryza rufipogon* (Ac. no. 103404), and BRRI dhan29/*Oryza rufipogon* (Ac. no. 103404) crosses respectively. Genotyping of mapping population of BRRI dhan28/*Oryza rufipogon* (Ac. no. 105890) has been completed (Fig. 7). Some backcrossed fixed materials of these crosses were evaluated as observational trials and selected the promising materials based on phenotype and yield performance during Boro 2013-14 (Tables 6, 7, 8 and 9).

DEVELOPMENT OF TRANSGENIC RICE

Salt tolerant rice lines through transformation
BRRI dhan29 and BRRI dhan28 were used as plant materials and salt tolerant genes *GlyI* (*GlyoxalaseI*) and *GlyII* (*GlyoxalaseII*) were used to make the rice variety salt tolerant through *Agrobacterium*-mediated transformation method. Four putative transformants (BRRI dhan29) were confirmed in T_2 generation by molecular analysis (PCR) and T_3 seeds were harvested (Fig. 8).

Drought and salt tolerant rice lines through transformation
BRRI dhan29 was used as plant materials and gene constructs having drought and salt tolerant gene *TPSP* (Trehalose phosphate synthase/phosphatase) were used for genetic transformation. Three putative transformants (BRRI dhan29) having

TPSP gene were confirmed by PCR in T_1 generation and seeds were harvested from selected plants (Figs. 9 and 10).
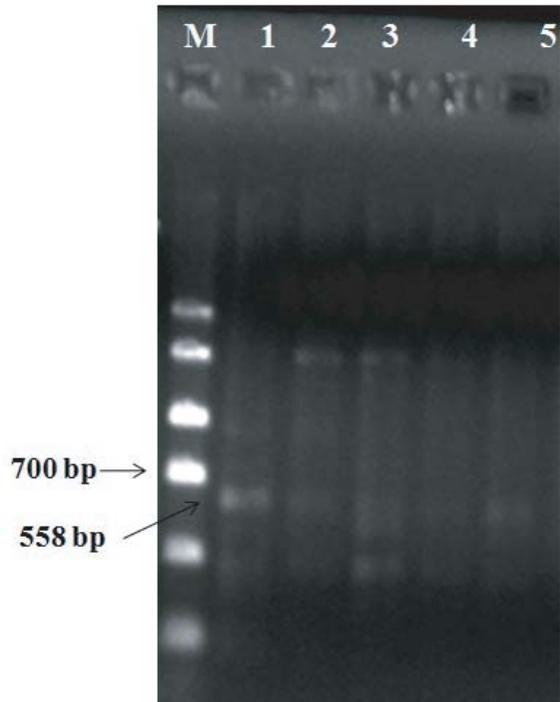
Fig. 8. Confirmation of putative transformants by PCR using *GlyI* primer.
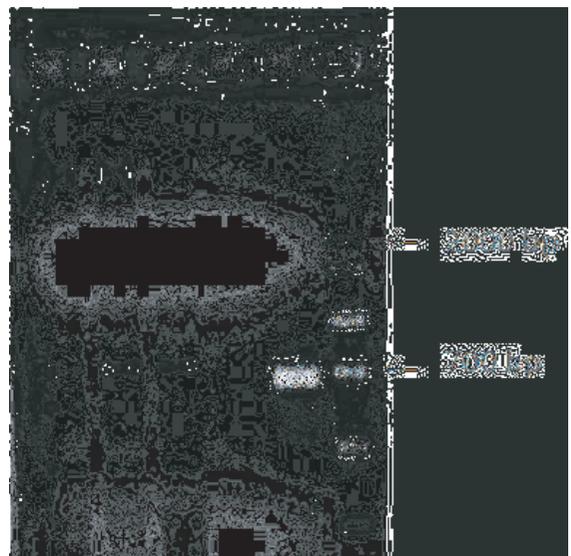
Fig. 9. Confirmation of putative transformants having *TPSP* genes by PCR analysis.

Fig. 7. Genotyping of BR28*3/*O. rufipogon* (Ac. no. 103404) population with RM7097 SSR marker.

Fig. 10. Putative transgenic plants having drought and salt tolerance *TPSP* gene grown in transgenic green house.

Genetic Resources and Seed Division

SUMMARY

A total of 185 rice germplasms of which 12 Aus, 168 T. Aman and five Boro were collected from different districts of Bangladesh including hilly areas. One hundred and fifty germplasms including 51 new collections from hilly and coastal areas were characterized with 53 morpho-agronomic characters during T. Aman and Boro seasons. Besides, 2,353 germplasm accessions including 174 new collections were rejuvenated. Apart from this, 297 new germplasms were registered as accession in BRRI Genebank accessions. In addition, molecular characterization was carried out for 96 germplasms using 100 SSR markers. Genetic diversity was pronounced in 46 Boro rice germplasms on the basis of thirteen morpho-agronomic and yield contributing characters and the varieties were grouped into seven clusters.

A total of 57 BRRI developed rice varieties were maintained as nucleus stock. Again, 151.39 tons of breeder seed (BS) of which 35.36 tons from 30 varieties in T. Aman and 116.03 tons from 12 varieties in Boro seasons were produced. On the other hand, about 28.96 tons from 23 varieties in T. Aman, 81.83 tons from 12 varieties in Boro and 4.92 tons from 10 varieties in Aus seasons were distributed during 2013-14. Besides, 811 kg seeds from 23 varieties of T. Aman, 168 kg seeds from two varieties of Boro and 189 kg from five varieties of Aus seasons were distributed as quality seed (QS) during the reporting year. Apart from this, three foundation seed producing farms were visited to monitor the varietal purity and performance of foundation seed.

RICE GERMPLASM CONSERVATION AND MANAGEMENT

Germplasm collection and acquisition. A total of 185 rice germplasms of which 12 in Aus, 168 in T. Aman and five in Boro seasons were collected from different districts of Bangladesh including hilly areas. Among the colletions, 46 germplasms were colleted from Patuakhali, 45 from Jhalakathi, 39 from Gopalganj, 20 from Bhola, 16 from Barguna, 11 from Chittagong, six from Narsingdi and two from Sirajganj districts.

Germplasm rejuvenation for storage. To increase the seed for safe storage in the Genebank, the accessions which possessed less than 80% germination and stored before 2009 were grown under transplant 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. Aman and Aus and @ 80-20-40 kg NPK/ha in Boro seasons.

A total of 2,353 germplasms accessions of which 323 accessions and 42 new collections in Aus 2013, 1,024 accessions and 132 new collections in T. Aman 2013 and 832 accessions in Boro 2013-14 seasons respectively were rejuvenated in field for fresh seed.

Characterization and evaluation of germplasm accessions. Ninety-nine accessions were grown in T. Aman season using a single row of 5.4 m long for each entry/accession with a spacing of 20- × 20-cm between rows and plants respectively for characterization of the stored rice germplasm. Fertilizers were applied @ 60-20-40 kg NPK/ha.

Ninety-nine germplasms were characterized using the Rice Germplasm Descriptors and Evaluation Form, GRSD in T. Aman season. According to the descriptor, seven accessions had medium growth duration (116-135 days), 83 had late (136-150 days) and 9 had very late (>150 days) growth duration (Table 1). Plant height was found short in eight germplasms (<110 cm), medium (110-130 cm) in 32, long (>130 cm) in 22 and very long (>140 cm) in 37 germplasms. Two germplasms were found with short panicle length (<20 cm), 46 with medium (21-25 cm), 47 with long (26-30 cm) and the rest four with very long (>30 cm) panicle length. Thousand grain weight (TGW) was found very low in 15 genotypes (<15 g), low to medium (16-23 g) in 51, high (24-27 g) in 22 and very high (>27 g) in 11 genotyes. Length-breadth ratio revealed that 20 genotypes were bold type (1.5-2.0), 42 were medium (2.1-2.5), 29 were medium slender (2.6-3.0) and eight were slender (>3.0) type. Besides, the shortest growth duration (126 days) was observed in Dudraj (acc. 237) and

Table 1. Mean values of different morphological traits of rice cultivars grown at BRRI during Aman 2013.

T. Aman 2012

	Leaf length (cm)		Leaf width (cm)		Effective tiller (no.)		Days to 50% flowering		Plant ht (cm)		Panicle length (cm)		Maturity	
	Range	Entry (no.)	Range	Entry (no.)	Range	Entry (no.)	Range (day)	Entry (no.)	Range	Entry (no.)	Range	Entry (no.)	Range (day)	Entry (no.)
	<35	3	<0.90	13	<10	78	<106	7	<110	8	<20	2	<136	7
	35-55	62	0.90-1.30	79	10-15	20	106-120	77	110-130	32	20-25	46	136-150	83
	>55	28	>1.30	6	>15	1	>120	15	>130	22	26-30	47	>150	9
	>65	6	>1.50	1					>140	37	>30	4		
	Shortest (31.67)	Begun bitchi (7358)	Shortest (0.76)	Jamaikuli (7643) and Kaisha binni (204)	Lowest (2.75)	Haitta binni (7560)	Shortest (96)	Dud Raj (237) and Sorbi maloti (5342)	Lowest (78.6)	Jamaikuli (7643)	Lowest (19.6)	Karkitsail (5012) and Rosa binni (7558)	Shortest (126)	Dud Raj (237)
	Longest (68.8)	Panboat (4774)	Longest (1.58)	Swarnapajam (5321)	Highest (16.4)	Mou biroin (5699)	Longest (124)	Sharimaloti (5184), Panboat (4774) and Arman sarder (4769)	Highest (166)	Gopal bhog (222)	Highest (32.4)	Gopal bhog (222)	Longest (154)	Sharimaloti (5184)
Mean	51.88		1.08		8.39		114.19		131.98		25.99		143.72	
Std. Dev.	8.47		0.17		2.32		6.04		16.88		2.43		5.91	
CV (%)	16.33		15.42		27.69		5.29		12.79		9.34		4.11	
LSD (5%)	1.67		0.03		0.46		1.19		3.33		0.48		1.16	

T. Aman 2012

	1000-grain ht (g)		Grain length (mm)		Grain width (mm)		Seed shape (L/W ratio)		Spikelet fertility (%)		Yield/hill (g)	
	Range	Entry (no.)	Range	Entry (no.)	Range	Entry (no.)	Range	Entry (no.)	Range	Entry (no.)	Range	Entry (no.)
	<15	15	<6	3	<2.5	20	1.5-2.0	20	<60	3	<5	2
	16-23	51	6-9	80	2.5-3.0	43	2.1-2.5	42	60-80	28	5-10	45
	24-27	22	>9	14	>3.0	29	2.6-3.0	29	>80	40	>10	49
	>27	11	>11	2	>3.5	7	>3.0	8	>90	28	>20	3
	Lowest (9.6)	Parbat jira (7351) and Chinisagar (7345)	Shortest (5.6)	Begun bitchi (7358)	Shortest (2.06)	Fulgainda (198)	Lowest (1.51)	Begun bitchi (7358)	Lowest (52.35)	Rasmala (7344)	Lowest (3.88)	Super basmoti (4911)
	Highest (30.8)	Rajmohan (5243)	Longest (11.44)	Fulgainda (198)	Longest (3.78)	Panboat (4774)	Highest (4.33)	Super basmoti (4911)	Highest (95.78)	Sharimaloti (5184)	Highest (26.9)	Gopal bhog (5346)
Mean	20.56		8.22		2.86		2.41		83.47		11.28	
Std. Dev.	5.44		1.14		0.41		0.46		9.02		4.17	
CV (%)	26.45		13.92		14.16		19.00		10.81		36.99	
LSD (5%)	1.07		0.23		0.08		0.09		1.78		0.82	

the longest (154 days) in Sabrimaloti (acc. 5184). The shortest plant height (78.6 cm) was observed in Jamaikuli (acc. 7643) and the longest (166 cm) in Gopalbhogh (acc. 222). Mou binni (acc. 5699) was found having the highest number of effective tillers (16.4). The highest grain length-breadth ratio (4.33) was observed in Super Bashmati (acc. 4911) and the heighest TGW (30.8 g) was found in Rajmohan (acc. 5243). The highest yield per hill (26.9 g) was observed in Gopalbhog (acc. 5346) and the lowest (3.88 g) in Super Basmoti (acc. 4911). Finally, the variety having higher yield would be used in crossing programme, if other characters are satisfactory to the breeder.

Agro-morphological characterization of newly collected rice germplasm from hilly and coastal areas of Bangladesh. To characterize and evaluate rice germplasm for protection from biopiracy, 51 newly collected germplasms from hilly and coastal areas (Table 2) were grown in Boro 2013-14 season using a single row of 5.4 m long per entry/accession with a spacing of 20- × 20-cm between rows and plants respectively. Fertilizers were applied @ 80-20-40 kg NPK/ha. Appropriate after planting actions were taken when necessary.

Table 3 shows the results of characterization data on the basis of 33 qualitative characters of 51 germplasm. It appears from the table that different accessions felt in different characters in variant pattern, which clearly revealed existence of wide diversity in the rice germplasm.

Molecular characterization and genetic diversity in landraces of rice (*Oryza sativa* L.) **using microsatellite markers.** To characterize the rice germplasm through molecular tools for varietal identification and to establish property right, 96 Boro rice landraces (acc. 7, 54, 178, 179, 180, 182, 253, 254, 255, 258, 260, 262, 929, 932, 933, 934, 935, 936, 1405, 1468, 1470, 1471, 1472, 1474, 1475, 1650, 1670, 1706, 1707, 1708, 1709, 1711, 1713, 1714, 1716, 1790, 1792, 1793, 1796, 1800, 1801, 1802, 1811, 1813, 1817, 1818, 1819, 1968, 1969, 1970, 1971, 1972, 2251, 2252, 2258, 2260, 2261, 2264, 2266, 2267, 2268, 3952, 3959, 3960, 3962, 3963, 3976, 3980, 3981, 3982, 3983, 3984, 3985, 3989, 3991, 3993, 3994, 3995, 4000, 4001, 4002, 4003, 4004, 4005, 4006, 4007, 4008, 4009, 4011, 4012, 4013, 4014, 4017, 4202, 4203, 4206) were used for molecular characterization using microsatellite or SSR markers.

DNA was extracted from young leaves of three-week-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 mM Tris-HCl pH 9.0 at 25°C, 500 mM KCl, 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. Based on polymorphism, twelve SSR markers with known amplification were used for genetic diversity

Table 2. List of the 51 rice germplasm characterized during Boro 2013-14.

Sl. no.	Name	District	Sl. no.	Name	District	Sl. no.	Name	District
1	Ratoil	Barisal	18	Sili	Bandarban	35	Tepu dhan	Patuakhali
2	Unknown 1	,,	19	Bekui 1	,,	36	Holoi	,,
3	Unknown 2	,,	20	Pidi 2	,,	37	23 dhan	Barguna
4	Binni dhan	Bandarban	21	Bekui 2	,,	38	Gota irri	,,
5	BR14	,,	22	Methui chang	,,	39	Sada mota	,,
6	Mangbui	,,	23	Rumkoi	,,	40	Sakkar khana	Jhalakathi
7	Mymensingh	,,	24	Kaponi	,,	41	Vogon/Chali boro	,,
8	Pidi 1	,,	25	Galong	,,	42	Abdul hai	,,
9	Hybrid	,,	26	Mongthong 1	,,	43	Chini gura	,,
10	Unknown 3	,,	27	Likchu	,,	44	Nakuchi mota	,,
11	Kapru	,,	28	Mongthong 2	,,	45	Dud kalam	,,
12	Binni dhan	,,	29	Kaborok	,,	46	Mota irri	,,
13	Binni	,,	30	Unknown 4	,,	47	Kalo aus	Patuakhali
14	Gunda	,,	31	Nasulu	,,	48	Sakar kana dhan	,,
15	Mema koia	,,	32	Unknown 5	,,	49	Gabbail dhan	,,
16	Shero	,,	33	Unknown 6	,,	50	Anonymous 7	,,
17	Barotia	,,	34	Kalo saitta	Patuakhali	51	Anonymous 8	,,

Table 3. Classification of 51 germplasms based on 33 qualitative characters.

Character	Classification	Total variety under classification	Genotype (As its serial number in Table 2)
Blade pubescence	02.intermediate	51	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49, 50,51
Blade colour	01. pale green	07	7,8,11,13,14,23,34
	02. green	28	1,6,9,10,12,16,17,18,20,22,24,25,26,28,29,30,31,36,38,40,43,44,45,48,50,51
	03. dark green	12	2,5,19,21,27,32,33,35,37,41,42,46
	05. purple margins	04	3,4,15,47
Leaf sheath: anthocyanin colour	01. absent	36	1,5,8,9,10,11,12,13,14,16,17,18,19,20,21,22,23,24,25,30,31,32,33,35,37,38,40,42,43,44,45,46,48,50,
	09. present	15	2,3,4,6,7,15,26,27,28,29,34,36,41,47,51
Basal leaf sheath color	01. green	36	1,5,8,9,10,11,12,13,14,16,17,18,19,20,21,22,23,24,25,30,31,32,33,35,37,38,39, 40,42,43,44,45,46,48,49,50
	02. purple lines	06	6,26,29,34,41,51
	03. light purple	05	7,26,28,36,47
	04. purple	04	2,3,4,15
Leaf angle	01.erect	43	1,2,3,4,5,7,8,9,10,11,13,14,19,20,21,23,24,25,26,27,28,29,30,31,31,34,35,36,37,38,40,41,42,43,44,45,46, 47,48,49,50,51,
	05. horizontal	04	6,12,15,33
	09. drooping	04	16,17,18,22
Flag leaf angle	01. erect (<30°)	19	1,2,3,4,5,9,31,32,34,35,36,41,43,44,45,47,50,51,
	03. semi erect (<30-45°)	11	6,10,11,23,27,30,37,38,42,46,48
	05. horizontal (<46-90°)	14	13,16,17,18,19,20,21,22,24,26,28,29,40
	07.descending (>90°)	07	7,8,12,14,15,25,33
Ligule colour	01. white	46	1,3,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,22, 23,24,25,27,28,29,30,31,32,33,34,35,36,37,38,40,41,42,43,44, 45,46,48,50,51
	02. purple lines	04	2,4,26,47
	03. purple	01	15
Ligule shape	02. 2- cleft	51	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51
Collar color	01.pale green	43	1,7,8,9,10,11,12,13,14,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,31,33,34,36,38,39,40,41,42,43,44,45,46, 47,48,49,50,51
	02. green	04	5,6,35,37
	03. purple	04	2,3,4,15
Auricle color	01. pale green	46	1,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,48,49,50,51
	02.green	05	2,3,15,29,47
Culm anthocyanin colour	01. absent	40	1,3,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,22,23,24,25,30,31,32,33,34,35,36,37,39,40,41,42,43,44,45,46,48,49,50,51
	09. present	09	2,4,15,26,27,28,29,38,47,
Culm Angel 43,44,46,48,49,50	01. erect(<30°)	24	2,3,4,10,12,13,14,15,16,18,23,30,31,32,35,39,40,41,
	03. intermediate	11	1,8,9,11,21,22,36,37,38,42,45
	05.open	16	5,6,7,17,19,20,24,25,26,27,28,29,33,34,47,51
Internode colour	01.green	15	2,5,16,17,19,20,23,27,28,38,42,44,45,46,51
	02.light gold	33	1,3,6,7,8,9,10,11,12,13,14,18,21,22,24,25,26,30,31,32,33,34,35,36,37,39,40,41,43,47,48,49,50

Table 3. Continued.

Character	Classification	Total variety under classification	Genotype (As its serial number in Table 2)
	03.purple lines	01	4
	04.purple	02	15,29
Culm strength (lodging resistance)	01. strong	28	2,3,4,5,9,10,11,12,13,14,15,16,17,18,21,22,23,29,35,40,42, 43,44,45,46,49,50,51,
	03. moderately strong	11	6,7,8,19,20,24,27,30,31,37,41
	05. intermediate	09	25,26,28,32,33,38,39,47,48
	07. weak	03	1,34,36
Panicle Type	01.compact	13	4,5,12,13,14,17,34,36,37,40,41,43,48,
	05.intermediate	20	1,8,9,10,11,15,18,20,26,28,30,35,38,39,44,46,47,49,50,51
	09. open	18	2,3,6,7,16,19,21,22,23,24,25,27,29,31,32,33,42,45
Secondary branching	02. heavy	51	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23, 24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42, 43,44,45,46,47,48,49,50,51
Panicle Exsertion	01. well exerted	07	17,19,40,43,47,48,50
	03. moderately well exerted	09	4,10,15,28,29,36,37,44,45
	05. just exerted	28	1,2,3,5,6,7,8,9,18,21,23,24,25,26,27,30,31,32,33,34,35,38,39, 41,42,46,49,51
	07.partly exerted	07	11,12,13,14,16,20,22
Axis	02. droopy	51	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23, 24,25,26,27,28,29,30,31,32,33,34,35,36,37,38, 39,40,41,42, 43,44,45,46,47,48,49,50,51
Shattering	01. very low	02	3,4
	03.low	35	1,2,5,7,9,10,11,12,15,16,19,21,24,25,26,27,28,31,32, 33,36, 37,38,39,40,41,42,43,44,45,47,48,49,50,51
	05.moderate	13	6,8,13,14,17,18,20,22,23,30,34,35,46
	07. moderately high	01	29
Threshability	09.easy	51	1,2,3,4,5,6,7,8,9,10,11,1213,14,15,16,17,18,19,2021, 22,23, 24,25,26,27,28,29,30,31,32,33,34,35,36,37,38, 39,40,41,42, 43,44,45,46,47,48,49,50,51
Spikelet: awns in the spikelet	01. absent	29	3,4,6,9,10,12,15,20,21,22,23,25,26,28,29,30,31,32,33,35,37, 39,40,42,43,44,45,48,49
	09. present	22	1,2,5,7,8,11,13,14,16,17,18,19,24,27,34,36,38,41,46,47,50,51
Distribution of awning	01. tip only	45	2,3,4,5,6,7,8,9,10,11,1213,14,15,16,19,2021,22,23,25,26,27, 28,29,30,31,32,33,34,35,36,37,38,39,40,41,42, 43,44,45,46, 48,49,51
	03.upper half only	03	17,18,24
	05.whole length	03	1,47,50
Awn colour	01.straw	18	1,2,5,7,13,14,16,17,18,19,27,34,36,38,41,46,50,51
	05. purple	03	8,11,24
	06. black	01	47
Apiculus colour	02.straw	26	3,5,7,9,10,14,17,18,19,21,25,30,32,35,36,37,38,41,42,44,45, 46,48,49,50,51
	03.brown	01	43
	04.red	02	16,40
	05.red apex	03	12,28,33
	06.purple	18	1,2,4,6,8,11,13,20,22,23,24,26,27,29,31,34,39,47
	07.purple apex	01	15
Stigma colour	01.white	47	1,3,4,5,6,7,8,9,10,110,12,13,14,16,17,18,19,20,21,22,23,24, 25,27,28,30,31,32,33,35,36,37,38,39,40,41,42,43,44,45,46, 48,49,50,51
	04.light purple	01	34
	05.purple	05	2,15,26,29,47

Table 3. Continued.

Character	Classification	Total variety under classification	Genotype (As its serial number in Table 2)
Stigma exsertion	01.no or a few	05	5,19,45,47,50
	03.low	44	1,2,3,4,6,7,8,9,10,11,12,14,15,16,17,18,20,21,22,23,24,26,27, 28, 29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,46, 48,49,51
	05.medium	02	13,25
Lemma and palea colour	0. straw	42	1,2,3,5,6,7,8,9,10,11,12,14,16,17,18,19,21,23,24,25,2627,28, 29,30,31,32,33,35,36,37,38,39,41,42,44,45, 46,48,49, 50,51
	01. gold	01	4
	05. reddish to light purple	05	13,20,22,40,43
	06. purple spots on straw	01	15
	09.black	02	34,47
Lemma and palea pubescence	02.hairs on lemma keel	02	15,36
	03.hairs on upper portion	01	34
	04.short hairs	47	1,2,3,4,5,6,7,9,10,11,12,13,14,16,17,18,19,20,21,22, 23,24, 25,26,27,28,29,30,31,32,33,35,37,38,39,40,41, 42,43,44,45, 46,47,48,49,50,51
	05.long hairs	01	8,
Sterile lemma color	01.straw	42	1,2,3,4,5,6,7,9,10,12,14,15,16,17,18,19,21,23,24,25, 26,27, 28,30,32,33,34,35,36,37,38,39,41,42,44,45,46, 47,48,49,50,51
	02.gold	04	8,11,20,29
	03.red	03	22,40,43
	04.purple	02	13,31
Seed coat (bran) colour	01.white	37	2,3,4,5,6,7,8,9,10,11,12,14,16,17,18,19,20,21,2324,27,28,30, 31, 32,33,35,37,39,40,42,43,45,46,48,49,50
	03. speckled brown	03	38,44,47
	04. brown	06	13,22,29,34,36,51
	05. red	04	1,25,26,41
	06. variable purple	01	15
Endosperm type	01.nonglutionus	13	1,4,7,9,14,28,29,30,33,34,40,47,50
	02.glutinous	27	3,5,8,10,11,12,13,15,17,18,19,20,21,22,23,24,25,27,31,35,36, 37,42,43,45,46,48
	03.indeterminate	11	2,6,16,26,31,38,39,41,44,49,51
Decorticated grain: Scent (aroma)	0. non scented	51	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23, 24,25,26,27,28,29,30,31,32,33,34,35,36,37,38, 39,40,41,42, 43,44,45,46,47,48,49,50,51
Leaf senescence	01.late and slow	06	2,4,9,10,21,27
	05. intermediate	32	3,5,6,7,12,13,14,15,16,17,18,19,20,22,26,28,29,30,32,35,37, 39, 40,42,43,44,45,46,47,48,49,50
	09.early and fast	13	1,8,11,23,24,25,31,33,34,36,38,41,51

analysis (Table 4). Molecular weight for each amplified allele was measured in base pair (bp) using Alpha-Ease 5.0 software. The summary statistics including the number of alleles per locus, major allele frequency, gene diversity, polymorphism information content (PIC) was determined using Power Marker version 3.25. Finally, a similarity matrix was calculated with the Simqual subprogramme using the Dice coefficient followed by cluster analysis with the SAHN subprogramme by UPGMA clustering method as implemented in NTSYS-pc.

Figure 1 shows an example of banding pattern of studied germplasm from which allele size was measured. A total of 252 alleles were detected at 12 microsatellite markers across 96 rice genotypes (Table 5). The number of alleles per locus ranged from 11 (RM163) to 41

Table 4. List of SSR markers used for diversity analysis of Boro rice.

Locus name	Chr.	Repeat motif	Forward primer	Reverse primer
RM 6	2	(AG)16	GTCCCCTCCACCCAATTC	TCGTCTACTGTTGGCTGCAC
RM 11	7	(GA)17	TCTCCTCTTCCCCCGATC	ATAGCGGGCGAGGCTTAG
RM 30	6	(AG)9A(GA)12	GGTTAGGCATCGTCACGG	TCACCTCACCACACGACACG
RM 44	8	(GA)16	ACGGGCAATCCGAACAACC	TCGGGAAAACCTACCCTACC
RM 125	7	(GCT)8	ATCAGCAGCCATGGCAGCGACC	AGGGGATCATGTGCCGAAGGCC
RM 147	10	(TTCC)5(GGT)5	TACGGCTTCGGCGGCTGATTCC	CCCCCGAATCCCATCGAAACCC
RM 163	5	(GGAGA)4(GA)11C(GA)20	ATCCATGTGCGCCTTTATGAGGA	CGCTACCTCCTTCACTTACTAGT
RM 273	4	(GA)11	GAAGCCGTCGTGAAGTTACC	GTTTCCTACCTGATCGCGAC
RM 277	12	(GA)11	CGGTCAAATCATCACCTGAC	CAAGGCTTGCAAGGGAAG
RM 278	9	(GA)17	GTAGTGAGCCTAACAATAATC	TCAACTCAGCATCTCTGTCC
RM 283	1	(GA)18	GTCTACATGTACCCTTGTTGGG	CGGCATGAGAGTCTGTGATG
RM 287	11	(GA)21	TTCCCTGTTAAGAGAGAAATC	GTGTATTTGGTGAAAGCAAC
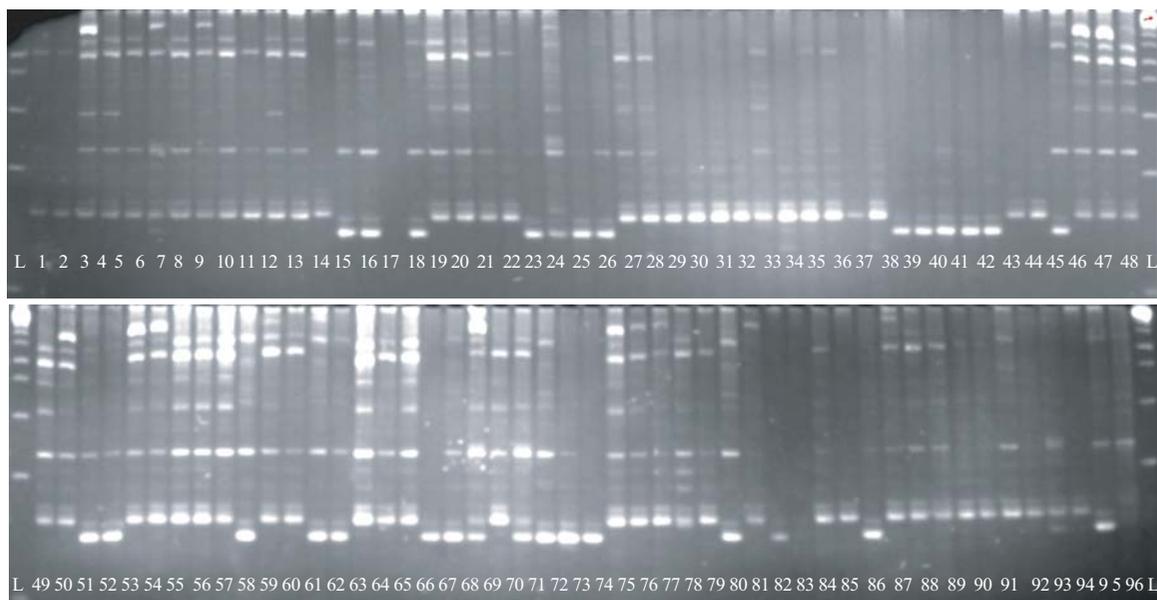
Fig. 1. DNA profile of 96 Boro landraces with marker RM6.

1=Banajira, 2=Pashusail, 3=Ceenail, 4=Bhaturi, 5=Dholi Boro, 6=Grugu Boro, 7=Boro, 8=Ausha Boro , 9=Jagli Boro, 10=Tepi Boro, 11=Kali Boro, 12=Kaiaka Boro, 13=Poshu Sail, 14=Gorchi Sail, 15=Jhati Sail, 16=Bimion, 17=Soiler Peena, 18=Khaia Boro. H. B. Jvi, 19=Boro Deshi, 20=Muktahar, 21=Banajira, 22=Bash ful, 23=Am Boro, 24=Lahi Boro, 25=Jamri Boro, 26=Mukta har, 27=Bati Boro, 28=Jamir, 29=Kali Boro, 30=Bawoi, 31=Khoea, 32=Ulia, 33=Solai, 34=Sada Boro (deske), 35=Chaita Boro, 36=Isamoti, 37=Jaista Boro, 38=Natel Boro, 39=Guchi Boro, 40=Lakhai, 41=Lakhai, 42=Bogra (Deshi), 43=Tupa, 44=Begun Bitchi, 45=Pankaij, 46=Bash Boro, 47=Raja Sail , 48=Tulsi Boro, 49=Lafai, 50=Sail Boro, 51=Gochi, 52=Biron, 53=Bogura, 54=Lahaya, 55=Chhola Boro, 56=Kolisha Boro, 57=Goa Bish, 58=Madhab Sail, 59=Mogol Sail, 60=Gola Tepi, 61=Lafa, 62=Beun Bichi, 63=Rata Boro, 64=Kori Topa, 65=Lal Dengi, 66=Panpiag, 67=KN-1B-361-1312-27-1, 68=Choudhury Sail, 69=Ashani, 70=Madanga, 71=Laitra Sail, 72=Fena Ful, 73=Kowla, 74=Madlai, 75=Lara, 76=Binni, 77=Lal Boro, 78=Gachi Boro, 79=Bachi Boro, 80=Birain, 81=Sona Rata, 82=Naula topa, 83=Hunga Boro, 84=Bimon, 85=Gobi Sail, 86=Nata Boro, 87=Chaula Birain, 88=Kala Birain, 89=Badal Boro, 90=Jomir Sail, 91=Gopal Beri, 92=Muirol, 93=Polash, 94=Gasbar, 95=Gumir Sail, 96=Jalda IRRI.

(RM283), with an average of 21 alleles across the 12 loci obtained in the study. The PIC values ranging from 0.75 (RM163) to 0.95 (RM283) were identified in all 12 loci. The allele frequency ranged from 8.33% (RM283) to 34.38% (RM163) with an average of 17.62 alleles per locus.

The PIC values for other markers were 0.93 (RM6, RM11), 0.92 (RM278), 0.91 (RM44), 0.90 (RM273), 0.89 (RM125, RM287), 0.87 (RM147,

RM277) and 0.83 (RM30), respectively (Table 5). PIC values revealed that RM283 was considered as the best marker for the studied 96 genotypes. Besides, the genetic distance-based unrooted neighbour-joining tree revealed that the genotypes were grouped into seven clusters (Fig. 2). The highest numbers of genotypes (25) were found in cluster I followed by clusters VII (19), V (17), II and III (10), IV (9) and the lowest in cluster VI (6).

Germplasm processing, registration and storage. To keep the rice germplasm with respective accession number in different storages
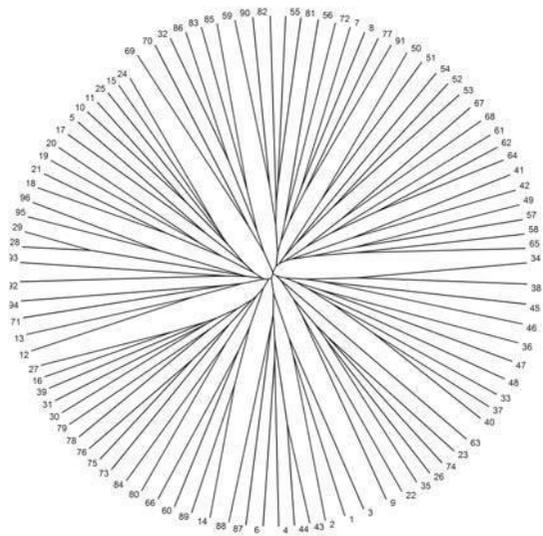
0.1

Fig. 2. An unrooted neighbour-joining tree showing the genetic relationships among 96 Boro rice genotypes of Bangladesh.

of Rice Genebank after duplicate sorting, 2,303 germplasms including 174 new collections were processed during Aus 2013, T. Aman 2013 and Boro 2013-2014.

A total of 2,303 accessions of which 353 accessions in Aus, 1,150 in T. Aman and 800 in Boro seasons were processed and stored in short term storage. On the other hand, in *Aus* season, 86 and 108 accessions were stored in medium and long term respectively. Similarly in T. Aman season 500 and 274 accessions were stored in medium and long and 82 and 119 accessions in Boro season was stored in medium and long term storages respectively.

A total of 297 germplasms were registerd in accession book as new accession of which 141 in Jhum (from accession 7684 to 7824), 31 in Aus (from accession 7825 to 7855) and 125 in T. Aman (from accession 7856 to 7980) germplasm.

Viability testing, periodic evaluation and routine monitoring of stored germplasm. Two hundred accessions in Aus, 250 in T. Aman and 300 in Boro seasons were checked randomly for viability test in short term storage during 2013-14. Five tester varieties *viz* Dharial (acc. 649), Hashikalmi (3575), Purbachi (6207), Nizersail (1229) and Patnai-23 (52) were used as testers in the medium and long term storages and their viability were measured on six month interval usually on October and March each year to predict the viability of germplasm in respective storages. Seed viability of the germplasm just before storage in the Genebank was also monitored.

Table 5. Number of alleles, allele size, frequency, genetic diversity and PIC among 96 Boro rice genotypes for 12 microsatellite markers.

Marker	Chr. no	Position (cM)	Allele no.	Allele size (bp)	Allele freq (%)	Genetic diversity	PIC value
RM 6	2	29.57	24	151.6	11.46	0.94	0.94
RM 11	7	47	25	120.88	10.42	0.94	0.94
RM 30	6	125.4	17	73	21.88	0.85	0.84
RM 44	8	2.88	21	97.09	13.54	0.92	0.91
RM 125	7	24.8	18	104	18.75	0.89	0.88
RM 147	10	20.68	15	87.53	22.92	0.89	0.88
RM 163	5	91.4	11	51.09	34.38	0.79	0.76
RM 273	4	94.4	21	119	14.58	0.91	0.91
RM 277	12	57.2	18	119.5	23.96	0.89	0.88
RM 278	9	77.5	24	140.79	13.54	0.93	0.93
RM 283	1	31.4	41	119.95	8.33	0.96	0.96
RM 287	11	68.6	17	106.47	17.71	0.89	0.88
Mean			21		17.62	0.90	0.89

Among the randomly selected 750 stored germplasm, 381 had viability between 80-90% and 178 had viability above 90%. The germplasm accessions stored during 2013-14 in short term were also found to have more than 90% germination. Only 45 germplasms possessed less than 80% germination which will grow 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 and in both October 2013 and March 2014 were 74-95% and 74-93% respectively.

Rice germplasm exchange. A total of 1,663 samples of rice germplasm as well as BRRI developed rice varieties in Aus, Aman and Boro seasons were supplied to different users. Among the samples, 790 germplasm samples and 316 BRRI varieties were supplied for research purpose and 557 samples from BRRI developed rice varieties were supplied for other purposes.

SEED PRODUCTION AND MAINTENANCE OF NUCLEUS STOCK

Breeder seed production. Genetic Resources and Seed Division (GRSD), Farm Management Division and eight regional stations of BRRI were engaged in production and supply the breeder seed (BS) as per national demand during 2013-14. The BS plots were visited to monitor the varietal purity and performances. Off-type plants were identified and rogued out in each growth stage. After harvesting of each 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 SCA for distribution.

A total of 151.39 tons of breeder seed were produced, of which 35.36 tons from 30 varieties in T. Aman and 116.03 tons from 12 varieties in Boro seasons were produced during 2013-14 (Table 6). On the other hand, 115.71 tons of breeder seed were distributed from previous seasons/years stock through the 'Rice Seed Network', of which 28.96 tons were distributed from 23 varieties in T. Aman, 81.83 tons from 12 varieties in Boro and 4.92 tons

from ten varieties in Aus seasons (Tables 7, 8 and 9). Besides, 811 kg seeds from 23 varieties of T. Aman, 168 kg from two varieties of Boro and 189 kg from five varieties of Aus varieties were also distributed as quality seed (QS) during 2013-14.

Nucleus seed production for variety maintenance. A total of 57 varieties of which 33 in T. Aman and 24 in Boro seasons were grown as nucleus stock (Table 10) to maintain genetic purity and homogeneity of morphological characteristics of BRRI developed rice varieties and to keep as the source of breeder seed. 'Panicle to row' method was used to maitain nucleus stocks, where intact panicles were sown instead of threshed seeds. Off-type plants were identified and rogued out in each growth stage. At maturity, panicles from true to type plants of all the varieties were harvested and kept intact in the storage.

Monitoring foundation seed production farms. Farms of BADC, BRAC and ACI were visited to monitor the varietal purity and performances of foundation seed. During the visit, no major insect-pest damage was noticed in the visited plots. Varietal purity (%) was observed as an average of more than 99% in all the varieties. The crops were found almost free from weed. In maximum cases, isolation distance was properly maintained. Seed 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

Studies on selection criteria and genetic divergence of Aus rice germplasm. Forty-six Aus accessions were grown under rainfed condition with three replications for diversity analysis with 13 morpho-agronomic characters. Based on D^2 analysis, the varieties/germplasm were grouped into seven clusters. Maximum 17 genotypes were clubbed in cluster VII and miminum two in cluster III (Table 11). The intra-cluster and inter-cluster distances ranged from

Table 6. Production of breeder seed in 2013-14.

Variety	Production (kg)										
	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
T. Aman											
BR10	270			1750							2020
BR11	600			2230				1670			4500
BR21	120										120
BR22	270										270
BR23	160								440		600
BR24	200										200
BR26	200										200
BRRI dhan27	280										280
BRRI dhan30	670										670
BRRI dhan31	110										110
BRRI dhan32								1000			1000
BRRI dhan33	440			2500							2940
BRRI dhan34	120		900	1070				460			2550
BRRI dhan39	310			1600							1910
BRRI dhan40								600			600
BRRI dhan41	400								150		550
BRRI dhan42	200										200
BRRI dhan43	400										400
BRRI dhan44	370								370		740
BRRI dhan46	80										80
BRRI dhan48	600				400						1000
BRRI dhan49	170	3100				4300					7570
BRRI dhan51	230	970	630								1830
BRRI dhan52								1000	1750		2750
BRRI dhan53	200										200
BRRI dhan54	230										230
BRRI dhan56	110					440					550
BRRI dhan57	110					350		630			1090
BRRI dhan62	50										50
Nizersail	150										150
Sub total	7050	4070	1530	9150	400	5090		5360	2710		35,360
Boro											
BR3	520										520
BR14								1000			1000
BR16	280		1580		1160			1800		700	5520
BR26	1140								1790		2930
BRRI dhan28	2800	2800	1080	3200	9920	12300	11000		5510	11000	59610
BRRI dhan29	2400			7640	13880		2800				26720
BRRI dhan36	720										720
BRRI dhan45	550										550
BRRI dhan47		1840							2760		4600
BRRI dhan50	2000			2170		2500					6670
BRRI dhan55	2670						2600				5270
BRRI dhan58	1920										1920
Sub total	15000	4640	2660	13010	24960	14800	16400	2800	10060	11700	116,030
Grand total											151,390

1.17 to 0.45 and 4.36 to 11.45 respectively (Table 12) which clearly indicated the presence of variability in the germplasm of different clusters. Principal component analysis (PCA) scores also indicate a high degree of genetic diversity among the genotypes. The highest cluster means for yield and panicle hill^{-1} (no.) were obtained from cluster III (Table 13) and the

Table7. Distribution of breeder seed in T. Aman 2013-14.

Organization	Organizations (no.)	BR10	BR11	BR22	BR23	BRRI dhan30	BRRI dhan31	BRRI dhan32	BRRI dhan33	BRRI dhan34	BRRI dhan39	BRRI dhan40	BRRI dhan41	BRRI dhan44	BRRI dhan46	BRRI dhan49	BRRI dhan51	BRRI dhan52	BRRI dhan53	BRRI dhan54	BRRI dhan56	BRRI dhan57	BRRI dhan62	Nizersail	Total
GO	7	1500	2670	200	250	670	10	620	1010	1090	1030	50	350	650	0	4370	620	2010	200	200	460	690	50	50	17400
NGO	9	30	120	10	20	0	0	0	220	50	50	10	30	0	0	180	50	60	0	30	40	70	0	0	970
PS	184	280	1510	60	310	0	10	470	1510	1180	690	30	160	110	80	2630	650	600	0	0	50	260	0	0	10590
Total	200	1810	4300	270	580	670	20	1090	2740	2320	1770	90	540	760	80	7180	1320	2670	200	230	550	1020	50	50	28960

Table 8. Distribution of beeder seed in Boro 2013-14.

Organization	Organizations (no.)	BR3	BR14	BR16	BR26	BRRI dhan28	BRRI dhan29	BRRI dhan36	BRRI dhan45	BRRI dhan47	BRRI dhan50	BRRI dhan55	BRRI dhan58	Total
GO	12	150	100	50	1340	9845	3780	10	0	1620	460	41	271	17667
NGO	10	0	60	180	50	2880	490	0	0	10	210	80	140	4100
PS	558	40	240	1610	1240	45490	7970	190	160	80	1670	590	780	60060
Total	580	190	440	1840	2630	58215	12240	200	160	1710	2340	711	1190	81827

Table 9. Distribution of breeder seed in Aus 2013-14 (in kg).

Organization	Organizations (no.)	BR3	BR16	BR21	BR24	BR26	BRRI dhan27	BRRI dhan42	BRRI dhan43	BRRI dhan48	BRRI dhan55	Total
GO	13	253	380	100	170	200	280	200	200	625	1190	3598
NGO	3	0	0	0	0	0	0	0	0	10	890	900
PS	6	0	0	10	30	0	0	0	0	350	30	420
Total	22	253	380	110	200	200	280	200	200	985	2110	4918

Table 10. List of BRRI developed rice varities maintained as nucleus stock in 2013-14.

Season	Number	Variety
T. Aman	33	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 dhan 62
Boro	24	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

shortest growth duration from cluster VII, whereas the highest panicle length (cm), plant height (cm) and grain breadth (mm) were obtained from cluster VI which also produced higher inter cluster-values over other clusters. Therefore, the genotypes of cluster III and VI can be used in hybridization programme to produce higher yielding genotypes.

Aromatic hybrid rice development: Screening germplasm for potential available component lines. A collaborative project between Bangabandhu Sheikh Mujibur Rahman Agricultual

Table 11. Distribution of 46 rice genotypes in different clusters.

Cluster no.	Genotypes no.	BRRI accession no.	Genotypes
I	5	654, 1202, 1529, 1641, 1645	Nayan tara, Begunbitchi, Benaful, Panock, Langra beni
II	11	564, 569, 572, 575, 1216, 1528, 1534, 1550, 1642, 1689, 1691	Dal kaisha, Garia, Marik madhu, Shoni, Porangi (7), Paik juta, Hasha, Batnuri, Chiknal, Parangi, Haitai saeta
III	2	1556, 1626	Holat, Mory saita
IV	4	1546, 1629, 1630, 1632	Ajabbeti, Rang mahal, Lakhi jhota, Katar
V	3	1205, 1211, 1700	Bolium, Laxmi lota, Pankhiraj
VI	4	1210, 1662, 1696, 1699	Noroi (4), Kamini sail, Baismagur, Sribalium
VII	17	1213, 1323, 1532, 1549, 1633, 1643, 1655, 1671, 1675, 1680, 1681, 1682, 1683, 1684, 1687, 1688, 1692	Saita, Manik moda, Tepakain, Bnamka, Kali bokri (1), Ingra, Lal galong, Mele, Gori saita, Goyal, Saita, Kala manik, Koe juri, Kautuk moni, Korcha muri, Boilam, Manik mendal

Table 12. Intra (bold) and inter cluster distances (D^2) for 46 Aus rice genotypes.

Cluster	I	II	III	IV	V	VI	VII
I	**1.178**	6.016	8.451	5.686	8.422	7.869	6.145
II		**0.708**	9.114	9.116	6.965	8.399	5.036
III			**0.653**	7.777	11.450	5.222	7.167
IV				**0.457**	10.609	6.695	6.808
V					**0.671**	11.220	8.509
VI						**0.524**	4.365
VI							**0.669**

Table 13. Cluster means for thirteen characters of 46 Aus rice genotypes.

Character	Cluster number						
	I	II	III	IV	V	VI	VII
Flag leaf length (cm)	60.82	49.58	55.00	59.45	47.33	52.15	51.38
Flag leaf width (cm)	1.52	1.16	1.07	1.56	1.13	1.31	1.20
Plant height (cm)	124.50	123.19	143.00	139.40	114.83	155.20	143.85
Days to 50% flowering	102.40	91.73	104.00	104.75	92.67	98.75	91.76
Days to maturity	132.80	122.00	134.00	135.25	122.67	129.25	121.76
Panicle hill^{-1} (no.)	6.56	13.24	14.00	7.25	3.90	9.75	11.60
Panicle length (cm)	25.98	24.00	25.10	25.00	18.83	26.90	24.59
Spikelet fertility (%)	88.85	83.87	72.34	90.04	73.10	85.01	87.93
Grain length (mm)	8.50	8.72	8.01	6.65	8.16	8.61	8.68
Grain breadth (mm)	1.97	2.09	2.10	1.79	2.26	2.27	2.19
Length-breath ratio	2.88	2.94	2.75	2.53	2.39	2.76	2.72
1000 grain weight (g)	21.74	25.91	22.80	15.10	28.63	28.52	28.21
Yield/hill (g)	11.31	11.37	12.98	9.91	6.60	11.42	10.00

University (BSMRAU) and BRRI was run to develop aromatic hybrid rice variety with different parental lines by using rice genetic resources of Bangladesh. A total of 120 aromatic and fine rice germplasm were grown at source nursery in BSMRAU during Aman seasons of 2010, 2011 and 2012. These germplasm were crossed with the standard CMS lines. After that, available test cross F_1s along with their respective pollen parents were grown in test cross nursery during Aman seasons 2011, 2012 and 2013 for judging the pollen sterility and fertility under compound microscope and to identify maintainer and restorer lines respectively. Finally, forty germplasm were identified as maintainer lines and all the maintainer lines were converted into new CMS lines through backcrossing and back cross (BC) generations were advanced for next generations. Besides, eleven restorer lines *viz* SakkorkhoraR, ChiniguraR, KataribhogR, BU dhan2R, BU dhan1R, BRRI dhan50R, SagordanaR, BaoizakiR, JirabhogR, JiradhanR, UkhnimodhuR and Jamai aduryR were identified and maintained.

Grain Quality and Nutrition Division

SUMMARY

Out of 386 breeding lines, 50 had long grain (>6mm) and 130 cultivars had medium grain (5.0-6mm). Only 16 had short grain length (<5mm). On the other hand, the length/breadth ratio of 50 lines were 'Very high' L/B ratio (>3), 129 had 'High' L/B ratio (2.0-3.0) and only seven had 'Medium' L/B ratio (<2). Out of 386 lines, 73 were more than 25.0% amylose, 231 lines were amylose content between the range of 20-25% and 82 lines had less than 20% amylose. Thirty-four lines had high (>9%), 119 had intermediate (7-9%) and 16 had low (<7%) protein content.

We identified four classes of alleles ranged from 100 to 120 bp in length and represented as class-I (100 bp), class-II (110 bp), class-III (116 bp) and class-IV (120 bp) respectively. Most of the high amylose content rice cultivars were grouped in class-I allele (100 bp). Furthermore, single nucleotide polymorphism were used to discriminate very low, low, intermediate and high amylose content rice cultivars. Cultivars of 11% or less amylose had AGTTATA sequence, which indicated very low amylose content cultivars. While, others had AGGTATA sequence, which indicated low, intermediate and high amylose containing cultivars.

Energy requirement for cooking of rice either raw or presoaking condition varies on the varieties. Presoaking affects the cooking time to a great extent and parboiled rice takes more energy than non-parboiled rice for cooking. About 60-65% on average energy can be saved over unparboiled raw rice compared to one hour presoaked unparboiled rice. On the other hand, considering the energy requirement for parboiling paddy and energy requirement for cooking parboiled rice, about 79% energy can be saved over parboiled rice compared to cooking of unparboiled rice.

Two different absolute amounts and ratios of Fe and Zn as well as an increasing amount of Zn solutions were added to soaking water were tested using two different major Bangladeshi rice varieties BRRI dhan29 and BR11 were compared. When both Fe and Zn were combined in the parboil soaking solutions, resulted in an increase in Zn content of the raw, parboiled, polished rice, while the Fe content generally decreased. After washing, Zn retention was very high (93-98%) regardless of treatment and variety whereas the retention of Fe was higher in BRRI dhan29 (85-89%) and lower in BR11 (66-71%). An increasing amount of Zn added to the soaking water of rice paddy resulted in a linear increase in the content of Zn in polished rice. In the raw, polished, parboiled rice, the Zn content increased from a baseline of 12.3 mgg^{-1} dry weight with no added Zn, to 23.6 mgg^{-1} dry weight, representing nearly a doubling (92%) of the Zn content at 300 mgL^{-1} solution (300 $mgkg^{-1}$ paddy). A similar pattern of increase was observed after washing the raw polished rice in excess water, and after cooking the washed rice using excess water.

GRAIN QUALITY CHARACTERISTICS FOR VARIETY DEVELOPMENT

Physicochemical and cooking properties of breeding lines

Grain quality is a combination of physical as well as chemical properties of rice which seems very important for consumer's preference. Since quality of rice is highly influenced by the genetic makeup of a grain, BRRI scientists are continuously trying to improve for better genetic characteristics of grain through breeding programme. A total of 386 paddy samples were provided from three different divisions of BRRI such as 280 breeding lines from Plant Breeding Division, 94 local cultivars from Genetic Resources and Seed Division and 12 biotechnologically derived lines from Biotechnology Division. Milling performance, physical and chemical properties of rough rice, brown rice and milled rice were analyzed for those samples.

Out of 386 samples, 169 were analyzed for physical and cooking properties and 217 were analyzed for amylose only to evaluate their quality. For milling outturn, out of 169 samples, 48 had more than 70% head rice yield (Badsha Bhog, Banatira, Daudin, Dud Sar, Chota, Bhawalia, Bhawalia Amon, Khirai, Jali, Malia, Bhangor, Bote Swar, Lal Roda dhan, Kartik Jhul, Ganga Sagar, Apchaya, Dhal Data, Hasheal Boron, Dudh

Bhanalia, Luta, Baila Bokri, BR7472-16-2-1-2-3, BR7639-68-2-1-1, BRRI dhan39 (ck), BRRI dhan49 (ck), HHZ5-SAL10-DT1-DT1, BRRI dhan39 (ck), SAGC-06, BRRI dhan44 (ck), BR7611-9-3-2-1, BR7830-16-1-5-3, Weed tolerant rice, BR7830-10-4-1, BR7800-63-1-7-3, BRRI dhan28 (ck), BR7182-2B-1-2-HR4, BR6976-2B-11-1, BR7384-2B-5, BRRI dhan43 (ck), BR8072-AC1-2-3-2-1-1, BR8072-AC5-4-2-1-2-1, BR8072-AC7-4-1-2-2-4, BR8072-AC8-1-1-2-1-1, BR8072-AC9-1-1-2-1-1, BR9782-AC3-1-3-2-3-3, BRRI dhan28 (ck), Niamat (ck), BR7881-10-1-5-3-1 RYT, BR7669-11-1-2-8-2-1 RYT, IR85850-75-2-2-3-2) and 65 had more than 85% head rice yield (Badsha Bhog, Banatira, Daudin, Dharial, Dud Sar, Dhepi, Gabora, Inra Sail, Jesso Balam, Jhinga Sail, Khirai Jali, Lati Sail, Malia Bhangor, Marich Bati, Nizer Sail, Patnai-23, Pashu Sail, Pukhi, Dhala Saita, Loroi, Bote Swar, Lal Roda dhan, Rata Sail, Lambo Sail, Marich Ful, Ropa Amon, Kartik Sail, Katrik Sail-2, Katrik Jhul, Lotha, Ganga Sagar, Pankait, Holid Jaran, Apchaya, Aricha Digh, Jhul Digh, Boron, Dhal Data, Haseal Boron, Chota Bhawalia, Bhora Bhawalia, Achaya, Diga, Manik Diga-1, Manik Diga-2, Bhanal Diga, Bora Diga, Dudh Bhawalia, Bhawalia Amon, Gonak Ray, Kala Mona, Belon dhan, Digha-2, Diga, Raj Bhawalia-1, Molla Diga-1, Molla Diga-2, Bhawalia-2, Bhawalia, Netpasha, Muktahar, Chini Sagar, Bansha Pur, Roshon Bok, Dhoil Ush). Appearance or colour of milled rice is one of the important physical properties to attract consumer's attention. All of the samples were brown in colour. Out of 63 kernels, 31 were translucent (Table 1) (Badsha Bhog, Daudin, Dhala Saita, Dud Sar, Dular, Gabora, Godalaki, Hashai Kalmi, Indra Sail, Jesso Balam, Jhinga Sail, Lati Sail, Malia Bhangor, Nizer Sail, Pashu Sail, Tilocikachari, Dhala Saita, Rata Sail, Marich Ful, Lotha, Holid Jaran,; Apchaya, Jamai Bhog, Aricha Digh, Boron, Sechi, Bhora Bhawalia, Diga, Manik Diga-1, Manik Diga-2, Bhanal Diga, Dudh Bhanalia, Kala Mona, Suna Digha-2, Rai Bhawalia-1, Bhawalia-1, Bawoi Jhak-3, Bawoi Jhak-6, MI-Pajang, Chakila, Shitki Saita, Muktahar, Bansha Pur, Roshon Bok, BR7472-16-2-1-2-3, BR7622-5-1-1-1, BR7639-68-2-1-1 BRRI dhan39 (ck), BRRI dhan49 (ck), BR7357-11-2-4-1-1, BR7369-16-5-2-3-1, BRRI dhan34 (ck),

Table 1. Physical and cooking properties of samples (including breeding lines, local cultivars and biotechnologically derived lines).

Range	Plant Breeding Division (n=63)	Genetic Recourses and Seed Division (n=94)	Biotechnology Division (n=12)
Milling outturn (%)			
>70.0	21	19	8
68.0-70.0	30	61	4
<68.0	12	14	-
Head rice recovery (%)			
>85.0		65	
75.0-70.0	-	19	-
68.0-74.0	1	4	
<68.0	62	6	12
Chalkiness (%)			
0 (Tr)	26	-	5
<10.0	4	-	-
10.0-20.0	19	-	5
>20	2	-	2
Length (mm)			
>6.0	34	7	9
5.0-6.0	26	74	3
<5.0	3	13	-
L/B ratio			
>3.0	21	3	9
2.0-3.0	42	84	3
<2.0		7	-
Size and shape			
ELS	1	2	-
LS	16	1	9
LB	16	4	3
MS	7	-	-
MB	22	72	-
SS	-	-	-
SB	1	6	-
SR	-	9	-
Cooking time (minute)			
>20.0	3	18	-
15.0-19.0	56	70	12
<15.0	4	6	-

*Tr- Translucent.

BRRIdhan37(ck), BRRI dhan39 (ck), IR83383-B-B-129-4, IR83373-B-B-27-4, IR87707-446-B-B-B, IR82589-B-B-84-3, BRRI dhan56 (ck), IR83140-B-28-B, IR83142-B-19-B, IR83142-B-60-B, HHZ5-SAL10-DT1-DT1; BRRI dhan39 (ck), BR7833-11-1-1-2-2B5, OM1490, BR6800-1-1-1, BR8072-AC1-2-3-2-1-1, BR8072-AC4-2-1-2-2-1, BR8072-AC5-4-2-1-2-1, BR8072-AC6-3-1-2-4-1, BR802-78-2-1-1 (ck), BR7669-11-1-2-8-2-1 RYT, BR7833-11-1-1-2-1-2B5, IR85850-75-2-2-3-2(IR 10M 300). The consumers in our country prefer

long and medium slender grain. Among 169 samples, 50 had long grain (>6mm) (Dud Sar, Dular, Dhepi, Nizer Sail, Pashu Sail, Chini Sagar, Roshon Bok, BR7472-16-2-1-2-3, BR7622-5-1-1-1, BR7357-11-2-4-1-1, BR7369-16-5-2-3-1, IR83383-B-B-129-4, IR83373-B-B-27-4, IR87707-446-B-B-B, IR82589-B-B-84-3, BRRI dhan56 (ck), IR83140-B-28-B, IR83142-B-19-B, IR83142-B-60-B, HHZ5-SAL10-DT1-DT1, IR83140-B-11-B, HUA 565, IR83377-B-B-93-3, IR83383-B-B141-2, BRRI dhan56, BR7830-16-1-5-3, BR7830-10-4-1, BR7671-37-2-2-3-7, BRRI dhan55 (ck), OM1490, BR7587-2B-3, BR7178-2B-19, BR6976-2B-11-1, BR7384-2B-5, BR6800-1-1-1, BR6855-3B-12, BR6848-3B-12, BR6976-2B-11-1, BR8072-AC1-2-3-2-1-1, BR8072-AC4-2-1-2-2-1, BR8072-AC5-4-2-1-2-1, BR8072-AC6-3-1-2-4-1, BR8072-AC7-4-1-2-2-4, BR8072-AC8-1-1-2-1-1, BR8072-AC9-1-1-2-1-1, BR10384-AC10-2-1-3-1, Niamat (ck), BR7669-11-1-2-8-2-1 RYT, IR85850-75-2-2-3-2(IR 10M 300), PSBRC 82 (IRRI 123) RYT) and 103 had medium grain (5-6mm). Only 16 had short grain length (<5mm). On the other hand, the length/breadth (L/B) ratio of 33 samples had 'Very high' L/B ratio (>3) Nizer Sail, Pashu Sail, Roshon Bok, BR7472-16-2-1-2-3, BRRI dhan39 (ck), BR7357-11-2-4-1-1, BR7369-16-5-2-3-1, BRRI dhan37 (ck), BRRI dhan39 (ck), IR83383-B-B-129-4, IR83373-B-B-27-4, IR83140-B-28-B, IR83142-B-19-B, IR83142-B-60-B, HHZ5-SAL10-DT1-DT1, IR83377-B-B-93-3, IR83383-B-B141-2, BRRI dhan28 (ck), BRRI dhan55 (ck), OM1490, BR6800-1-1-1, BR8072-AC1-2-3-2-1-1, BR8072-AC4-2-1-2-2-1, BR8072-AC5-4-2-1-2-1, BR8072-AC6-3-1-2-4-1, BR8072-AC7-4-1-2-2-4, BR8072-AC8-1-1-2-1-1, BR8072-AC9-1-1-2-1-1, BRRI dhan28 (ck), Niamat (ck), BR7669-11-1-2-8-2-1 RYT; IR85850-75-2-2-3-2 (IR 10M 300), PSBRC 82 (IRRI 123) RYT) 129 had 'High' L/B ratio (2-3) and only seven had 'Medium' L/B ratio (<2). Grain length (L) and (L/B) ratio determines the grain size and shape. Out of 169 samples, three were extra long slender (Pashu Sail, Roshon Bok, IR85850-75-2-2-3-2(IR 10M 300), followed by 26 were long slender, 23 were long bold, seven were medium slender, 94 were medium bold, seven were short bold and nine were short round. In Bangladesh, medium slender

and medium bold grains are suitable for milling. But long slender rice is sold at high price in the market. Among the samples, 21 had more than 20 minutes cooking time and 138 had cooking time between the ranges of 20-15 minutes (Table 1) and 10 (Badsha Bhog, Daudin, Patnai-23, Dudh Bhanalia, Kala Mona, Belon Dhan, BR7369-16-5-2-3-1, BRRI dhan34 (ck), IR83383-B-B-129-4, Zhongzu 14 had cooking time lower than 15 minutes.

Rice contains two types of starch namely amylose and amylopection. Amylose content of rice grain determines the stickiness of cooked rice. More than 25% amylose content gives non-sticky cooked rice; 20-25% amylose containing rice gives soft and comparatively sticky cooked rice. Out of 386 samples, 73 (Jesso Balam, Jhinga Sail, Khirai Jali, Lati Sail, Nizer Sail, Panbira, Panbira-23, Pashu Sail, Pukhi, Raja Sail, Tilocikachari, Hasha Kumira, Dhala Saita, Loroi, Bote Swar, Lal Roda dhan, Rata Sail, Lambo Sail, Marich Ful, Ropa Amon, Kartik Sail, Kartik Sail-2, Kartik Jhul, Lotha, Ganga Sagar, Apchaya, Diga, Manik Diga-1, Manik Diga-2, Goirol, Bhawalia Amon, Hash Ful, BR8143-53-3-1-1-1, BR8444-50-3-1-1, BR7831-59-1-1-4-3-1-7-P2, BR7831-59-1-1-4-5-1-9-P4, BR7831-59-1-1-4-6-1-10-P3, BR8631-12-3-6-P3, BR8417-5-5-27-69-P1, BR7671-37-2-2-3-7-3-P5, BR7671-37-2-2-3-7-3-P16, BR7833-19-2-3-5-P3, BR7833-19-2-3-5-P10, BR7831-59-1-1-4-3-1-7, BR8626-19-5-1-2; BR7528-2R-19-HR16-13-3-2, BRRI dhan39 (ck), BRRI dhan39 (ck), HHZ5-SAL10-DT1-DT1, BRRI dhan39 (ck), BRRI dhan44 (ck), BR7611-31-5-3-2, BR7974-1-3-1-P1, BR7812-19-1-6-1-P2, BR7830-16-1-5-3, BR7671-37-2-2-3-7, BR7833-11-1-1-2-2B5, BRRI dhan28 (ck), OM1490, BR7587-2B-3, BR7182-2B-1-2-HR4, BR7384-2B-5, BRRI dhan43(ck), BR6800-1-1-1, BR6855-3B-12, BR6855-3B-13, BR6848-3B-12, BRRI dhan43 (ck), BR8072-AC1-2-3-2-1-1, BR8072-AC5-4-2-1-2-1, BR9782-AC3-1-3-2-3-3, BRRI dhan28 (ck); Niamat (ck); BRRI dhan50) were more than 25% amylose, 231 samples had amylose content between the range of (20-25%) and 82 had less than 20% amylose (Table 2). Protein content is the measure of the nutritional value of rice. Thirty-four (Banatira, Dhala Saita, Hashi Kalmi, Kartik Jhul, Holid Jaran,

Apchaya, Jamai Bhog, Aricha Digh, Mank Diga-1, Goirol, Bash Ful, Bawoi Jhak-4, Bawoi Jhak-6, MI-Pajng, Chakil, Lema, BR7357-11-2-4-1-1, BR7369-16-5-2-3-1, BRRI dhan34 (ck), BRRI dhan37 (ck), IR82589-B-B-84-3, IR83140-B-28-B, IR83142-B-19-B, IR83142-B-60-B, HHZ5-SAL10-DT1-DT1, BRRI dhan39 (ck), Zhongzu14, HUA 565, BR7611-9-3-2-1, IR82635-B-B-75-2, IR82635-B-B-145-1, IR82589-B-B-84-3, BR8072-AC5-4-2-1-2-1, BR8072-AC6-3-1-2-4-1, BR8072-AC7-4-1-2-2-4, BR8072-AC8-1-1-2-1-1, Niamat (Ck)) samples had high (>9%), 119 had intermediate (7-9%) and 16 had low (<7%) protein content. Generally, a variety, having less than 7% protein content in brown rice, is not recommended for release (Table 2). Imbibition ratio (Volume expansion) is one of the important parameters for rice quality. It shows the value of expansion of rice after cooking. Hard working people of our country prefer rice having more volume expansion. Out of 169 samples, volume expansion ratio of 44 (Badsha Bhog, Dud Sar, Dhepi, Gabora, Hashi Kalmi, Hati Sail, Jhinga Sail, Lati Sail, Malia Bhangor, Pukhi, Hasha Kumaria, Dhala Saita, Loroi, Rata Sail, Lambo Sail, Marich Ful, Kakrik Sail, Holid Jaran, Jamai Bhog, Sechi, Achya, Bhanal Diga, Gabura, Molla Diga-1, Molla Diga-2,

Bhawalia-2, Bhawalia, Ijol Diga, Bawoi Jhak-4, MI-PAJANG; Shitki Saita, Chini Sagar, BRRI dhan44 (ck), BR7611-17-2-2-2, BR7611-31-5-3-2, IR83377-B-B-93-3, IR83383-B-B141-2, IR82635-B-B-145-1, BRRI dhan43(ck); BRRI dhan28 (ck); BR7881-10-1-5-3-1 RYT; BR7833-11-1-1-3-4 RYT; BR7669-11-1-2-8-2-1 RYT; BR7830-16-1-5-9-9 RYT) samples were >4, 60 samples had within 3.5-4.0 and65 samples were less than 3.5 (Table 2). Elongation ratio is responsible for fine or coarse cooked rice. If rice elongation is more in length, it gives a finer appearance, but if expands in breadth, it gives a coarse look. Long slender and medium slender rice should elongate more in length (Khirai Jali, Ropa Amon, Dhal Data, Sechi; Bhawali Amon, Kala Mona, Luta, Gabura, Molla Diga-1, Molla Diga-2, Baila Bokri, Bansha Pur, Roshon Bok, BR7671-37-2-2-3-7; BRRI dhan28 (ck); BRRI dhan43 (ck)), as they are consumed mostly by people having higher income. The elongation ratio of most of the samples varied between 1.3-1.5 (Table 2). Details of these promising samples' physiochemical and cooking properties information along with their respective divisional accession number were kept at GQN Division.

EVALUATION OF GENETIC DIVERSITY OF *WAXY* GENE IN SELECTED RICE GERMPLASM

Amylose content in rice grain is one of the most important traits of eating, cooking and processing quality that determines market price of rice. Traditionally amylose content is determined from the matured rice grain. But microsatellite marker (RM190) and restriction enzyme (AccI) are used to determine amylose content at the seedling stage.

Waxy gene encodes granule-bound starch synthase that is responsible for amylose content in rice endosperm. Thirty-five BRRI germplasm cultivars were collected from GRS Division. DNA was extracted from fresh leaves (14 days) using the (CTAB) method (Doyle, 1991) Rice microsatellite marker RM190, GBSSW2 and restriction enzyme AccI were used to amplify isolated DNA to find out polymorphism among the cultivars. For determination of allelic variations of *Waxy* gene,

Table 2. Chemical properties of breeding lines (including breeding lines, local cultivars and biotechnologically derived lines).

Range	Plant Breeding Division (n=280)	Genetic Recourses and Seed Division (n=94)	Biotechnology Division (n=12)
Amylose content (%)			
>25.0			
36	32	5	
20.0-25.0	169	58	4
<20.0	75	4	3
Protein content (%)			
>9.0	13	16	5
7.0-9.0	35	77	7
<7.0	15	1	-
Volume expansion ratio			
>4.0	10	34	-
3.5-4.0	12	42	6
<3.5	41	18	6
Elongation ratio			
>1.5	4	12	1
1.3-1.5	51	76	1
<1.3	8	6	10

35 cultivars were selected based on amylose content and analyzed by microsatellite marker RM190F-R for polymorphism and cleaved amplified polymorphic sequence marker RM190F-GBSSW2R for G/T single nucleotide polymorphism (SNP) (Table 3). Result of this study identified Identified four classes of alleles ranged from 100-120 bp in length and represented as class-I (100 bp), class-II (110 bp), class-III (116 bp) and class-IV (120 bp) respectively. Most of the high amylose content rice cultivars were grouped in class-I allele (100bp) (Figs. 1 and 2). Furthermore, single nucleotide polymorphisms were used to discriminate very low, low, intermediate and high amylose content rice cultivars. Cultivars of 11% or less amylose had AGTTATA sequence, which indicated very low amylose content cultivars. Others had AGGTATA sequence, which indicated low, intermediate and high amylose containing cultivars (Fig. 3).

ENERGY SAVING IN COOKING

About 55 million tons of paddy are produced in Bangladesh annually of which 90% of the rice is consumed as parboiled condition. People in Bangladesh are habituated to the taste of parboiled rice, which is claimed to have a better shelf-life than raw rice (unparboiled) due to the

Table 3. Polymorphism in the Waxy gene by microsatellite classes and SNP (G/T) variation.

Variety	Length of grain	Class of amylose				G/T	RM190 classes based on band size in base pairs (bp)			
		High	Intermediate	Low	Very low		100	110	116	120
Motichak	M	26				G		+		
Neda	L	26				G		+		
Joal Bogh	L	26				G	+			
Patnai-231	L	29				G		+		
Kala Binni	L				6	T				+
Kalimanik	L		25			G			+	
Jol	L	28				G			+	
Cylindrical Tepi-629	L				6.1	T	+			
Dudh Kalam	L	26				G	+			
Kanai Bansi	L			18		G	+			
Maloti	M		23			G	+			
Leda Binni	M			11		G	+			
Ranga Binni	M				5.2	T	+			
Gohati Binni	L				8.4	T			+	
Dud Sail	S		21			G				+
Magoi Balam	M	27				G	+			
Baoi jhaki	S		21			G				+
Latha mona	L	28				G	+			
Hari Laxmi	L		24			G				+
Pakhisail	L	28				G		+		
Tepe Boro	S		22			G		+		
Depa	L	29				G	+			
Boradudh Kalam	L	26				G		+		
Karaila dhan	L	29				G		+		
Poush Moricha	M	29				G		+		
Molla Digha	L	27				G	+			
Boylam	M	25.2				G	+			
Khorma	L			17		G	+			
Binni -1	L				5	T				+
Khar mao	L		21			G		+		
BR11	L	26				G	+			
BRRI dhan28	M	28				G	+			
BRRI dhan29	M	29				G	+			
Binni -2	L				6	T				+
Hati Sail	L		24			G				+
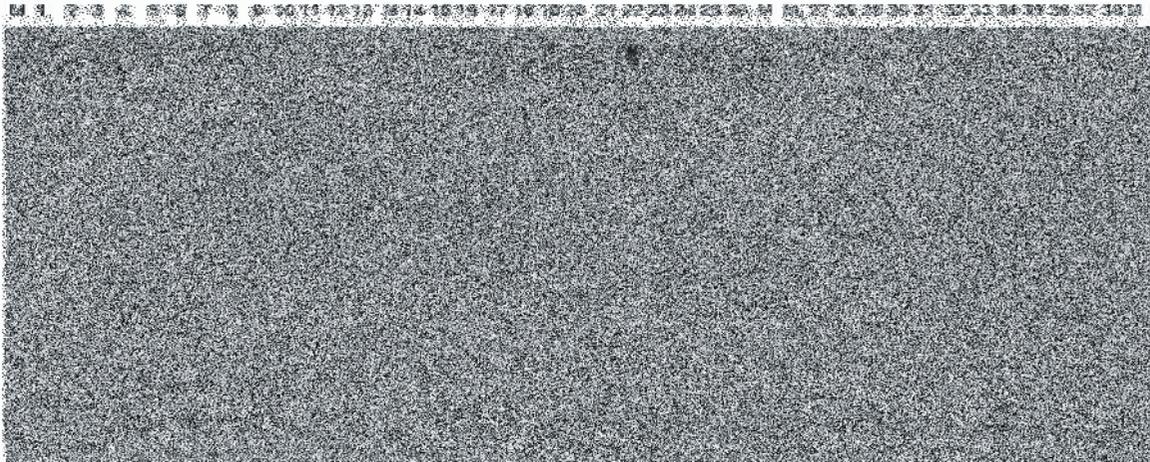
Fig. 1. PAGE showing four classes of allele of rice cultivars, class-I (100 bp), class-II (110 bp), class-III (116 bp) and class-IV (120 bp). In the above figure numerical values indicates the variety name: 1. Shita Bhog, 2. Joal Bhog, 3. TR Aman, 4. BRRI dhan28, 5. BRRI dhan29, 6. Kalimanik, 7. Jol, 8. Cylindrical Tepi-629, 9. Kanai Bansi, 10. Maloti, 11. Ata Binni, 12. Leda Binni, 13. Ranga Binni, 14. Hatisail, 15. Gohati Binni, 16. Baoijaki, 17. Lathamona, 18. Hari laxmi, 19. Pakhi Sail, 20. Tepe Boro, 21. Kala Binni, 22. Dud Sail, 23. Khorma, 24. Binni-1, 25. Binni-2, 26. Khorma, 27. Motichak, 28. Neda, 29. Patnai-231, 30. Dudh Kalam, 31. Magoi Balam, 32. Depa, 33. Borodudh Kalam, 34. Karaila dhan, 35. Poush Moricha, 36. Molla Digha, 37. Boylam, 38. BR11 and M- 1kb+ ladder, M1- 200 bp ladder.
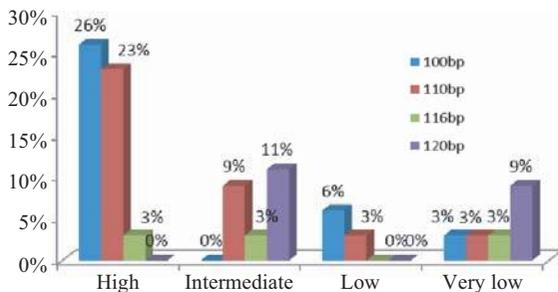
Fig. 2. The relationship between amylose content and SSR alleles.

gelatinization of starch. Cooking rice without presoaking is the general practice in many parts of the world especially in Bangladesh. While presoaking needs to be promoted as an energy conservation measure, there is a necessity to look for further saving in energy.

A total of 61 BRRI released rice varieties were taken for determining the energy requirement for parboiling of paddy and cooking of rice on the basis of parboiled and unparboiled condition. Substantially, it revealed from the experiment that unparboiled rice took less energy than parboiled one. Moreover, energy requirement varied and required less with the increasing of soaking time. Without soaking of rice on average 0.47 kWh and 0.54 kWh energy required for unparboiled and parboiled rice respectively. For 1 hour soaking 0.28 kWh and 0.37 kWh energy required and for 2 hour soaking it took 0.24 and 0.34 kWh for cooking unparboiled and parboiled rice respectively (Table 4).

Cooking of parboiled rice concerned with the parboiling of paddy which involved huge energy. More energy requirement is associated with the cooking of parboiled rice as extra energy needed for parboiling paddy. On average, 1.34 kWh, 1.17 kWh and 1.14 kWh energy required for 0h, 1h and 2h soaking of rice including energy required for parboiling of paddy (Table 5). Average energy required for cooking unparboiled rice ranged from 0.24 kWh to 0.47 kWh. On the contrary, average energy required for cooking parboiled rice ranged from 1.44 kWh to 1.34 kWh depend on the variety Cooking unparboiled rice can save huge amount of energy over parboiled condition where no need of parboiling paddy (Table 6). On average up to 79% energy can be saved over cooking parboiled rice compared to cooking of un-parboiled rice. Cooking after 1 hour and 2 hour soaking of unparboiled rice can save 76% and 79% energy respectively which are closer and 53% can be saved without presoaking of rice (Table 7).
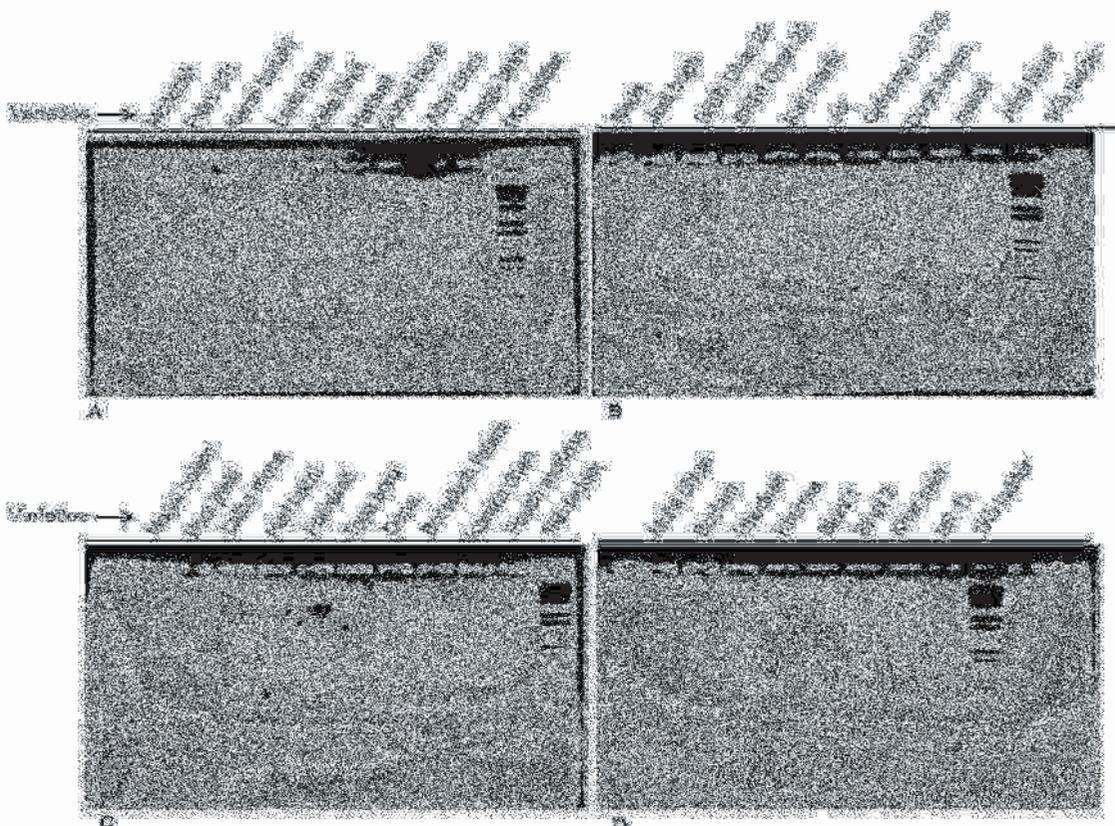
Fig. 3. AGE of PCR products showing the single nucleotide substitution (G/T polymorphisms) assayed by AccI digestion. 1kb ladder used as MW marker.

Table 4. Energy required for parboiling paddy and cooking of un-parboiled and parboiled rice at different soaking periods (n=61).

Parameter	Cooking of rice						
	0 hour soaking		1 hour soaking		2 hour soaking		Paddy parboiling
	Unparboiled	Parboiled	Unparboiled	Parboiled	Unparboiled	Parboiled	
Variety	61	61	61	61	61	61	61
Average energy required (kWh)	0.47	0.54	0.28	0.37	0.24	0.34	0.80
Standard Deviation	0.06	0.07	0.06	0.07	0.04	0.06	0.01
Minimum energy required (kWh)	0.33	0.36	0.01	0.21	0.01	0.20	0.58
Maximum energy required (kWh)	0.60	0.75	0.38	0.55	0.33	0.45	1.10

Table 5. Total energy required for cooking of parboiled rice along with parboiling of paddy at different soaking periods.

Parameter	Cooking along with parboiling		
	0 hour soaking	1 hour soaking	2 hour soaking
	Parboiled	Parboiled	Parboiled
Variety	61	61	61
Average energy required (kWh)	1.34	1.17	1.14
St Dev	0.15	0.15	0.14
SE mean	0.02	0.02	0.02
Minimum energy required (kWh)	1.03	0.86	0.85
Maximum energy required (kWh)	1.73	1.48	1.45

Table 6. Comparison of total energy required for cooking of unparboiled and parboiled rice at different soaking periods.

Parameter	Cooking of rice					
	0 hour soaking		1 hour soaking		2 hour soaking	
	Unparboiled	Parboiled	Unparboiled	Parboiled	Unparboiled	Parboiled
Variety	61	61	61	61	61	61
Average energy required (kWh)	0.47	1.34	0.28	1.17	0.24	1.14
Minimum energy required (kWh)	0.33	1.03	0.01	0.86	0.01	0.85
Maximum energy required (kWh)	0.60	1.73	0.38	1.48	0.33	1.45

Table 7. Energy savings over cooking of parboiled rice compared to un-parboiled rice at different soaking periods.

Parameter	Cooking		
	0 hour soaking	1 hour soaking	2 hour soaking
Variety	61	61	61
Average energy saving (%)	65	76	79
St Dev	3.77	4.64	3.73
Minimum energy saving (%)	53	68	71
Maximum energy saving (%)	72	99	99

THE IMPACT OF ADDING ZINC AND IRON FORTIFICANTS DURING PARBOILING ON THE ZINC AND IRON CONTENT OF RAW AND COOKED BANGLADESHI RICE

Parboiling offers an opportunity to increase the zinc and iron content of rice by adding Fe and Zn fortificants to the soaking water before parboiling. The objective of this study was to determine the increase in Zn and Fe content in Bangladeshi rice varieties when Zn-sulfate and Fe-EDTA, in different ratio, were added to the soaking water before parboiling, following local parboiling conditions. The dose-response effect of adding increasing amounts of Zn-sulfate alone to the soaking water was also studied.

The studies were conducted at the Grain Quality and Nutrition Division laboratory of BRRI. Two different absolute amounts and ratios of Fe and Zn added simultaneously to soaking water (150:100 and 200:150mgL^{-1}) as selected on the basis of results of previous studies. The study was conducted using two major Bangladeshi rice varieties representing the two main growing seasons: one Boro rice variety (BRRI dhan29) and one Aman variety (BR11). The dose-response study was conducted using only BRRI dhan29, where Zn was added to soaking water at increasing concentrations. The changes in Zn and Fe content were determined in raw rice, and cooked rice after washing and cooking and the retention of Zn and Fe were calculated.

An increasing amount of Zn added to the soaking water of rice paddy resulted in a linear increase in the content of Zn in polished rice (Fig. 4). In the raw, polished, parboiled rice, the Zn content increased from a baseline of 12.3 mgg^{-1} dry weight with no added Zn, to 23.6 mgg^{-1} dry weight, representing nearly a doubling (a 92% increase) of the Zn content at 300 mgL^{-1} solution (or 300 mgkg^{-1} paddy). A similar pattern of increase was also observed after washing the raw polished rice in excess water, and after cooking the washed rice in excess water.
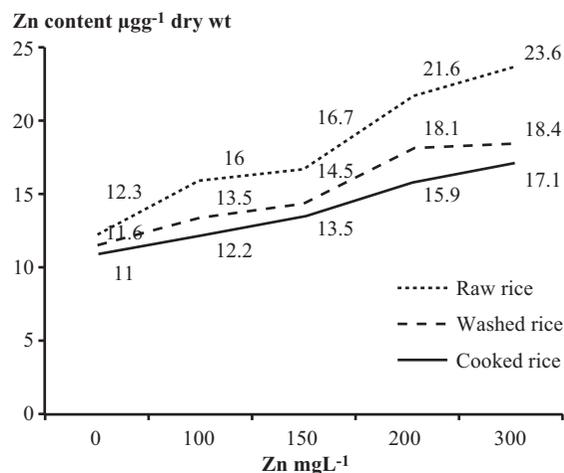
Fig. 4. Zn content in parboiled rice produced with Fe-EDTA and Zn sulfate added to the parboil soaking water measured in polished raw rice before and after washing, and after cooking.

When expressed as the percent retention of Zn in the raw, polished, parboiled rice, the washing and cooking protocols resulted in a moderate to high rate of retention, ranging from 72-94% across all levels of Zn solution tested (Fig. 5). Zn retention in washed and cooked samples declined, however, with increasing amount of Zn in the soaking water. As a result, the magnitude of increase in Zn content over the control was lower in the washed and cooked rice samples achieving, respectively, a 59% and 55% increase in Zn content over the control in the 300 mgL^{-1} soaking water (Fig. 4). When both Fe and Zn were combined in the parboil soaking solutions, both

Fe:Zn ratios tested resulted in an increase in Zn content of the raw, parboiled, polished rice, while the Fe content generally decreased (Table 8). The magnitude of increase in the Zn content of the parboiled polished rice was observed to be substantially lower with the solution containing higher concentrations of Fe and Zn. This pattern of change in Fe and Zn content were somewhat different in brown rice (Table 8). The magnitude of increase in Zn content was higher in brown rice compared to polished rice, but the lower magnitude of increase with higher concentration of Fe and Zn in the soaking water was still observed. However, in case of Fe content, a small positive change was observed rather than the negative change observed with polished rice.

In this experiment combining Fe and Zn, the retention of these minerals after washing and soaking was determined for the control and 150:100 Fe:Zn ratio solution in both BRRI dhan29 and BR11 varieties. After washing, Zn retention was very high (93-98%) regardless of treatment and variety whereas the retention of Fe was higher in BRRI dhan29 (85-89%) and lower in BR11 (66-71%). This general pattern was observed as well after cooking; the retention of Zn remained high, although was higher in the control rice than in the 150:100 (Fe:Zn) solution, as was observed for studies using Zn alone. In case of Fe retention after cooking was moderately high in BRRI dhan29 (75-81%) but again lower in BR11 (63%).

Zn retention (100 µgg^{-1})

Fig. 5. Retention of Zn in parboiled rice produced with Fe-EDTA and Zn sulfate added to the parboil soaking water, measured in polished rice after washing and after cooking.

Table 8. Fe and Zn content of parboiled brown and polished rice produced with Fe-EDTA and Zn sulfate added to the parboil soaking water.

Variety	Soaking water	Zn		Fe	
	Fe:Zn (mgL^{-1})	Mgkg^{-1} dry weight	Change (%)	Mgkg^{-1} dry weight	Change (%)
		Brown rice			
BRRI dhan29	0	22.3	-	11.2	-
	150:100	33.7	+ 51	11.4	+ 2
	200:150	31.3	+ 40	11.5	+ 3
BR11	0	16.4	-	9.7	-
	150:100	25.0	+ 52	10.3	+ 6
	200:150	23.2	+ 41	10.5	+ 8
		Polished rice			
BRRI dhan29	0	12.3	-	5.2	-
	150:100	17.6	+ 43	5.3	+ 2
	200:150	15.1	+ 23	4.6	- 12
BR11	0	6.7	-	6.5	-
	150:100	9.9	+ 48	4.9	- 25
	200:150	8.5	+ 27	5.0	- 23

Hybrid Rice Division

SUMMARY

During T. Aman season 2013, 35 test crosses and 60 (A × R) crosses were made from source nursery. Twenty-four test crosses (F_1s) were evaluated for their pollen fertility status of which two entries have been found heterotic over check varieties. Pollen parents of those combinations were regarded as suspected restorers and selected for fertility restoration ability with other CMS lines in the next season. All the backcross generations were stable in terms of pollen sterility and other desirable agronomic traits except for one BC_1 combination (BRRI53A/IR87584-11-3-1). It showed incomplete pollen sterility and hence discarded. A total of 118 CMS lines along with their respective maintainer lines were maintained by hand crossing. Forty BB resistant parental lines were selected from pedigree nursery and advanced as F_6 generations.

A total of 242 test crosses and 142 (A × R) crosses were made using seven CMS lines during Boro season 2013-14. Forty test crosses (F_1s) were evaluated for their pollen fertility status but none of the entries shown complete sterile or high fertility hence the entire test crosses were rejected. Three BC_6 generations were stable in terms of pollen sterility and other desirable agronomic characteristics and shifted to CMS nursery as new CMS line in the background of corresponding elite maintainer lines. Other BC generations were advanced for next generations. In total 118 CMS lines along with their respective maintainer lines were maintained by hand crossing.

Out of 130 hybrids under observational trials nine combinations were selected based on yield, duration and grain type and produced more than 10-25% yield advantage over the check varieties BR11 and BRRI dhan49 with one to two weeks shorter growth duration. Out of 65 hybrids nine combinations were selected based on yield, duration and grain type and showed yield advantage ranging from 31-50% over BRRI dhan28 and 2-17% over BRRI dhan29. Under preliminary yield trials one hybrid (IR79156A/BRRI20R) out of five produced 1.27 t/ha and 1.05 yield advantage over BR11 and BRRI dhan49 respectively during T. Aman 2013 and during Boro season 2013-14, four hybrids out of 14 showed yield advantage ranging from 1.94 to 3.31 t/ha over BRRI dhan28. National hybrid rice yield trials were conducted through SCA during T. Aman 2013 and Boro 2013-14 which included 16 and 49 hybrids. Results were compiled by SCA.

Seed yield of 70 kg/plot (1.5 t/ha), 48 kg/plot (1.5 t/ha) and 22 kg/plot (1.1 t/ha) were obtained from BRRI10A, BRRI11A line and IR58025A, respectively in T. Aman season. On the other hand, during Boro 2013-14 seasons, CMS seed yield of 75 kg (1.3 t/ha), 90 kg (1.4 t/ha) and 23 kg (1.1 t/ha) were obtained from BRRI10A/B, BRRI11A/B and IR58025A/B, respectively. Ninety kg (1.4 t/ha), 30 kg (1.4 t/ha) and 32 kg (1.2 t/ha) hybrid seeds were produced from BRRI11A/BRRI15R, BRRI10A/BRRI10R and IR58025A/BRRI10R respectively in 2013 T. Aman season. During Boro 2013-14 seasons, F_1 seeds of released hybrids were obtained 18 kg (1.6 t/ha) from BRRI hybrid dhan1, 150 kg (2.5 t/ha) from BRRI hybrid dhan2, 180 kg (2.8 t/ha) from BRRI hybrid dhan3 and 40 kg (1.9 t/ha) from BRRI hybrid dhan4. An experiment was conducted to determine suitable row ratio and dosages of GA_3 of selected promising hybrid rice combination and got the highest yield 3.49 t/ha in 2: 10 row ratios with GA_3 240 g/ha.

During the reporting year, Hybrid Division supplied 665 kg of parental lines and F_1 seeds among 32 farmers, four seed companies, scientists and staffs of BRRI and BADC.

DEVELOPMENT OF PARENTAL MATERIALS

Source nursery
Thirty-five test crosses and 60 (A × R) crosses were made using 11 CMS lines during T. Aman season 2013. A total of 242 test crosses and 142 (A × R) crosses were made using seven CMS lines during Boro 2013-14.

Test cross nursery
In 2013 T. Aman season 24 test crosses (F_1s) were evaluated for their pollen fertility status of which two entries have been found heterotic over standard check variety having yield advantage ranging from 29-40% over BR11 and 7-16% over BRRI dhan49. In Boro 2013-14, forty test crosses were evaluated but none of the entries showed complete pollen sterility and high pollen fertility.

Back cross nursery
In T. Aman 2013, all the backcross generations were stable in terms of pollen sterility and other desirable agronomic traits except one BC_1 combi-

nation (BRRI53A/IR87584-11-3-1). It showed unstable pollen sterility and hence it was discarded. In Boro season 2013-14, three BC_6 generations were stable in terms of pollen sterility and other desirable agronomic characteristics and shifted to CMS nursery as new CMS line in the background of corresponding elite maintainer lines (Table 1).

CMS maintenance and evaluation nursery
A total of 118 CMS lines were maintained by hand crossing for seed increase and genetic purity during T. Aman 2013 and Boro 2013-14.

Pedigree nursery for development of BB resistance parental lines of hybrid rice
Forty-five progenies were selected as F_6 generations from three cross combinations during T. Aman 2013 and 28 progenies as F_7 from Boro 2013-14.

EVALUATION OF EXPERIMENTAL HYBRIDS

Out of 130 hybrids nine combinations were selected based on yield, duration and grain type (Table 2). In Boro 2013-14, out of 65 hybrids nine combinations were selected based on yield, duration and grain type (Table 3). None of the hybrids showed complete superiority over the check variety BRRI hybrid dhan3. For commercial seed production feasibility of these selected hybrid combinations multilocation trials will be conducted and based on satisfactory yield advantage over the check hybrid combination will be submitted to SCA trials.

Preliminary yield trials of promising hybrids
In T. Aman 2013, IR79156A/BRRI20R produced 1.27 t/ha yield advantage over BR11 and 1.05 t/ha yield advantage over BRRI dhan49 and growth duration 32 and 22 days earlier than BR11 and BRRI dhan49 (Table 4). In Boro 2013-14, four entries produced more 2 to 3 t/ha yield advantage over standard check variety of BRRI dhan28. The selected entries were BRRI7A/BRRI31R (3.31 t/ha) followed by BRRI33A/BRRI31R (2.96 t/ha), BRRI11A/F2277R (2.05 t/ha) and IR79156A/ BRRI20R (1.94 t/ha) and among the selected hybrids two hybrids showed more than one ton yield advantage over hybrid SL8H (Table 5).

Determination of suitable row ratio and dosages of GA_3 of a selected promising hybrid rice variety
Maximum seed yield (3.49 t/ha) was obtained from the application of GA_3 at the rate of 240 g/ha with row ratio of 2:10 and the lowest (0.97 t/ha) was obtained from control plot having row ratio of 2:14 during Boro 2013-14. GA_3

Table 1. List of newly developed CMS lines from backcross nursery in Boro 2013-14.

BC generation	Combination	Sterility status	Grain type	Seed amount	Remark
BC_6	BRRI3A / BR7414-25-1	CS	Slender	80	Adv. as new CMSL
BC_6	BRRI18A/ BR7288-4B-8	CS	Slender	75	Adv. as new CMSL, grain with purple shade
BC_6	BRRI25A/ WAB 96-1-1	CS	Medium	55	Adv. as new CMSL

DS: P_1=2 Dec 2013, P_2/F_1= 5 Dec 2013, P_3=8 Dec 2013; DT: 13 Jan 2014. Adv. as new CMSL=Advanced as new CMS lines.

Table 2. Results of observational trials (OT) in T. Aman 2013.

Entry no.	Designation	Plant ht (cm)	E/T	DFF	SF (%)	Maturity (day)	Yield (t/ha)	Grain type	Yield advantage (%) over		
									Ck-1	Ck-2	Ck-3
3	Jin23A/BAU521R	120.2	10	88	83.87	116	8.09	S	23.51	22.58	3.32
11	IR79156A/BAU521R	121.6	11	91	81.67	120	8.35	MS	27.48	26.52	6.64
29	BRRI7A /BAU521R	123.8	9.3	87	85.39	116	7.80	M	19.08	18.18	-
32	BRRI7A/BR1543-1-1-1-1	113.4	7.2	94	78.23	122	7.25	S	10.68	9.85	-
47	BRRI13A/BAU521R	117.6	7.4	98	82.30	126	7.55	S	15.27	14.39	-
52	BRRI28A/BAU521R	113.2	8.6	91	83.55	118	8.05	S	22.90	21.97	2.81
62	BRRI46A/BAU521R	121.4	7.4	90	80.60	118	7.55	S	10.68	9.85	-
84	BRRI48A/ BAU521R	118.3	7.3	96	77.25	123	7.36	S	12.37	11.52	-
128	BRRI11A/BR1543-1-1-1-1	112.6	7.2	93	77.30	121	7.29	S	11.30	10.45	-
Ck-1	BR11	115	8.0	113	75.40	143	6.55	B	-	-	-
Ck-2	BRRI dhan49	98.5	7.7	107	74.09	133	6.60	MS	-	-	-
Ck-3	BRRI hybrid dhan4	110	8.0	93	81.50	120	7.83	S	19.54	18.64	

DS: 20 Jul 2013, DT: 16 Aug 2013. S=Slender, M=Medium, B=Bold, MS=Medium slender.

Table 3. Results of observational trials (OT) in Boro 2013-14.

Entry no.	Designation	Plant ht (cm)	E/T	DFF	SF (%)	Maturity (day)	Yield (t/ha)	Grain type	Yield advantage (%) over		
									Ck-1	Ck-2	Ck-3
3	Jin23A/BAU521R	110.2	10	121	83.87	146	8.09	S	45.8	13.9	3.3
11	IR79156A/BAU521R	111.6	11	125	81.67	150	8.35	MS	50.5	17.6	6.6
19	BRRI7A/BAU521R	109.8	9.3	120	85.39	146	7.80	M	40.5	9.9	-
26	BRRI7A/BR1543-1-1-1-1	110.4	7.2	119	78.23	145	7.25	S	30.1	2.1	-
33	BRRI13A/BAU521R	111.6	7.4	121	82.30	147	7.55	S	36.01	6.3	-
45	BRRI28A/BAU521R	109.2	8.6	121	83.55	147	8.05	S	45.05	13.4	2.81
48	IR79156A/B.I. Rice	107.3	7.4	120	80.60	148	8.15	S	46.8	14.8	4.09
53	BRRI48A/BAU521R	108.3	7.3	118	77.25	143	7.36	S	32.6	3.7	-
62	BRRI11A/BR1543-1-1-1-1	106.6	7.2	117	77.30	141	7.29	S	31.4	2.8	-
Ck-1	BRRI dhan28	105	8.0	117	75.40	143	5.55	S	-	-	-
Ck-2	BRRI dhan29	98.5	7.7	131	74.09	157	7.10	MS	-	-	-
Ck-3	BRRI hybrid dhan3	110	8.0	124	81.50	150	7.83	M	41.08	10.3	-

DS: 10 Dec 2013, DT: 17 Jan 2014. S=Slender, M=Medium, MS=Medium slender.

Table 4. Results of preliminary yield trial in T. Aman 2013.

Designation	Plant ht (cm)	Maturity (day)	Tiller (no./m²)	Spikelet fertility (%)	Yield (t/ha)	Yield advantage (t/ha)
BRRI13A/ PR828R	112.1	105	243	78	4.84	
BRRI11A/ F2277R	111.6	110	222	82	5.48	
IR79156A/BRRI20R	110.9	108	250	80	6.55	1.27 over BR11 and 1.05 over BRRI dhan49
BRRI11A/AGR	108.8	110	239	82	5.50	
Jin23A/PR344R	104.5	105	178	79	4.62	
BR 11	112.8	140	223	79	5.28	
BRRI dhan49	101.3	130	230	82	5.50	
Lsd $_{(0.05)}$	4.2	13.5	23.1	1.7	0.6	-
CV(%)	4.0	12.0	10.5	2.1	11.4	

DS: 4 Jul 2013, DT: 25 Jul 2013; Plot size: 30 m².

Table 5. Results of preliminary yield trial in Boro 2013-14.

Designation	Plant ht (cm)	Maturity (day)	Spikelet fertility (%)	Effective tiller/m²	Yield (t/ha)	Yield advantage (t/ha)
BRRI13A/PR828R	116.3	150	89	253	5.97	-
BRRI11A/F2277R	111.4	150	87	257	7.29	2.05 t/ha over BRRI dhan28
IR79156A/F2277R	114.8	153	80	315	6.51	-
IR79156A/BRRI20R	115.1	149	85	290	7.18	1.94 t/ha over BRRI dhan28
BRRI11A/AGR	106.9	154	88	260	7.24	-
Jin23A/PR344R	101.1	142	68	304	6.16	-
BRRI7A/BRRI31R	109.6	148	86	235	8.55	3.31 t/ha over BRRI dhan28
BRRI13A/ShaktiR	111.9	151	74	222	6.50	-
BRRI28A/ShaktiR	114.2	150	91	136	7.38	-
BRRI33A/BRRI31R	108.6	148	86	268	8.20	2.96 t/ha over BRRI dhan28
BRRI48A/ShaktiR	110.8	156	78	238	6.76	-
BRRI28A/BRRI26R	117.5	152	83	231	7.10	-
BRRI48A/BRRI26R	110.1	154	81	216	6.79	-
BRRI53A/BRRI26R	110.0	155	91	240	6.82	-
BRRI dhan28 (ck-1)	107.8	141	85	310	5.24	
BRRI dhan29 (ck-2)	099.4	157	81	323	7.41	
BRRI hybrid dhan3 (ck-3)	105.6	148	87	260	8.24	
SL-8H(ck-4)	103.1	152	85	265	7.08	
Lsd$_{(0.05)}$	3.1	2.6	3.6	27.0	0.5	
CV (%)	4.6	2.8	7.1	17.3	11.6	

DS: 10 Dec 2013; DT: 11 Jan 2014. Plot size: 30 m².

application on different level of row ratio combinations significantly affected panicle exertion, out crossing rate and seed yield of a promising hybrid rice combination. The application of GA_3 level of 240 g ha^{-1} at row ratio of 2:10 had maximum significant effects on seed yield of this promising (BRRI33A/ BRRI31R) hybrid combination (Table 6).

SEED PRODUCTION OF PARENTAL LINES AND HYBRIDS

CMS line multiplication of released hybrids
Seed yield 70 kg/plot (1.5 t/ha) and 48 kg/plot (1.5 t/ha) and 22 kg/plot (1.1 t/ha) were obtained from BRRI10A, BRRI11A and IR58025A respectively (Table 7). In Boro 2013-14, seed yield of 75 kg (1.3 t/ha), 90 kg (1.4 t/ha) and 23 kg (1.1 t/ha) were obtained from BRRI10A/B,

BRRI11A/B and IR58025A/B respectively (Table 8).

F_1 hybrid seed production of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan4 T. Aman 2013 and Boro 2013-14
Seed yield was obtained 30 kg (1400 kg/ha) from BRRI10A/BRRI10R, 90 kg (1400 kg/ha) from BRRI11A/BRRI15R and 32 kg (1200 kg/ha) from IR58025A/BRRI10R (Table 9). In Boro 2013-14, seed yield was obtained 150 kg (2.5 t/ha), 180 kg (2.80 t/ha) and 40kg (1.90 t/ha) respectively from BRRI10A/BRRI10R, BRRI11A/BRRI15R and IR58025A/BRRI10R respectively (Table 10).

Dissemination of hybrid rice technology
In the reporting year, hybrid rice division supplied 665.0 kg of parental lines and F_1 seeds to four seed companies including BADC, farmers and BRRI staffs **(**Table 11).

Table 6. Interaction effect of GA_3 and row ratio on seed yield of a promising hybrid (BRRI33A/BRRI31R).

Treatment combination		PER (%)	OCR (%)	Seed yield (t/ha)
GA_3 (0)	2:6	56.60	21.05	0.99
	2:8	59.61	22.78	1.02
	2:10	62.66	26.87	1.08
	2:12	59.93	24.47	1.01
	2:14	57.82	22.92	0.97
GA_3 (80)	2:6	68.38	30.29	1.41
	2:8	71.57	31.35	1.48
	2:10	73.65	33.33	1.54
	2:12	71.76	32.35	1.42
	2:14	70.01	31.03	1.40
GA_3 (160)	2:6	73.19	32.37	1.83
	2:8	75.05	33.22	2.02
	2:10	77.13	33.56	2.21
	2:12	74.32	31.52	1.89
	2:14	72.28	31.42	1.78
GA_3 (240)	2:6	81.11	39.39	2.76
	2:8	83.57	40.65	2.92
	2:10	86.33	41.90	3.49
	2:12	83.09	39.89	3.18
	2:14	81.37	38.87	2.89
GA_3 (320)	2:6	78.55	34.58	2.45
	2:8	79.94	34.73	2.54
	2:10	83.73	36.56	2.62
	2:12	80.18	34.45	2.45
	2:14	78.59	34.17	2.5
Lsd$_{(0.05)}$ for GA_3	0.442	0.617	0.08	
Lsd$_{(0.05)}$ for Row ratio	0.442	0.617	0.08	
Lsd$_{(0.05)}$ for GA_3×Row ratio		0.57	0.80	0.103
CV(%)		0.47	1.49	3.04

DS: R_1=9 Dec 2013, R_2=12 Dec 2013, A=19 Dec 2013; DT: R=13 Jan 2014, A=20 Jan 2014. **Significant at the 1% level of probability. PER=Panicle exertion rate; OCR=Out crossing rate.

Table 7. CMS multiplication of BRRI10A, BRRI11A and IR58025A lines during T. Aman season 2013.

Combination	Plant ht (cm)		50% flowering (day)		PER (%)	OCR (%)	Yield (kg/plot)	Yield (t/ha)
	A line	B line	A line	B line	A line	A line		
BRRI10A/B	85	87	73	72	72	34	70	1.5
BRRI11A/B	83	86	75	73	75	36	48	1.5
IR58025A/B	89	90	90	79	70	31	22	1.1

DS: B_1=4 Jul 2013, A/B_2=7 Jul 2013, B_3=8 Jul 2013; DT: A/B=28 Jul 2013. DS: B_1=6 Jul 2013, A/B_2=9 Jul 2013, B_3=12 Jul 2013; DT: A/B=30 Jul 2013. DS: B_1=3 Jul 2013, A/B_2=6 Jul 2013, B_3=9 Jul 2013; DT: A/B=27 Jul 2013.

Table 8. CMS multiplication of released hybrids in Boro 2013-14.

Combination	Plant ht (cm)		50% flowering (day)		PER (%)	OCR (%)	Yield (kg/plot)	Yield (t/ha)
	A line	B line	A line	B line	A line	A line		
BRRI10A/B	83	85	72	71	72	37	75	1.3
BRRI11A/B	81	84	74	72	75	39	90	1.4
IR58025A/B	87	89	89	78	69	28	23	1.1

DS: B_1=29 Nov 2013, A/B_2=2 Dec 2013, B_3=5 Dec 2013; DT: A/B=31 Dec 2013. DS: B_1=1 Dec 2013, A/B_2=4 Dec 2013, B_3=7 Dec 2013; DT: A/B=04 Jan 2014. DS: B_1=3 Dec 2013, A/B_2 =6 Dec 2013, B_3=9 Dec 2013; DT: A/B=5 Jan 2014.

Table 9. F_1 seed production of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan4 during T. Aman 2013.

Combination	Plant ht (cm)		50% flowering (day)		PER (%)	OCR (%)	Area (m^2)	Yield (kg/plot)	Yield (t/ha)
	A line	R line	A line	R line	A line	A line			
BRRI hybrid dhan2 (BRRI10A/ BRRI10R)	75	102	88	86	75	44	215	30	1.4
BRRI hybrid dhan3 (BRRI11A/ BRRI15R)	78	88	75	72	72	27	650	90	1.4
BRRI hybrid dhan4 (IR58025A/ BRRI10R)	76	110	129	132	76	39	270	32	1.2

DS: R_1=6 Jul 2013, A=9 July 2013, R_2=12 Jul 2013, DT: R/A=30 Jul 2013. DS: R_1=9 Jul 2013, A=13 Jul 2013, R_2=17 Jul 2013, DT: R/A= 3 Aug 2013. DS: R_1=6 Jul 2013, A=9 July 2013, R_2=12 Jul 2013, DT: R/A=30 Jul 2013. PER=Panicle exertion rate, OCR= Out crossing rate.

Table 10. F_1 seed production of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan4 in Boro 2013-14.

Combination	Plant ht (cm)		50% flowering (day)		PER (%)	OCR (%)	F_1 seed	
	A line	R line	A line	R line	A line	A line	Yield (kg/plot)	Yield (t/ha)
BRRI hybrid dhan2 (BRRI10A/BRRI10R)	77	88	121	121	86	48	150	2.5
BRRI hybrid dhan3 (BRRI11A/BRRI15R)	79	87	122	123	85	50	180	2.8
BRRI hybrid dhan4 (IR58025A/BRRI10R)	78	87	121	120	83	39	40	1.9

DS: R_1=2 Dec 2013, A=6 Dec 2013, R_2=9 Dec 2013; DT: A/R=5 Jan 2014. DS: R_1=27 Nov 2013, A=1 Dec 2013, R_2=5 Dec 2013; DT: A/R=1 Jan 2014. DS: R_1=2 Dec 2013, A=6 Dec 2013, R_2= 9 Dec 2013; DT: A/R=5 Jan 2014. PER=Panicle exertion rate, OCR=Out crossing rate.

Table 11. Amount of parental line and hybrid seeds supplied to different organization.

Recipient	No.	F_1 (kg)	A line (kg)	B line (kg)	R line (kg)
BADC	1	0.00	95.00	-	25.00
Seed companies	4	40.0	128.0	-	45.00
Farmers	32	232.0	15.00	-	5.00
BRRI scientists + staffs	8	80.00	-	-	-
Total	45	352.00	238.00	0.00	75.00
Grand total			665.00		

Agronomy Division

SUMMARY

Promising line BR7528-2R-19-HR10 showed comparable grain yield with check variety BRRI dhan49 which was mature four days earlier. Additional 1 to 2.5 t ha^{-1} grain yield of BRRI dhan51 and BRRI dhan52 could be achieved at Rangpur region by applying 30 kg ha^{-1} additional N with recommended N within five to 15 days after desubmerge at vegetative stage. BRRI dhan44 and BRRI dhan49 produced higher grain yield with USG treated plot compared to BRRI recommended prilled urea application in Barisal region in Aman season. About 49% higher grain yield was found in USG as well NPK briquette treated plot at Uzirpur, Barisal in Boro season. Fertilizer management based on rice crop manager gave higher grain yield compared to farmer's practice with all the tested cultivars in Barisal region. Deep placement of USG before panicle initiation stage gave considerable higher grain yield in local rice varieties during Aman season in tidal submergence area. Differentiating the quadratic equation of yield response with respect to applied N doses in T. Aman season, the maximum N rate appeared as 73, 58, 75 and 60 kg ha^{-1} for BRRI dhan49, BRRI dhan56, BRRI dhan57 and BRRI dhan62 respectively, but it was 148, 163, 144 and 159 kg ha^{-1} for Boro varieties BRRI dhan58, BRRI dhan59, BRRI dhan60 and BRRI dhan61 respectively. Application of 200 kg urea ha^{-1} in three equal splits at 20, 40 and 60 DAT for Aman season and 300 kg urea/ha in four equal splits at 20, 40, 60 and 80 DAT for Boro season were suitable for mechanically transplanted rice. Farmers achieved more than one ton ha^{-1} additional rice yield in BRRI dhan56 and BRRI dhan57 by practicing Pre-emergence herbicide with one hand weeding (HW); Post-emergence herbicide with one HW; Pre-emergence herbicide + Post emergence herbicide; and three HW. In soil seed bank study, the broad leaf weed *Lindernia ciliata* abundance was found as highest in 30 cm deep soil layer during Boro season in Maize-Mungbean-Rice cropping pattern at BRRI HQ farm Gazipur.

SEEDS AND SEEDLINGS

Effect of mixed rice husk and bran as tray media on rice seedling in Boro season for mechanical transplanter

This experiment was conducted at the Agronomy Field Laboratory, Bangladesh Rice Research Institute, during December 2013 to January 2014 to study the effect of mixed rice husk and bran as tray media on tray seedling quality. Seedlings were raised on plastic trays using five different tray media. The tray media consisted of T_1 (100% soil), T_2 (75% soil+25% mixed rice husk and bran), T_3 (50% soil+50% mixed rice husk and bran), T_4 (25% soil+75% mixed rice husk and bran) and T_5 (100% mixed rice husk and bran). The experiment was conducted in RCB design and replicated thrice. Tray media were prepared and placed on trays three days before sowing of seeds and sprouted seed of BRRI dhan29 was used. Twenty seedlings per tray were randomly taken and data on seedling root and shoot length, leaf number, leaf colour, dry weight were recorded 25 days after seeding. T_3 treatment performed better in terms of leaf number, leaf colour, seedling height and dry matter.

The highest seedling strength was also obtained from T_3 treatment which was statistically similar to T_2 (Table 1). T_5 treatment produced the lowest seedling strength. Therefore, 75% soil+25% rice husk and bran or 50% loamy soil + 50% rice husk and bran may be used as tray media to produce quality seedling for mechanical transplanting in Boro season.

Validation of seedling age on the growth and yield of rice in Aman season

An experiment was conducted in Aman season 2013 at Kalapara, Patuakhali to determine the optimum age of seedling for sustainable rice production. The treatments were- with 30, 40, 50, 60 and 70-day-old seedling. The experiment was laid down in RCB design with three replications. Transplanting was done at 20- × 20-cm spacing. Applied fertilizer rate was- 202, 75, 60, 50 and 5 kg ha^{-1} urea, TSP, MOP, gypsum and $ZnSO_4$ respectively. All fertilizers were applied at final land preparation but urea was top dressed in three

Table 1. Effect of tray media on seedling quality in Boro season for rice transplanter.

Treatment	Root length (cm)	Shoot length (cm)	Leaf number	Leaf colour	Dry wt (gm)	Seedling strength (mg cm^{-1})
T_1	4.57	7.70	2	2.03	0.20	26.33
T_2	4.07	9.47	3	3.07	0.26	28.03
T_3	4.40	11.07	3	3.37	0.35	31.89
T_4	4.80	11.00	3	3.17	0.33	29.83
T_5	2.30	8.48	3	1.10	0.22	25.81
LSD(0.05)	0.83	1.5	0.38	0.41	0.024	6.91
CV (%)	11.2	8.6	7.6	8.7	4.8	12.9

T_1=100% soil, T_2=75% soil+25% mixed rice husk and bran, T_3=50% soil+50% mixed rice husk and bran, T_4=25% soil+75% mixed rice husk and bran and T_5=100% mixed rice husk and bran.

equal splits. Plant height varied significantly due to the variation of seedling age. The tallest plant height was observed in 30-day-old seedlings while the shortest plant was found in 70-day-old seedling. The highest number of panicle m^{-2} and grains panicle^{-1} was found in younger seedlings over the older seedlings. The highest sterility percentage was found in older seedlings. The grain yield was significantly affected by the treatments. Younger seedling (30-day-old seedling) enhanced the number of panicles per unit area, grains per panicle and low spikelet sterility those were reflected on the increase of grain yield. On the contrary, low yield components in older seedlings reduced grain yield (Table 2).

PLANTING PRACTICES

Effect of planting time on growth and yield of advanced lines in T. Aman season
The experiment was conducted at the BRRI farm, Gazipur in Aman 2013 to find out the optimum planting time and to select best promising lines. Transplanting was started from 31 July with the promising lines BR8417-2-1-2 and BR7528-2R-

19-HR10 including check varieties BRRI dhan39 and BRRI dhan49. From the next set (14 August to 2 October) promising lines BR7472-16-2-1-2-3, BR7622-5-1-1-1, BR7639-68-2-1-1, BR7357-11-2-4-1-1, BR7369-16-5-2-3-1, IR83383-B-B-129-4, IR87707-446-B-B-B and IR82589-B-B-84-3 were included. Thirty-day-old seedling was transplanted with 20- × 20-cm spacing at 15 days intervals. The experiment was laid down in split-plot design, where planting date was in the main plots and the promising lines/varieties were in the sub-plots. Fertilizers were applied at 175, 53, 82 and 59 kg ha^{-1} urea, TSP, MOP and gypsum respectively. All fertilizers were applied during final land preparation but urea was applied as top dress in three equal splits.

Grain yield of rice and growth duration gradually decreased with the advancement of planting dates irrespective of promising line or variety. None of the promising lines produced higher grain yield over the check varieties BRRI dhan39 and BRRI dhan49 irrespective of planting date (Table 3). However, only one promising line BR7528-2R-19-HR10 showed comparable grain yield with the check variety BRRI dhan49 which matured 2-6 days earlier than the check variety.

Table 2. Effect of seedling age on the growth and yield of BRRI dhan49 at Kalapara and Patuakhali in Aman season 2013.

Seedling age (day)	Plant ht (cm) at harvest	Panicle (no. m^{-2})	Grain panicle^{-1}	Sterility (%)	Grain yield (t ha^{-1})
30	103.00	373	154	13.63	5.81
40	101.00	327	146	15.15	5.41
50	98.00	252	126	17.44	3.89
60	93.00	244	119	25.77	2.94
70	88.00	*	*	*	*
LSD $_{(0.05)}$	2.79	23.86	6.04	1.67	0.30
CV (%)	1.05	3.20	2.22	4.69	3.40

*Seventy-day-old seedling did not flower.

Table 3. Effect of planting time on yield and growth duration (in the parenthesis) of advanced lines/varieties in T. Aman 2013 at BRRI, Gazipur.

Advanced line/variety	Transplanting late				
	31 Jul	14 Aug	1 Sep	22 Sep	2 Oct
BR8417-2-1-2	4.78 (121)	4.68 (119)	4.2 (115)	3.04 (112)	1.2
BR7528-2R-19-HR10	5.25 (131)	5.03 (128)	4.52 (126)	3.24 (123)	*NF
BRRI dhan39 (ck)	4.95 (125)	4.80 (123)	4.41 (118)	3.74 (114)	0.74
BRRI dhan49 (ck)	5.33 (137)	5.03 (133)	4.53 (128)	3.10 (125)	*NF
BR7472-16-2-1-2-3		4.27 (129)	4.31 (127)	1.80 (123)	*NF
BR7622-5-1-1-1		4.43 (126)	4.05 (118)	1.95 (114)	0.28
BR7639-68-2-1-1		4.37 (124)	4.36 (121)	3.29 (117)	*NF
BR7357-11-2-4-1-1		3.80 (133)	3.70 (124)	1.52 (120)	*NF
BR7369-16-5-2-3-1		3.95 (134)	3.87 (126)	1.77 (121)	*NF
IR83383-B-B-129-4		4.34 (124)	4.22 (118)	2.51 (114)	0.55
IR83373-B-B-27-4		5.05 (125)	4.38 (117)	2.24 (115)	0.67
IR87707-446-B-B-B		4.13 (122)	4.10 (118)	2.30 (117)	*NF
IR82589-B-B-84-3		4.7 (123)	3.75 (117)	2.72 (114)	*NF

Thus, plant breeders may use this promising line BR7528-2R-19-HR10 in future research work to develop a new variety.

Validation of modern rice varieties at Barisal region in Aman season

An experiment was conducted in Barisal and Patuakhali to find out the suitable rice varieties for growing in Aman season. The test varieties were; i) BRRI dhan33, ii) BRRI dhan39, iii) BRRI dhan56, iv) BRRI dhan57 v) BRRI dhan62 compared with vi) local variety (Tepusail at Patuakhali; Sadamota at Barguna and Jhalokathi; and Dudmona at Barishal). The treatments were distributed following RCB design with three replications. Thirty-day-old seedlings were transplanted at 20- × 20-cm spacing in T. Aman season 2013. TSP, MOP, gypsum and $ZnSO_4$ were applied at 75, 60, 50 and 5 kg ha^{-1} respectively during final land preparation. Urea was top dressed at 202 kg ha^{-1} in three equal splits at 15, 30 and 45 DAT. Other intercultural operations were done as and when necessary.

Kalapara, Patuakhali and Barguna sadar, Barguna. The variation of plant height, yield and yield components among the treatments were statistically significant. The tallest plant was observed in local variety (Tepusail), while the shortest plant was found in BRRI dhan62 at both the locations. The traditional variety Tepusail exhibited the highest number of panicles per unit area over modern varieties. BRRI dhan33 and BRRI dhan56 produced the highest grains/panicle and less spikelet sterility was found in BRRI dhan56 producing more grain yield over the tested varieties at both the locations. However, the grain yield of local variety Tepusail was comparable with top yielder BRRI dhan56 at Patuakhali reigon. Thus, farmers of Kalapara may choose intermediate stature plant like BRRI dhan56 instead of local variety Tepusail to increase rice grain yield in Aman season (Table 4).

Nalchiti, Jhalokathi and Gournadi, Barisal. The varietal performance at Kalapara, Patuakhali and Barguna sadar had the similarity with the results of Nalchiti, Jhalokathi and Gournadi, Barisal where the height of local variety Sadamota and Dudhmona was the highest. The modern varieties BRRI dhan56 and BRRI dhan57 exhibited the higher number of panicle per unit area. The variation of grains per panicle and spikelet sterility, were insignificant. BRRI dhan56 produced the highest grain yield both at Nolchiti and Gournadi locations which had the similarity with the findings of Kalapara and Barguna sadar (Table 5). Thus, the modern variety BRRI dhan56 performed well at different locations in the districts of Patuakhali, Barguna, Jhalokathi and Barisal.

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

The experiment was conducted at the BRRI HQ farm, Gazipur in Boro 2013-14 season. Tested

Table 4. Yield performance and yield component of rice varieties at Patuakhali and Borguna in T. Aman season 2013.

Variety	Plant ht (cm) at harvest		Panicle (no. m^{-2})		Grains panicle^{-1}		Sterility (%)		Grain yield (t ha^{-1})	
	L$_1$	L$_2$	L$_1$	L$_2$	L$_1$	L$_2$	L$_1$	L$_2$	L$_1$	L$_2$
BRRI dhan33	104 d	90 d	238 d	238	131 a	127 a	22.2 a	26.6 a	4.43 c	4.43 b
BRRI dhan39	105 d	102 c	279 b	278	120 b	117 b	20.1 c	21.5 bc	4.67 b	4.71 a
BRRI dhan56	114 b	112 b	257 c	257	131 a	117 b	21.9 b	23.4 b	4.92 a	4.93 a
BRRI dhan57	111 c	111 b	250 c	248	118 b	116 c	21.8 b	22.4 b	4.52 d	4.79 a
BRRI dhan62	103 e	102 c	273 b	275	93 c	95 b	19.3 d	19.2 cd	3.47 d	3.44 c
Local variety	123 a	136 a	323 a	321	127 a	114 b	26 b	17.8 d	4.47 a	4.37 b
LSD$_{(0.05)}$	1.62	3.13	9.89	15.34	4.53	7.73	1.38	2.32	0.1	0.25
CV (%)	0.8	1.58	2.01	3.13	2.07	3.71	3.49	5.84	1.28	3.09

L1=Kalapara using the local ck Tepusail and L2=Barguna sadar using the local ck Sadamota.

Table 5. Performance of yield components and grain yield of rice varieties at Jhalokathi and Barisal in Aman season 2013.

Variety	Plant ht (cm) at harvest		Panicle (no. m^{-2})		Grains panicle^{-1}		Sterility (%)		Grain yield (t ha^{-1})	
	L$_3$	L$_4$	L$_3$	L$_4$	L$_3$	L$_4$	L$_3$	L$_4$	L$_3$	L$_4$
BRRI dhan33	97 d	94e	204 b	199b	66 a	73a	35.8 b	31.6b	3.58a	3.34a
BRRI dhan39	94 d	91e	187 c	171d	72 a	72a	38.3 ab	36.2a	3.51a	3.27a
BRRI dhan56	111 c	110c	221 a	209a	66 a	73a	38.7 ab	36.5a	3.79a	3.7a
BRRI dhan57	122 b	120b	225 a	212a	64 a	71a	36.6 ab	36.9a	3.63a	3.45a
BRRI dhan62	98 d	99d	183 c	170d	72 a	71a	39.5 a	36a	2.32c	2.59b
Local variety	155 a	152a	206 b	179c	75 a	60b	37.6 ab	35.7a	2.54b	2.58b
LSD$_{(0.05)}$	7.02	6.1	12.43	15.02	11.92	15.3	3.2	3.3	0.55	0.75
CV (%)	3.42	3.1	3.34	4.33	9.4	12.3	4.69	5.11	9.15	13.1

L$_3$=Nalchiti, Jhalokathi, L$_4$=Gournadi, Barisal.

promising lines were BR7830-16-1-5-3, weed tolerant rice, BR7671-37-2-2-3-7, BR7833-11-1-1-2-1-2B5 and Zhongzu 14 including the check variety BRRI dhan28. All planting were done on 12 January to 15 March with 40-day-old seedlings at 20- × 20-cm spacing. The trail was laid down in a split-plot design, where planting date in the main plots and promising lines/varieties in the sub-plots with three replication. Fertilizers were applied @ 120-35-60-10 kg ha^{-1} N-P-K-S as urea, TSP, MOP and gypsum respectively. All fertilizers except urea were applied during final land preparation. Urea was top-dressed in three equal splits.

The growth duration and grain yield of promising lines/varieties gradually decreased with the advancement of planting dates. The promising line BR7830-16-1-5-3 produced 4-5% higher grain yield over BRRI dhan28, irrespective of planting date up to 16 February and then decreased (Table 6). BR7830-16-1-5-3 matured 10-13 days later than BRRI dhan28. However, weed tolerant rice showed similar grain yield with BRRI dhan28 but matured 10 days later than the check variety. So, the promising line BR7830-16-1-5-3 could be used

in future research work to develop a new variety by the plant breeder.

FERTILIZER MANAGEMENT

Validation of nutrient management of rice at farmer's field condition at southern region in Aman season

The experiment was conducted at Uzirpur, Barisal and Amtoli, Barguna during Aman season 2013 to determine the optimum level of fertilizer requirement for rice production. The treatments were- i. BRRI Recommended fertilizer doses, ii. USG treated plot, iii. Farmer's practice and iv. Control (No fertilizer). The experiment was laid down in RCB design with three replications. Thirty-day-old seedlings were transplanted at both the locations with 20- × 20-cm spacing. The test variety BRRI dhan44 was grown in Uzirpur, Barisal and BRRI dhan49 in Amtoli, Barguna. BRRI Recommended fertilizer doses were applied as @ 202, 75, 60, 50 and 5 kg ha^{-1} urea, TSP, MOP, gypsum and ZnSO$_4$ respectively whereas

Table 6. Effect of planting time on yield and growth duration (parenthesis) of advanced lines/varieties in Boro 2013-14.

Advanced line/variety	Date of transplanting				
	12 Jan	2 Feb	16 Feb	1 Mar	15 Mar
BR7830-16-1-5-3	6.07 (155)	5.58 (150)	4.61(146)	2.84(140)	1.2 (135)
Weed tolerant rice	5.86 (154)	5.41 (151)	4.54(145)	2.68(139)	Not germinated
BR7671-37-2-2-3-7	5.74 (152)	5.42 (147)	4.57(141)	2.79(137)	1.1 (130)
BR7833-11-1-1-2-1-2B5	5.23 (140)	4.86 (136)	4.20(133)	2.62(129)	0.9 (126)
Zhongzu14	4.96 (152)	4.45 (148)	4.04(142)	2.49(123)	Not germinated
BRRI dhan28 (ck)	5.81 (142)	5.43 (139)	4.63(136)	2.87(131)	1.23 (125)
CV(%)			6.83		
LSD$_{(0.05)}$			0.39		

the farmers applied @ 180, 52, 50 kg ha^{-1} urea, TSP, MoP respectively. Urea super granule was applied at 7 DAT as per treatment. All fertilizers were applied at final land preparation except urea.

The result from Uzirpur, Barisal showed that significantly higher taller plant, panicles m^{-2} higher number of grains panicle^{-1}, lowest spikelet percentage and grain yield were recorded in USG treated plot followed by BRRI recommended plot. And the lower number of panicle, grains per panicle and high sterility was observed in farmer's field. USG treated plot gave 29% higher grain yield over control plots (Table 7).

Farmers participatory field evaluation of Rice Crop Manager during Boro season in Barisal region

A farmers' participatory field experiment was conducted at 72 farmer's field of Gournadi, Agailjhara and Uzirpur of Barisal district to evaluate the field specific fertilizer guideline obtained form rice crop manager compared to farmer's fertilizer practice during Boro 2014. The treatments were- i. Rice Crop Manager (RCM) based fertilizer management, and ii. Farmers' practice (FP). We followed randomized complete block design. Farmers transplanted high yielding inbred as well as hybrid varieties. To calculate fertilizer for RCM a questionnaire was developed and each farmer was interviewed. Required amounts of NPK were applied through urea, TSP and MOP respectively.

Varietal effect was not significant in grain yield at Gournadi and Agailjhara (Tables 8 and 9). But, fertilizer effect was statistically significant in producing grain in all locations. Again, grain yield was statistically influenced by the interaction of variety and fertilizer management practices at Gournadi only.

Rice Crop Manager based fertilizer management produced significantly higher grain yield than that of FP during cultivating BRRI dhan28, BRRI dhan29, BRRI dhan47 and BRRI dhan50. At Agailjhara, local cultivar Kazla produced slightly higher grain yield with RCM than FP. Significantly higher grain yield was obtained by RCM than that of FP during growing BRRI dhan29, Shakti and Super (Table 9). Fertilizer management effect was also statistically significant in producing grain. In Barisal sadar, RCM produced significantly higher grain yield than that of FP with all the cultivated varieties (Table 10). So, rice crop manager could be used for fertilizer management during Boro season.

Table 7. Effect of nutrient management on the growth and yield of BRRI dhan44 in Aman season 2013-14 at Uzirpur, Barisal and Amtoli, Barguna.

Treatment	Plant ht (cm) at harvest		Panicle (no. m^{-2})		Grains panicle^{-1}		Sterility (%)		Grain yield (t ha^{-1})	
	L$_1$	L$_2$	L$_1$	L$_2$	L$_1$	L$_2$	L$_1$	L$_2$	L$_1$	L$_2$
BRRI recom.	129 b	102 a	197 a	242 b	126 a	127 a	22.9 a	16.6 a	4.96 b	5.04 b
USG treated plot	129 a	102 a	209 a	253 a	131 a	125 a	16.5 b	14.5 b	5.31 a	5.63 a
Farmer's practice	128 c	101 ab	169 b	207 c	116 a	117 b	24.7 a	17.1 a	4.62 c	4.43 c
Control	127 d	99 b	152 c	186 d	81 b	109 c	25.2 a	14.1 b	4.1 d	4.04 d
CV (%)	0.15	1.35	3.35	2.14	8.62	1.72	8.98	1.96	1.58	2.42
LSD$_{(0.05)}$	0.39	2.73	12.18	9.55	19.66	4.12	4.01	0.61	0.15	0.23

L1=Uzirpur, Barisal, L2=Amtoli, Barguna.

Table 8. Variety wise yield performance using rice crop manager at Gournadi, Boro 2014.

Variety	Yield (t ha^{-1})		
	Rice crop manager	Farmers' practice	Difference
Mota Kajla	5.13	5.02	0.11^{NS}
BRRI dhan28	6.32	4.67	1.65**
Lal Kajla	5.35	4.70	0.65*
BRRI dhan29	6.49	5.40	1.09**
BRRI dhan50	6.54	5.72	0.82*
BRRI dhan47	5.18	3.38	1.8**
LSD$_{0.05}$ for variety		NS	
LSD$_{0.05}$ for variety × fertilizer		1.29	

** and *Significant at the 1 and 5% level of probability, NS=Not significant.

Table 9. Variety wise yield performance using rice crop manager at Agailjhara, Boro 2014.

Variety	Yield (t ha^{-1})		
	Rice crop manager	Farmers' practice	Difference
BRRI dhan29	7.72	5.90	1.82**
Shakti	7.39	6.10	1.29**
Kajla	6.57	5.94	0.63*
Super	7.46	6.35	1.11**
LSD$_{0.05}$ for variety		NS	
LSD$_{0.05}$ for variety × fertilizer		NS	

** and *Significant at the 1 and 5% level of probability, NS=Not significant.

Table 10. Variety wise yield performance using rice crop manager at Barisal sadar, Boro 2014.

Variety	Yield (t ha^{-1})		
	Rice crop manager	Farmers' practice	Difference
Binadhan-8	6.60	5.89	0.71^{NS}
Hira2	8.26	7.78	0.48^{NS}
BRRI dhan28	7.97	6.78	1.19**
BRRI dhan47	7.52	6.79	0.73*
LSD$_{0.05}$ for variety		0.99	
LSD$_{0.05}$ for variety × fertilizer		NS	

**and *Significant at the 1 and 5% level of probability, NS=Not significant.

Deep placement of urea super granule before panicle initiation stage of Aman rice to increase grain yield in tidal submergence areas of Barisal region

A farmers' participatory field experiment was conducted at 72 farmers' field of Gournadi, Bakerganj and Nalchiti to increase production through application of USG at PI stage of rice in tidal submergence-prone areas during Aman season. The treatments were- i. Deep placement of USG (UDP) before PI stage and ii. Farmers practice (FP) followed by RCB design. Farmers transplanted local Aman varieties. USG was applied at the last week of September to the first week of October (before PI of different varieties).

Varietal interaction with fertilizer had significant effect in grain yield at Gournadi and Bakerganj (Tables 11 and 12). But, fertilizer effect was significant in grain yield at all locations. At Gournadi, cultivated variety Mutha gave 2.41 t ha^{-1} grain yield by UDP where 1.78 t ha^{-1} by FP (Table 11). So, UDP gave half t ha^{-1} more grain yield over FP. Local variety Kutiagoni yielded 2.18 t ha^{-1} through UDP which was 0.29 t ha^{-1} higher than FP. Rajashail, produced more than 3 t ha^{-1} grain yield in UDP plot. About 2.74 t ha^{-1} grain yield was obtained from FP which was 0.43 t ha^{-1} less than UDP. At Bakerganj, Sadamota produced 4.13 t ha^{-1} where FP plots gave 3.36

Table 11. Effect of urea deep placement before PI on grain yield of local rice in Gournadi, Aman 2014.

Variety	Yield (t ha^{-1})		
	Urea super granule	Farmers' practice	Difference
Mutha	2.41	1.78	0.63**
Kutiagoni	2.18	1.89	0.29^{NS}
Rajashail	3.18	2.74	0.44**
LSD$_{0.05}$ for variety		0.370	
LSD$_{0.05}$ for variety × fertilizer		0.490	

**Significant at the 1% level of probability, NS=Not significant.

Table 12. Effect of urea deep placement before PI on grain yield of local rice in Bakerganj, Aman 2014.

Variety	Yield (t ha^{-1})		
	Urea super granule	Farmers' practice	Difference
Sadamota	4.13	3.36	0.77**
Dudkalam	2.69	1.85	0.84**
Dishari	4.19	3.62	0.57**
Nakochimota	3.59	2.85	0.74**
Moulata	3.23	2.90	0.33^{NS}
Motadhan	3.81	3.05	0.76**
LSD$_{0.05}$ for variety		0.595	
LSD$_{0.05}$ for variety × fertilizer		0.690	

**Significant at the 1% level of probability, NS=Not significant.

t ha^{-1} grain yield (Table 12). Dudkolom variety gave 0.84 t ha^{-1} more grain yield by UDP over FP. This variety was cultivated by four farmers. The FP plot produced 1.85 t ha^{-1} where UDP treated plots gave 2.69 t ha^{-1} grain yield. About 4.19 t ha^{-1} grain yield was produced by Dishari in UDP plots. The farmers practice plot yielded 3.62 t ha^{-1} which was 0.57 t ha^{-1} less compared to UDP. Local varieties Nikochimota cultivated by one farmer produced 3.59 t ha^{-1} by UDP which was 0.74 t ha^{-1} higher than FP. Moulata produced 3.23 and 2.90 t ha^{-1} by UDP and FP respectively. Motadhan cultivated by 10 farmers. UDP plots produced 0.70 t ha^{-1} more grain than FP plots.

In Nalchiti, Lalmota yielded 4.26 t ha^{-1} where FP produced 3.62 t ha^{-1} (Table 13). Sadamota produced 4.38 and 3.93 t ha^{-1} grain yield by UDP and FP respectively. Dudkolom and Khoiya gave more or less similar grain yield by UDP and FP. About 0.88 t ha^{-1} more grain yield was recorded in UDP than FP plots cultivating local variety Aochin. More than 1.0 and 0.5 t ha^{-1} more grain yield was recorded in UDP than FP plots using Dishari and Moulata respectively. Nikochimota gave 0.78 t ha^{-1} more grain yield by UDP than FP. Farmers could obtain more than 0.5 ha^{-1} yield advantages through UDP before PI stage.

Nitrogen requirement in modern T. Aman and Boro varieties

T. Aman. The experiment was conducted at BRRI HQ farm, Gazipur in T. Aman 2013 to find out optimum nitrogen rate from prilled urea, LCC and observe the yield performance from USG. Tested four T. Aman varieties were BRRI dhan49, BRRI dhan56, BRRI dhan57 and BRRI dhan62. Four N management treatments were- i. N application at 25, 50, 75 kg h^{-1} from prilled urea, ii. N application by LCC (52 kg N ha^{-1}), iii. Urea from USG (50 kg N ha^{-1}) and iv. Control (without N). The experiment was conducted in split plot design with three replications. The optimum N dose for the tested rice varieties was determined by regression as the grain yield with the N rates: $Y = a + bN + cN$. Where, Y is rice yield (kg ha^{-1}), N is nitrogen dose (kg ha^{-1}), a is intercept (estimated yield without N application), b and c are coefficients respectively (Saleque *et al.,* 2004). Differentiating Y with respect to N of the Eqn gives the nitrogen dose for the maximum yield. The estimated N dose for maximum yield N= -b/2c.

The variation of grain yield of the rice genotypes at different levels of N with USG application was estimated through regression equation (Fig. 1). The relationship of grain yield and applied nitrogen in different varieties was quadratic. The quadratic regression equation of BRRI dhan49, BRRI dhan56, BRRI dhan57 and BRRI dhan57 was y=-0.00025x^2 + 0.03658x + 2.89431, R^2 = 0.97**, y = -0.00042x^2 + 0.04831x

Table 13. Effect of urea deep placement before PI on grain yield of local rice in Nalchiti, Aman 2014.

Variety	Yield (t ha^{-1})		
	Urea super granule	Farmers' practice	Difference
Lalmota	4.26	3.62	0.64**
Sadamota	4.38	3.93	0.45**
Dudkalam	3.09	2.95	0.14 NS
Khoiya	3.33	2.95	0.38 NS
Aochin	4.74	3.86	0.88**
Moulata	4.10	3.53	0.57**
Dishari	3.65	2.65	1.00**
Nakochimota	4.35	3.57	0.78**
LSD$_{0.05}$ for variety		NS	
LSD$_{0.05}$ for variety × fertilizer		NS	

**Significant at the 1% level of probability, NS=Not significant.

Fig. 1. Grain yield of modern T. Aman rice as affected by N levels.

+ 2.799, $R^2 = 0.85*$, y = $-0.00020x^2 + 0.03024x +$ 2.933, $R^2 = 0.98**$ and y = $-0.00029x^2 + 0.03475x$ + 2.44590, $R^2 = 0.87*$, respectively. Nitrogen treatment accounted about 97, 85, 98 and 87% variation in grain yield for BRRI dhan49, BRRI dhan56, BRRI dhan57 and BRRI dhan57, respectively. The estimated optimum dose of nitrogen for BRRI dhan49, BRRI dhan56, BRRI dhan57 and BRRI dhan62 were 73, 58, 75 and 60 kg N ha^{-1} respectively.

Boro. Recently BRRI has developed BRRI dhan58, BRRI dhan59, BRRI dhan60 and BRRI dhan61. Yield potential of these varieties was more than 7 t ha^{-1}. So, the experiment was conducted to determine the requirement of N from prilled urea and response of USG to yield and yield character of newly developed Boro varieties during 2013-14.

The experiment was conducted at BRRI HQ, Gazipur in Boro season. Four varieties were tested under six N management practices. The varieties were BRRI dhan58, BRRI dhan59, BRRI dhan60 and BRRI dhan61. The N management treatments were control (without N), N application at 80,120,160, 200 kg ha^{-1} from prilled urea, and N from USG (75 kg N ha^{-1}). The experiment was laid down in split plot design with three replications. The optimum N dose for the tested variety was determined by regression equation (Saleque *et al.,* 2004) (Fig. 2).

Yield (t ha^{-1})
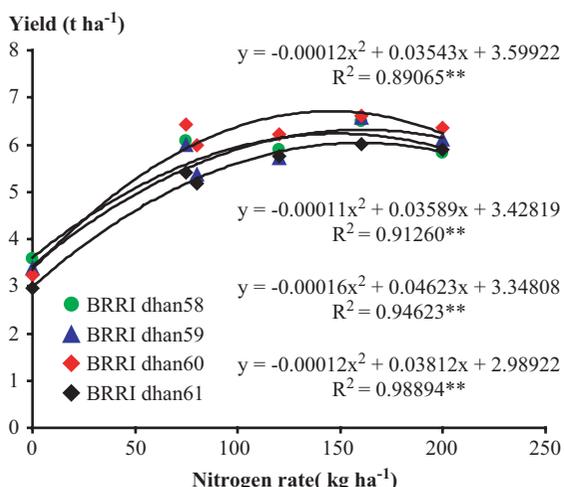
Fig. 2. Grain yield of modern Boro varieties as affected by N application from prilled urea and USG.

The variation of grain yield of Boro rice genotypes at different levels of N with USG application was estimated through regression equation. The relationship of grain yield and applied nitrogen in different varieties was quadratic. The quadratic regression equation of BRRI dhan58, BRRI dhan59, BRRI dhan60 and BRRI dhan61 was y = $-0.00012x^2 + 0.03543x +$ 3.599, $R^2 = 0.89**$, y = $-0.00011x^2 + 0.03589x +$ 3.4291, $R^2 = 0.91**$, y = $-0.00016x^2 + 0.034623x$ + 3.34808, $R^2 = 0.95**$ and y = $-0.00012x^2 +$ 0.03812x + 2.98922, $R^2 = 0.99**$ respectively. Nitrogen treatment accounted about 89, 91, 95 and 99% variation in grain yield for BRRI dhan58, BRRI dhan59, BRRI dhan60 and BRRI dhan61 respectively. The optimum nitrogen dose for BRRI dhan58, BRRI dhan59, BRRI dhan60 and BRRI dhan61 was 148, 163, 144 and 159 kg N ha^{-1} respectively.

Evaluation of nitrogen use efficiencies of modern Boro varieties using prilled urea and USG applicator

To minimize nitrogen loss, USG application might be a good technology to increase rice yield as well as the reduction of production cost. The present study was undertaken to observe NUEs, N uptake of Boro varieties by prilled urea and USG applicator and to compare yield and yield component of BRRI varieties under different methods of N application.

The experiment was conducted at BRRI HQ, Gazipur in Boro 2013-14 season, with BRRI dhan28 and BRRI dhan29 under four N management practices- i) N application by prilled urea applicator (70% of total urea application by broadcasting) ii) USG (2.7gm) application by applicator, iii) hand broadcasting of prilled urea with three splits and iv) control (without urea). The experiment was conducted in factorial RCB design with three replications.

Varietal effect showed highly significant (P<0.01) and BRRI dhan29 (5.97 t ha^{-1}) achieved significantly higher yield compared to BRRI dhan28 (Table 14). Regarding N management treatment the highest grain yield was produced by urea broadcasting (124 kg N ha^{-1}) followed by N application of USG using USG applicator. The

Table 14. Effect of varieties and nitrogen management on plant height, yield and yield contributing characters during Boro 2014, BRRI HQ, Gazipur.

Treatment	Plant ht (cm)	Panicle m^{-2}	Grain panicle^{-1}	TGW	Panicle length (cm)	Grain yield (t ha^{-1})
			Variety			
BRRI dhan28	97.47	263	87	22.26	21.56	5.45
BRRI dhan29	99.94	295	90	22.68	22.99	5.97
LSD$_{(0.05)}$	ns	*13.62*	ns	ns	*0.92*	*0.36*
			N management			
PUA	101.00	276	88	22.36	21.98	6.13
USG	101.90	278	91	23.57	22.21	6.46
UB	101.46	300	96	22.29	23.63	6.96
Control	90.46	215	80	21.67	21.30	3.28
LSD$_{(0.05)}$	7.37	19.27	5.95	ns	1.29	0.50
CV (%)	5.9	5.6	5.5	7.5	4.8	7.2

highest N% in grain and straw were observed in urea broadcast plots followed by N application using prilled urea applicator. Control plot observed the lowest N%. Nitrogen uptake model from different N application methods followed a similar pattern (Table 15).

Interaction effect of V × N treatment on NUEs varied significantly (Table 16). The highest AE, PE, APE, and ARE was observed in BRRI dhan28 with N application from USG by USG applicator. The highest UE and PFP were produced from BRRI dhan29 × USG application by USG applicator and the lowest was observed from BRRI dhan29 × urea broadcast with three splits plots. The lowest PFP was observed in three splits urea broadcasting in both the varieties. There was an overall increase in gross return in different N management treatments over the control (Table

17). Cost dominance analyses (Table 18) showed that cost was the highest for the treatment prilled urea broadcasting with BRRI dhan29. From Table 18 it was observed that the treatment V2N$_3$, V2N$_2$, V2N$_1$ and V1N$_2$ was found cost dominated, where cost is more but gross margin is less than that of other treatments. Table 19 shows the marginal analysis of cost. The treatment BRRI dhan28 × USG application by USG applicator showed the highest MMR and was more profitable than the other N treatments. That is why treatment BRRI dhan28 × USG application by USG applicator was more profitable than the other N management treatments.

Effect of nitrogen management for yield maximization after desubmergence of BRRI dhan51 at Rangpur region

The experiments were conducted at farmer's field to identify and recommend the appropriate nitrogen management for BRRI dhan51 to maximize yield after desubmergence for sustainable rice production during T. Aman season at Pirgasa of Rangpur, Kaliganj of Lalmonirhat and Sayedpur of Nilphamari district. The treatments were T$_1$=AEZ based recommended dose of N management, T$_2$=T$_1$ + additional 30 kg N ha^{-1} after five days of submergence, T$_3$=T$_1$ + additional 30 kg N ha^{-1} after 10 days of submergence, T$_4$=T$_1$ + additional 30 kg N ha^{-1} after 15 days of de submerge and T$_5$=Without N (Control). The experiment was laid down in RCB design with three replications. Transplanting was done by two seedlings per hill and the seedling age was 35 days. All fertilizers were applied as basal before

Table 15. Effect of varieties and nitrogen management on N% and uptake during Boro 2014 at BRRI HQ, Gazipur.

Treatment	Nitrogen (%)		Nitrogen uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw
BRRI dhan28 (V1)	1.05	0.52	59.2	27.9
BRRI dhan29 (V2)	0.99	0.54	59.5	31.3
LSD$_{(0.05)}$	ns	ns	ns	ns
	N management			
PUA	1.05	0.55	64.92	31.33
USG	1.03	0.45	66.62	29.40
UB	1.10	0.62	76.13	39.42
Control	0.91	0.45	29.82	18.40
LSD$_{(0.05)}$	0.12	0.61	10.41	5.21
CV (%)	9.9	9.5	14.3	14.4

Control=No urea, PUA=Prilled urea applicator (87 kg N ha^{-1}), USG=Urea super granule (75 kg N ha^{-1}) UB=Urea broadcasting 124 kg N ha^{-1}).

Table 16. N use efficiencies of different N sources and method of application in variety and Nitrogen interaction during Boro 2014 at BRRI HQ, Gazipur.

Variety	N management	Nitrogen use efficiency					
		AE (kg ha^{-1})	PE (kg ha^{-1})	APE (kg ha^{-1})	ARE (%)	UE (kg ha^{-1})	PFP (kg ha^{-1})
BRRI dhan28	PUA	33	108	68	57	77	67
	USG	47	109	56	81	62	86
	UB	30	98	56	53	56	54
BRRI dhan29	PUA	32	117	60	53	70	74
	USG	38	135	83	46	112	87
	UB	29	92	53	55	50	59
LSD $_{(0.05)}$	Variety (V)	7.20	18.29	12.34	14.53	23.28	4.81
	N management (N)	8.82	22.41	15.12	17.81	28.52	5.89
	V×N	12.47	31.69	21.38	25.18	40.33	8.34
CV(%)		20.1	16.2	19.1	24.5	31.9	6.6

AE=Agronomic efficiency, PE=Physiological efficiency, APE=Agro-physiological efficiency, ARE=Apparent recovery efficiency, UE=Utilization efficiency, PFP=Partial factor productivity.

Table 17. Treatment that varies (N fertilizer), gross return and gross margin.

N management	Variable cost (Tk ha^{-1})	Gross return (Tk ha^{-1})	Gross margin (Tk ha^{-1})
	BRRI dhan28 (V1)		
Control (N$_0$)	0	66083	66083
PUA (N$_1$)	4990	126776	121786
USG (N$_2$)	4782	141000	136218
UB (N$_3$)	7438	145212	137774
	BRRI dhan29 (V2)		
Control (N$_0$)	0	81470	81470
PUA (N$_1$)	4823	141235	136335
USG (N$_2$)	4900	141629	136806
UB (N$_3$)	7479	158610	151131

Table 18. Cost dominated treatment.

Gross margin (Tk ha^{-1})	Treatment	Variable cost (Tk ha^{-1})	Cost dominated treatment
151131	V2N$_3$	7479	
137774	V1N$_3$	7438	*
136806	V2N$_2$	4900	
136335	V2N$_1$	4823	
136218	V1N$_2$	4782	
121786	V1N$_1$	4990	*
81470	V2N$_0$	0	
66083	V1N$_0$	0	

transplanting except urea. Other intercultural operations were done as and when necessary.

Grain yield was significantly affected by different treatments in T. Aman 2013 (Table 20) at different locations. The highest grain yield was observed at treatment T$_2$ and T$_4$ followed by T$_3$ but the lowest was obtained from treatment T$_5$ than T$_1$ at Pirgasa, Rangpur. At Kaliganj, Lalmonirhat, the highest grain yield was recorded

from treatment T$_4$ followed by T$_2$ than T$_3$ and the lowest was obtained from treatment T$_5$ than T$_1$. Similarly, the highest grain yield at Sayedpur, Nilphamari was obtained from treatment T$_2$ followed by T$_4$ than T$_3$ and the lowest was from treatment T$_5$ than T$_1$. Based on these results it may be concluded that additional 1 to 2.5 t ha^{-1} grain yield of BRRI dhan51 may be achieved at Rangpur region by applying 30 kg ha^{-1} additional N with recommended N within 5 to 15 days after desubmergence at vegetative stage.

Effect of nitrogen management for yield maximization after desubmergence for BRRI dhan52 at Rangpur region

The experiments were conducted at farmer's field to identify and recommend the appropriate nitrogen management for BRRI dhan52 for yield maximization after desubmergence for sustainable rice production during T. Aman season at Pirgasa of Rangpur district, Kaliganj of Lalmonirhat district and Sayedpur of Nilphamari district. The treatments were T$_1$=AEZ based recommended dose of N management, T$_2$=T$_1$ + additional 30 kg N ha^{-1} after five days of submergence, T$_3$=T$_1$ + additional 30 kg N ha^{-1} after 10 days of submergence, T$_4$=T$_1$ + additional 30 kg N ha^{-1} after 15 days of submergence and T$_5$=Without N (Control). The experiment was laid down in RCB design with three replications. Thirty-five-day-old seedling was transplanted with two seedlings per hill. All fertilizers were applied as basal before transplanting except urea.

Table 19. Marginal rate of return of the applied N fertilizer and varieties.

Gross margin (Tk ha^{-1})	Treatment	Variable cost (Tk ha^{-1})	Marginal variable cost (Tk ha^{-1})	Marginal gross margin (Tk ha^{-1})	Marginal rate of return
151131	V2N3	7479	2579	14324	555.4241
136806	V2N2	4900	77	471	612.0306
136335	V2N1	4823	41	118	286.5948
136218	V1N2	4782	4782	54748	1144.868
81470	V2N0	0		15387	
66083	V1N0	0			

Table 20. Effect of different nitrogen management on grain yield production of BRRI dhan51 after desubmergence at different locations during T. Aman 2013.

Treatment	Location		
	Pirgasa, Rangpur	Kaliganj, Lalmonirhat	Sayedpur, Nilphamari
T_1	4.26 a	5.54 ab	3.95 a
T_2	5.49 a	6.28 a	4.34 a
T_3	5.12 a	5.82 a	4.18 a
T_4	5.49 a	6.46 a	4.31 a
T_5	3.47 c	3.51 b	3.54 b
CV (%)	4.5	8.0	8.2

Grain yield was significantly affected by different treatments during T. Aman 2013 season at different locations (Table 21). The highest grain yield was observed from treatment T_3 followed by T_2 than T_4 and the lowest was obtained from treatment T_5 than T_1 at Pirgasa, Rangpur. But the higher grain yield at Kaliganj, Lalmonirhat was observed from treatment T_3 followed by T_2 than T_4 and the lower was from treatment T_5 than T_1. Similarly, the higher grain yield was obtained from treatment T_3 followed by T_2 than T_4 and the lower was obtained from treatment T_5 than T_1.

Based on these results it may be concluded that additional 1 to 2 t ha^{-1} grain yield of BRRI dhan52 may achieve at Rangpur region by

Table 21. Effect of different nitrogen management on grain yield production of BRRI dhan52 after desubmergence at different locations during T. Aman 2013.

Treatment	Location		
	Pirgasa, Rangpur	Kaliganj, Lalmonirhat	Sayedpur, Nilphamari
T_1	4.17 a	4.02 ab	5.00 b
T_2	4.61 a	5.15 b	6.30 a
T_3	4.65 a	5.45 a	6.39 a
T_4	4.53 a	5.09 b	6.16 a
T_5	3.53 c	3.96 b	4.19 c
CV (%)	12.8	14.2	8.0

applying 30 kg ha^{-1} additional N with recommended N within 5 to 15 days after de submerge at vegetative stage.

Effect of urea splitting on yield of rice transplanted by mechanical trasplanter

The present experiment was conducted to find out a suitable urea splitting schedule for rice transplanted by transplanter. Two experiments, in Aman 2013 and Boro 2013-2014 were conducted at Agronomy field, BRRI HQ, Gazipur. In Aman season. the urea splitting schedule were T_1 (200 kg urea/ha, 50% at 20 and 50% at 40 DAT), T_2 (200 kg urea/ha, 1/3rd at 20, 1/3rd at 40 and 1/3rd at 60 DAT), T_3 (200 kg urea/ha, 30% at 20, 30% at 40, 30% at 60 DAT and 10% after flowering) and T_4 (N-control). For Boro season, the urea splitting schedule were- T_1 (300 kg urea/ha, 1/3rd at 20, 1/3rd at 40 and 1/3rd at 60 DAT), T_2 (300 kg urea/ha, 1/4th at 20, 1/4th at 40, 1/4th at 60 and 1/4th at 80 DAT), T_3 (300 kg urea/ha, 30% at 20, 30% at 40, 30% at 60 DAT and 10% after flowering), T_4 (300 kg urea/ha, 25% at 20, 25% at 40, 20% at 60, 20% 80 DAT and 10% after flowering) and T_5 (N-control). The experiment was conducted in a randomized complete block design and replicated thrice. BRRI dhan49 and BRRI dhan29 were used as planting materials for Aman and Boro season respectively. Fourteen days old seedlings for Aman and 25 days old seedlings for Boro was transplanted using a walking type transplanter.

In Aman season, the highest yield was recorded from the treatment T_2. The highest yield is attributed due the more number of effective tillers/panicle, number of grains/panicle. In Boro season, the highest yield was recorded from the treatment T_2. For mechanically transplanted rice T_2 both in Aman (200 kg urea/ha) and Boro (300 kg urea/ha) season was found suitable.

WEED MANAGEMENT

Effect of weed control option for yield maximization of BRRI dhan56 and BRRI dhan57 in drought condition at Rangpur region in T. Aman season

Six experiments were conducted at farmer's field at Pirgasa of Rangpur, Kaliganj of Lalmonirhat and Sayedpur of Nilphamari district to identify and recommend appropriate weed management option for BRRI dhan56 and BRRI dhan57 under drought condition for yield maximization during T. Aman season. The treatments were T_1=Pre emergence herbicide + one hand weeding, T_2=Post emergence herbicide + one hand weeding, T_3=Pre emergence herbicide + Post emergence herbicide, T_4=Three hand weeding at 15, 30 and 45 DAT, T_5=No weeding and T_6=Farmer's practice. The experiment was laid down in RCB design with three replications. Transplanting was done by two seedlings per hill and seedling age was 25-day-old. All fertilizers were applied as basal before transplanting except N.

Grain yield of BRRI dhan56 was significantly affected by different treatments at different locations (Table 22) and the highest grain yield was observed from treatment T_3 followed by T_4 than T_1 at Pirgasa, Rangpur . But the highest grain yield was recorded from the treatment T_4 followed by T_2 than T_1 at Kaliganj, Lalmonirhat. Similerly, the highest grain yield was observed from treatment T_4 followed by T_3 than T_1 at Sayedpur, Nilphamari.

Grain yield of BRRI dhan57 was significantly affected by different treatments (Table 22) during T. Aman 2013 season. The highest grain yield was observed from treatment T_1 followed by T_3 than T_4 and the lowest was obtained from treatment T_5 than T_6 ha^{-1}at Pirgasa, Rangpur. But at Kaliganj, Lalmonirhat the highest yield was observed from treatment T_1 followed by T_2 than T_3 and the lowest yield was obtained from treatment T_5 than T_6. Similarly, the highest grain yield was observed from treatment T_1 followed by T_4 than T_3 and the lowest yield was obtained from treatment T_5 than T_6 at Sayedpur, Nilphamari. Based on these results it may be concluded that to control weed efficiently at drought prone area of Rangpur region where BRRI dhan56 and BRRI dhan57 were cultivated during T. Aman season, Pre-emergence herbicide + one hand weeding or Post-emergence herbicide + one hand weeding or Pre emergence herbicide + Post emergence herbicide or three hand weeding may produce higher grain yield. Farmers may achieve more than one ton ha^{-1} additional rice yield from their existing weed control practice.

Weed seed bank dynamics in Maize-Mungbean-Rice cropping system at BRRI farm

The experiment was taken to find out the richness of weed seed population in Maize-Mungbean-Rice cropping system with different soil depth. Experiment was conducted during January to June 2014. Soil samples were collected from field following Maize-Mungbean-Rice cropping pattern. Thirty soil samples were collected randomly from three soil depths: 0-10, 10-20 and 20-30 cm using a PVC pipe with a diameter of 8 cm and depth 30 cm. The soil was spread on a plastic tray following length 58 cm, breath 24 cm and depth 2.5 cm.

Table 22. Effect of different weed control option on grain yield production of BRRI dhan56 and BRRI dhan57 in drought condition at different locations during T. Aman 2013.

| Treatment | Locations | | | | | |
| | Kaliganj, Lalmonirhat | | Sayedpur, Nilphamari | | Pirgasa, Rangpur | |
	BRRI dhan56	BRRI dhan57	BRRI dhan56	BRRI dhan57	BRRI dhan56	BRRI dhan57
T_1	3.25 a	3.79 a	4.04 a	4.19 a	4.56 a	3.64 a
T_2	3.11 a	3.58 a	4.33 a	3.61 a	4.44 a	3.34 a
T_3	3.60 a	3.69 a	4.02 a	3.67 a	4.73 a	3.40 a
T_4	3.49 a	3.76 a	4.62 a	4.01 a	5.08 a	3.39 a
T_5	2.87 ab	3.18 b	3.10 b	3.08 b	3.62 b	2.95 b
T_6	2.65 b	3.29 a	3.14 b	3.19 b	3.65 b	3.19 a
CV (%)	16.5	10.8	11.2	12.6	9.5	12.7

During January to June higher weed seed germination was found in upper layer (10 cm) of soil. Most of the species showed significant differences among three different soil depths except *Echinochloa crusgalli, Eleusine indica, Desmodium trifolium and Oxalis europea*. The density of *Lindernia ciliata* was higher in 30 cm soil depth (365 weeds m^{-2}). On the other hand Tridax procumbens density was lower among twelve different weed species (Tables 23 and 24). *Lindernia ciliata* showed the highest percent of abundance while the lowest abundance percent was found in case of *Tridax procumbens*. It can be concluded that the broad leaf weed prevalence was higher in Maize- Mungbean- Rice cropping pattern.

Table 23. Weed vegetations in Maize-Mungbean-Rice cropping system and % abundance and weed ranking of different weed species during January to June 2014.

Common name	Scientific name	Family	Broad group	Weed abundance (%)	Weed ranking
Shama	*Echinochloa crusgalli*	Poaceae	grass	17.00	3
Mutha	*Cyperus rotundus*	Cyperaceae	sedge	22.65	2
Durba	*Cynodon dactylon*	Poaceae	grass	2.20	9
Katahenchi	*Lindernia ciliate*	Scrophulariaceae	broad leaf	29.30	1
Chapra	*Eleusine indica*	Poaceae	grass	5.41	5
Tunaki	*Tridax procumbens*	Compositae	broad leaf	1.02	12
Tripotri shak	*Desmodum trifolium*	Leguminosae	broad leaf	3.61	7
Chechra	*Scirpus maritimus*	Cyperaceae	sedge	4.96	6
Amrul	*Oxalis europea*	oxalidaceae	broad leaf	1.34	10
Panilong	*Ludwigia octovalsis*	Onagraceae	broad leaf	1.32	11
Choto dudhia	*Euphorbia parviflora*	Euphorbiaceae	broad leaf	3.34	8
Halde mutha	*Cyperus difformis*	Cyperaceae	sedge	6.27	4

Table 24. Weed density (no./m^2) in different soil depth in Maize-Mungbean-Rice cropping pattern during January to June 2014.

Species	Soil depth			CV%	LSD$_{(0.05)}$
	10 cm	20 cm	30 cm		
Echinochloa crusgalli	213	201	197	3.86	NS
Cyperus rotundus	307	239	267	6.30	29.54
Cynodon dactylon	28	27	24	5.37	2.447
Lindernia ciliate	343	344	365	1.54	9.358
Eleusine indica	69	65	61	7.74	NS
Tridax procumbens	15	11	10	11.30	2.378
Desmodum trifolium	48	42	40	14.55	NS
Scirpus maritimus	63	61	54	5.52	5.673
Oxalis europea	19	15	14	8.38	Ns
Ludwigia octovalsis	20	16	11	17.68	4.817
Euphorbia parviflora	46	39	35	9.0	6.232
Cyperus difformis	87	75	63	4.79	6.212
Total	1258	1135	1141		

Soil Science Division

SUMMARY

In T. Aman, BR8417-2-1-2 can be used as low input entry in terms of N fertilizer requirement, but BR7528-2R-19-HR10 was responsive up to N 120 kg N/ha (4.95 t/ha yield). In Boro season, BR7830-16-1-5-3 required 180 kg N/ha for producing 5.98 t/ha grain yield, while 120 kg N/ha was sufficient for weed tolerant rice, BR7671-37-2-2-3-7 and BR7833-11-1-1-2-1-2B5 to produce maximum grain yields.

In T. Aman, N uptake was more (78 kg N/ha) with BR7528-2R-19-HR10 N than other genotypes and N recovery efficiency (RE) was 36%. Weed tolerant rice showed higher N RE (47%). About 15-16 kg N in T. Aman and 14-17 kg N in Boro seasons were required to produce one ton rice grain.

Rice cultivation without K application created its negative balance in soil (-36 kg K/ha/year). At least 100 kg K/ha is needed to have 12 kg K/ha balance in Boro-Fallow-T. Aman pattern. BRRI dhan29 has capacity to produce 4.26 t/ha grain in P deficient soil (3.1-3.5 ppm P). Poultry manure @ 2 t/ha + IPNS based chemical fertilizer produced the highest grain yield of 4.31 and 6.69 t/ha in T. Aman and Boro seasons respectively. Long term omission of N, P and K decreased grain yield by 0.55, 0.40 0.63 t/ha in T. Aman and 3.87, 2.60 and 2.26 t/ha respectively in Boro season. Yield significantly increased with 80 kg K/ha than 40-60 kg K/ha.

In Barisal, Satkhira and Rangpur sites, N was the most yield limiting nutrient for both T. Aman and Boro seasons. In T. Aman, omission of P in Barisal and Satkhira significantly reduced grain yield. In Rangpur site, Zn omission in both the seasons and S omission in Boro season significantly reduced grain yield.

In continuous wetland rice culture, trend in grain yield with NPKS fertilization over 33 years showed a positive increment compared to base year (1981). Soil productivity can be recuperated to its original state by addition of complete fertilizer dose.

The STB fertilizer dose and INM may be good options for higher grain yield of rice in double or triple rice cropping pattern. Cow dung applied with IPNS based chemical fertilizer (except N) was a good practice to get maximum grain yield in tidal flood ecosystem. Use of rice straw with IPNS based chemical fertilizer was a better option to get maximum grain yield in submergence and cold prone area.

The N P C fertilizer can produce statistically similar grain yield like TSP fertilizer. Flood water NH_4^+-N increased with broadcast urea than urea deep placement (UDP) as USG and NPK briquette in all seasons. In Boro season, 78 kg N/ha as deep placement produced satisfactory grain yield. In T. Aus and T. Aman seasons, 52 kg N/ha as deep placement produced satisfactory rice grain yield.

Omission of P and K reduced bacterial population but not fungal ones. Higher total number of free living N fixing (NFB) and phosphate solubilizing (PSB) bacteria were found in CD and IPNS based chemical fertilizer treatments. No free living NFB and PSB was found in soils of continuous wetland intensive rice cropping system.

In Rajshahi region, none of the introduced variety superseded Swarna variety, though some farmers were interested to grow BRRI dhan56 for early establishment of tomato. Most of the farmers were interested to cultivate BRRI dhan46 because of its suitability as late planted rice and higher yield performance in Barisal regions. Cultivation of vegetables in waterlogged soils with rice under ridge/pyramid culture was more profitable than rice alone in pre-monsoon and monsoon seasons in Barisal region.

In Rajshahi site, maximum rice equivalent yield was recorded with Wheat-T. Aus-T. Aman pattern (13.66 t/ha) having the highest BCR (1.46) and gross margin (68,061 Tk/ha) followed by Mustard-T. Aus-T. Aman (11.91 t/ha) pattern. In Baroisal site, farmers are following Mustard/Wheat-T. Aus-T. Aman, Boro-Fallow-T. Aman and Felon/Sunflower-Fallow-T. Aman patterns using introduced modern varieties. In both the study sites, non-rice cropping patterns were more profitable than Rice-Rice patterns.

SOIL FERTILITY AND PLANT NUTRITION

Nitrogen rates for some newly released BRRI varieties/lines

Rice crop requires a large amount of N for its growth and development. Biomass production of irrigated rice is mainly driven by the supply of N having adequate water supply and no weed or pest problems (De Datta *et al.,* 1988; Kropff *et al.,* 1993). Plant N status mostly determines rice yield potential through leaf area development and canopy photosynthesis (Kropff *et al.,* 1993), and N drives the demand for other micronutrients in irrigated rice system (Dobermann *et al.,* 1998). In Bangladesh, most of the soils are N deficient. So, N fertilizer is essential to meet the crop requirement. There are considerable uncertainties about N requirements because N response pattern may vary depending on variety. It is necessary to know N response behaviour of newly developed varieties compared to their traditional plant types for recommending appropriate N fertilizer dose.

An investigation was undertaken to determine N response behaviour of promising lines compared to BRRI rice varieties. The experiment was conducted in T. Aman and Boro seasons 2013-14 at BRRI farm, Gazipur (AEZ28). In T. Aman season, four N doses were evaluated with four MV rice. The N doses used were 0, 40, 80 and 120 kg N/ha, which were applied as 34% at basal, 33% at 20 DAT and rest 33% at seven days before PI stage. Promising lines and varieties used were BR8417-2-1-2, BR7528-2R-19-HR10, BRRI dhan39 and BRRI dhan49. In Boro season, BR7830-16-1-5-3, weed tolerant rice, BR7671-37-2-2-3-7 and BR7833-11-1-1-2-1-2B5 were compared with BRRI dhan28 under 0, 60, 120 and 180 kg N/ha. Nitrogen was applied in three splits as 34% at basal, 33% at 25 DAT and the rest 33% at 5-7 days before PI stage. The treatments were assigned in a split-plot design with N doses in the main plots and varieties in the sub-plots. Phosphorus, K, S and Zn were applied @ 12-42-10-2 kg/ha and 20-60-10-2.2 kg/ha in T. Aman and Boro seasons respectively as STB at final land preparation.

BR8417-2-1-2 and BRRI dhan39 produced about 3 t/ha grain, while BR7528-2R-19-HR10 and BRRI dhan49 produced about 4 t/ha without N fertilizer (Table 1). BR7528-2R-19-HR10 produced comparatively higher grain yield than BRRI dhan49 at all N levels. However, yield difference between BR7528-2R-19-HR10 and BRRI dhan49 was significant at N_{120} level. Application of N @ 120 kg/ha significantly increased grain yield of all tested rice genotypes in T. Aman season. All promising lines and varieties produced maximum straw yield at N_{80} and N_{120} kg/ha (Table 1). BR7528-2R-19-HR10 produced higher straw yield than others.

BR7830-16-1-5-3 produced significantly higher grain yield than other genotypes under native N condition (Table 2). Application of 60 kg N/ha significantly improved grain yield of all tested genotypes. All genotypes produced the highest grain yield at 180 kg N/ha. However, application of 180 kg N/ha significantly increased grain yield compared to 120 kg N/ha only in BR7830-16-1-5-3. So, 120 kg N/ha was sufficient for weed tolerant rice, BR7671-37-2-2-3-7 and BR7833-11-1-1-2-1-2B5 to produce maximum grain yield. All promising lines and check variety produced maximum straw yield at 180 kg N/ha (Table 2).

Changes in N uptake. Nitrogen uptake in control plot was 29-39 kg N/ha in T. Aman 2013, which increased significantly (46-78 kg/ha) with greater N rates. The highest N uptake varied from 57 to 78 kg N/ha at N_{120}. BR7528-2R-19-HR10 took up 78 kg N/ha, which was significantly higher than other entries (57-74 kg N/ha) at N_{120}. The amount of N required for producing one ton rice grain varied from 9-10 kg in control plots depending on genotypes; however it was 15-16 kg N/t grain production at N_{120}.

In Boro 2013-14, N uptake in control plot varied from 16 to 23 kg N/ha depending on genotypes. BR7830-16-1-5-3 absorbed 23-93 kg N/ha depending on its rates. BRRI dhan28 absorbed 67 kg N/ha at N_{120} and 76 kg N/ha at N_{180}. The amount of N required for producing one ton rice grain varied from 8 to 10 kg in control plots depending on genotypes tested. Weed tolerant rice used 10-14 kg N/t, which was comparatively lower than other entries. BR7671-37-2-2-3-7 and BR7833-11-1-1-2-1-2B5 used 10-17 kg N/t and

Table 1. Effect of N rates on grain and straw yields (t/ha) of promising lines and varieties, T. Aman 2013, BRRI, Gazipur.

N rate (kg/ha)	Grain yield (t/ha)				Straw yield (t/ha)			
	BR8417-2-1-2	BR7528-2R-19-HR10	BRRI dhan39	BRRI dhan49	BR8417-2-1-2	BR7528-2R-19-HR10	BRRI dhan39	BRRI dhan49
0	3.09	3.87	3.14	3.92	2.85	3.41	2.62	3.49
40	3.21	4.27	3.29	4.30	3.00	3.95	2.59	3.88
80	3.30	4.67	3.39	4.53	3.32	4.33	2.96	4.12
120	3.60	4.95	3.82	4.76	3.32	4.56	3.24	4.22
LSD0.05 for N		0.23				0.22		
$LSD_{0.05}$ for V		0.17				0.24		
$LSD_{0.05}$ for N×V		ns				ns		
CV (%)		5.1				7.3		

Table 2. Effect of N rates on grain and straw yields (t/ha) of promising lines and varieties, Boro 2013-14, BRRI, Gazipur.

N rate (kg/ha)	BR7830-16-1-5-3	Weed tolerant rice	BR7671-37-2-2-3-7	BR7833-11-1-1-2-1-2B5	BRRI dhan28 (ck)
0	2.64 (1.70)	1.99 (1.61)	1.97 (1.71)	2.10 (1.68)	2.10 (1.43)
60	3.83 (3.20)	3.14 (2.75)	3.51 (2.83)	3.65 (2.91)	3.53 (2.51)
120	5.39 (4.63)	5.87 (4.21)	5.17 (4.57)	4.58 (4.23)	4.62 (3.74)
180	5.98 5.74)	6.33 (5.41)	5.49 (5.58)	4.78 (4.40)	4.87 (4.70)
$LSD_{0.05}$ for N	0.56 (0.37)				
$LSD_{0.05}$ for V	0.24 (0.20)				
$LSD_{0.05}$ of N×V	0.49 (0.41)				
CV (%)	7.2 (7.1)				
GD	147	147	158	137	142

GD=Growth duration (day); Figures in the parentheses indicate straw data.

8-17 k N/t respectively. These imply that weed tolerant entry is efficient in utilizing N for grain production.

Nitrogen recovery efficiency. In T. Aman, N recovery efficiency (RE) decreased with its increased rates and it was the highest at N_{40}. The highest RE was in BRRI dhan49 (49%) followed by BR7528-2R-19-HR10 (48%). BR8417-2-1-2 and BRRI dhan39 had identical RE at N_{40}, which was significantly lower than BRRI dhan49 and BR7528-2R-19-HR10. BR8417-2-1-2 and BRRI dhan39 had statistically identical RE irrespective of N levels. The RE with BR7528-2R-19-HR10 was 48% and 38% at N_{40} and N_{80} respectively, which was statistically similar with BRRI dhan49. At the highest N level, BR7528-2R-19-HR10 had significantly higher N RE (36%).

In Boro season, RE of N significantly varied from 37 to 54% depending on tested genotypes at N_{60}. The highest RE (54%) was recorded with BR7833-11-1-1-2-1-2B5 at N_{60}. Weed tolerant rice had the lowest RE (37%) at N_{60}. Higher N dose (120 kg/ha) significantly influenced its RE in weed tolerant rice from 47% at N_{120} to 38% at N_{180}, which were statistically similar with BRRI dhan28.

However, RE with BR7830-16-1-5-3 and BR7671-37-2-2-3-7 was not affected significantly at any N dose indicating that they are not N responsive lines.

Evaluation of K rates with BRRI varieties

Potassium is the most abundant cation and is absorbed in large quantities by rice roots. Intensive cropping with modern rice varieties is responsible for increasing K deficiencies in soil in many areas of the world (Goswami and Banerjee, 1978). Rice crops remove at least 70 kg K from soil to produce 4 t/ha grains. Present level of K fertilization may not be enough for sustaining a favourable K fertility status of soil in the long run. Potassium deficiency symptoms in rice are less conspicuous than N or S. So, most of the farmers apply urea than other fertilizers. As a result, soils, those were not K deficient the past are likely to become deficient in near future. Potassium deficiency in wetland rice culture has so far been received limited attention, although hidden K deficiencies limit its yield seriously. Optimum K fertilizer doses for modern rice varieties released or proposed ones have not been determined. Therefore, the experiment was conducted to develop response

curve and to find out economic optimum dose of K for different BRRI varieties in a Rice-Fallow-Rice cropping pattern of Bangladesh.

The experiment was conducted in a long-term permanent layout of K response study both in T. Aman (26th crop) and Boro seasons (27th crop) at BRRI farm, Gazipur. Initial soil available K at surface layer was 0.18 cmol/kg in 2003 and after 10 years it is 0.19-0.22 cmol/kg. In T. Aman and Boro seasons, K rates were 0, 50, 100, 150 and 200 kg/ha. The experiment used RCB design with three replications. Each plot received a blanket dose of NPS @ 145-25-24 kg/ha and 97-15-14 kg/ha in Boro and T. Aman seasons respectively. Test varieties were BRRI dhan49 and BRRI dhan28 in T. Aman and Boro seasons respectively.

T. Aman 2013. A significant yield increase was observed at 50 kg K/ha compared to K control plots, but no significant yield variations were observed at higher K rates (Table 3). The highest straw yield (5.58 t/ha) was found in K_{200}, which was statistically similar with K_{50}, K_{100} and K_{150}. The lowest straw yield (4.53 t/ha) was found in K control plot.

Boro 2013-14. Significant effect of K rates on grain and straw yield was found over K control plots (Table 3). With the increase of K doses, grain yield increased up to K_{150} then it decreased. The highest grain yield (5.63 t/ha) was found in K_{150}, which was statistically similar to K_{50} and K_{100}. The lowest grain yield (2.69 t/ha) was found with K control plots. The highest straw yield (5.66 t/ha) was found in K_{200}, which was statistically similar with K_{50}, K_{100} and K_{150}. The lowest straw yield (3.53 t/ha) was found with K control plots. Quadratic response of K fertilization was observed in Boro season only ($Y = -0.000X^2 + 0.043X + 2.917$, $R^2 = 0.926$).

Potassium uptake and balance. Application of K fertilizer significantly influenced K uptake in Boro and T. Aman seasons. However, Boro rice plant removed more K from soil than T. Aman rice. At K_0, T. Aman rice absorbed 24 kg K/ha but it was 47 kg K/ha with Boro rice. The highest total K uptake (291 kg/ha/year) was observed in K_{200}, while the lowest (71 kg/ha/year) in K_0. Application of K improved apparent soil K balance. In K control plot, negative K balance (-36 kg K/ha/year) indicated its mining from soil. At least 50 kg K/ha was needed for every crop in a Boro-Fallow-T. Aman pattern to have 12 kg/ha/year K build up.

Evaluation of BRRI dhan29 in phosphorus deficient soil

Rice production is limited by soil P deficiencies in many parts of the world. Its availability in soil is closely related not only to soil P content but also to soil physicochemical and biological properties. In intensified modern wetland rice culture, more P is removed than its replenishments through fertilizer or manure. Rice yield in P-deficient soil can be reduced by 50% compared to soils containing even moderate P levels (Saleque *et al*., 1998). By keeping P fertilizers away from fertilizer inputs in intensive cropping systems, many soils of Bangladesh have become P deficient (Ali *et al.,* 1997). Studies of Bangladesh Rice Research Institute (BRRI, 2006) showed how a P rich soil became P deficient within four years in Rice-Rice cropping sequence. Under P deficient soil conditions, we do not know whether yield of modern rice variety like BRRI dhan29 will be affected. However, yield and P uptake by this variety under deficient soil P condition is unknown to us. The study was, therefore, undertaken to determine yield of BRRI dhan29 in deficient soil P

Table 3. Effect of K rates on grain and straw yields of rice at BRRI, Gazipur.

Treatment	T. Aman 2013, BRRI dhan49		Boro 2013-14, BRRI dhan28	
	Grain yield (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)
K_0	3.16	4.53	2.69	3.53
K_{50}	4.62	5.00	5.23	5.13
K_{100}	4.67	5.07	5.51	5.34
K_{150}	4.68	5.38	5.63	5.50
K_{200}	4.80	5.58	5.44	5.66
$LSD_{(0.05)}$	0.42	0.58	0.44	0.59
CV (%)	5.1	6.1	4.8	6.3

conditions and to determine P uptake by grain at P deficient soil.

A field experiment was conducted in Boro 2013-14 at long term experimental field of Soil Science Division, BRRI, Gazipur. The experimental plots having different available soil P were created by long time P management under Rice-Rice cropping pattern. Four different ranges of inherent soil available P levels were considered: T_1=1.5-2.0 ppm, T_2=2.1-2.5 ppm, T_3=2.6-3.0 ppm and T_4=3.1-3.5 ppm, which were below critical limit of 8.0 ppm. The experiment was conducted in a RCB design with three replications. Other nutrients applied were 145-50-10-3 kg/ha of N-K-S-Zn respectively. Rice was transplanted in 1st week of January with 45-day-old seedlings and harvested in May. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis. Thousand grain weights (TGW) were also determined. Grain samples were analyzed for determining P content and uptake by grain.

Indigenous soil P levels significantly influenced tiller and panicle production of BRRI dhan29 (Table 4). The lowest soil P level (T_1) produced 174 tiller/m^2 and tiller number gradually increased to 240 with increasing soil P levels. The highest level of soil P (T_4) produced significantly the highest tiller number, which was statistically similar with T_3. Panicle production had similar trend. Soil P levels also significantly increased TGW and it varied from 19.19 g in T_1 treatment to 21.37 g in T_4 having 3.1-3.5 ppm P. Soil P levels significantly influenced grain and straw yields of BRRI dhan29 (Table 4). Grain yield ranged from 0.54 t/ha in T_1 (1.5-2.0 ppm P) to 4.26 t/ha in T_4 (3.1-3.5 ppm P). Similar trend was observed for straw yield. Grain P uptake significantly increased with increasing soil P levels, which ranged from 0.43 to 4.22 kg/ha. The P uptake in T_1 was only 0.43 kg/ha and with increasing soil P level, P

uptake increased. Among four deficient soil P levels, the highest P uptake 4.22 kg/ha) by grain was observed in T_4 (3.1-3.5 ppm soil P) followed by T_3 (2.6-3.0 ppm soil P, 2.22 kg/ha).

MANAGEMENT OF NUTRITIONAL DISORDERS IN RICE

Long-term missing element trial at BRRI farm
Missing element trial is an effective technique of field evaluation for soil fertility status. Long-term missing element experiment is also a mirror image in respect of rice response behaviour in nutrient stress environment and its reverse response of fertilizer due to its addition in same soil conditions. It can be considered as an effective medium for yield response behaviour study in both nutrient stress and optimum conditions for finding out nutrient use-efficient genotypes.

The experiment was initiated on a permanent layout at BRRI farm Gazipur in 1985 Boro season having 12 treatments assigned in a RCB design with four replications (Table 5). Since Boro 2000, each plot was divided 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, but in T. Aman it was 100-25-35-20-5 kg/ha. After 47th crop, treatments were modified with omission of Zn because of its sufficiency in soil. STB dose of NPKS was 138-10-80-5 kg/ha and 100-10-80-5 kg/ha for Boro and T. Aman respectively was calculated from complete treatment after 47th crop using Fertilizer Guide-2005 (BARC, 2005). Higher level of available S in control plot compared to initial soil may be due to recent industrial urbanization effect and thus S dose was reduced. Urea N was applied in three equal splits at final land preparation, at active

Table 4. Effect of inherent soil P on growth and yield of BRRI dhan29, Boro 2014, BRRI, Gazipur.

Treatment	Tiller/m^2	Panicle/m^2	1000-grain wt (g)	Grain yield (t/ha)	Straw yield (t/ha)
T_1 = 1.5 - 2.0 ppm	174	157	19.19	0.54	2.28
T_2 = 2.1- 2.5 ppm	184	171	19.69	1.13	2.77
T_3 = 2.6 - 3.0 ppm	201	192	20.56	2.35	3.03
T_4 = 3.1- 3.5 ppm	240	228	21.37	4.26	4.02
LSD (0.05)	43	43	0.45	0.54	0.65
CV (%)	10.8	11.6	1.10	13.0	10.7

Table 5. Treatment details of long-term missing element experiment, BRRI, Gazipur, 1985-2014.

Original treatment, 1985	Reverse treatment, 2000	Treatment, 2009-10	Treatment, 2011-14
NPKSZn	All missing	NPKSZn	NPKSZn @138/100-7-80-3-5 kg/ha
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	Cow dung (3 t/ha) + 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	PM (2 t/ha) + IPNS fert.
NP (-KSZn)	NP (+ KSZn)	Saw dust @ 3 t/ha	NPKSZn @ 138/100-7-60-3-5 kg/ha
NK (- PSZn)	NK (+ PSZn)	Oilcake@ 2.0 t/ha	Oil cake (2t/ha) + IPNS fert.
N (-PKSZn)	N (+ PKSZn)	Mixed Manure	NPKSZn @ 138/100-7-40-3-5 kg/ha
All missing	+ NPKSZn	Control	Control

tillering and at 5-7 days before PI. Rest of the fertilizers was applied at final land preparation.

In Boro 2009-10, organic materials were used as third modification in T_5, T_8, T_9 T_{10} and T_{11} treatments. Oil cake (OC, 2 t/ha), saw dust (SD, 3 t/ha), cow dung (CD, 3 t/ha), mixed manure (CD: PM: SD: OC = 1:1:1:0.5) and poultry manure (PM, 2 t/ha) in T_{10}, T_9, T_5, T_{11} and T_8 treatments. Only N @ 138 kg/ha was applied as top dress with organic amended treatments. However, both missing and reverse management plots were merged for making 12 treatments. In T. Aman 2011-12, T_9 and T_{11} treatments were changed to accommodate 60 and 40 kg K/ha, respectively. NPKSZn @ 100-7-80-3-5 kg/ha was used in T. Aman 2013 and it was 138-7-80-3-5 kg/ha in Boro 2013-2014. CD (3 t/ha), PM (2 t/ha) and mustard OC (2 t/ha) were used in T_5, T_8 and T_{10} treatments. Table 5 provides the treatments. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis.

Yield. In T. Aman 2013, omission of nutrients except Zn produced lower grain and straw yields than NPKSZn (Table 6). Application of PM @ 2 t/ha with IPNS based chemical fertilizers produced a little bit higher grain yield than complete fertilizer use. However, other organic amendments did not excel its performance compared to complete fertilization. In Boro 2014, application of PM @ 2 t/ha with IPNS based chemical fertilizers produced significantly higher grain yield (6.69 t/ha) than control and even omission plot. Omission of N, P and K produced significantly lower grain yield compared to complete fertilization. But omission of Zn and S plot produced statistically similar grain yield compared

to complete fertilizer treatment. The effects of K rates on grain yield of MV rice were clearly visible in Boro and T. Aman seasons. Application of K @ 80 kg/ha produced higher grain yield (6.43 t/ha) in Boro and T. Aman seasons (4.22 t/ha). Potassium @ 40 kg/ha produced significantly lower yield compared to K @ 80 kg/ha in both the seasons.

Nutrient uptake in T. Aman 2013. Nutrient uptake pattern of BRRI dhan49 varied significantly with different treatments (Table 7). The highest total N and P uptake was found with the application of PM with IPNS based chemical fertilizer and the lowest in control plots. The K uptake was the highest in treatment receiving mustard OC with IPNS based chemical fertilizer, which was identical to PM + IPNS based chemical fertilizer. $NPK_{80}SZn$ treatment was responsible for the highest S uptake followed by PM, mustard OC, CD containing and $NPK_{40}SZn$ treatments. The lowest K and S uptake was found in control treatment.

Nutrient uptake in Boro 2013-14. Complete fertilization showed higher nutrient uptake compared to control treatment and even from any other nutrient omission treatment (Table 8). Nitrogen and P uptakes were higher with CD applied with IPNS based chemical fertilizers, but statistically similar with T_8 and T_{10}. This might be due to improved nutrient use-efficiency associated with organic manure addition. Potassium uptake was higher at 80 kg K/ha, which was significantly higher than K @ 60 and 40 kg/ha.

It is found that PM @ 2 t/ha + IPNS based chemical fertilization is a good option for rice cultivation in soils like BRRI farm. The intensity of

Table 6. Effect of long-term missing element on grain and straw yields (t/ha), T. Aman 2013 and Boro 2013-14, BRRI, Gazipur.

Treatment	BRRI dhan49, T. Aman 2013		BRRI dhan29, Boro 2013- 2014	
	Grain	Straw	Grain	Straw
NPKSZn @138/100-7-80-3-5 kg/ha	4.22	5.69	6.43	6.05
NPSZn (-K)	3.59	4.67	4.17	3.87
NKSZn (-P)	3.82	5.03	3.83	3.84
PKSZn (-N)	3.67	4.15	2.56	2.11
CD (3 t/ha) + IPNS	4.17	6.08	6.45	5.91
NPKS (-Zn)	4.27	5.39	6.25	6.06
NPKZn (-S)	4.08	5.43	6.17	5.80
PM (2 t/ha) + IPNS	4.31	5.92	6.69	6.39
NPKSZn @ 138/100-7-60-3-5 kg/ha	4.05	5.67	6.02	5.59
OC (2 t/ha) + IPNS	3.73	6.37	6.15	6.13
NPKSZn @ 138/100-7-40-3-5 kg/ha	3.82	5.09	5.0	4.80
Control	2.76	3.36	2.04	1.85
LSD$_{(0.05)}$	0.34	0.48	0.62	0.57
CV (%)	6.1	6.3	8.3	8.2

*NPKSZn@ 100-7-80-3-5 kg/ha for T. Aman and 138-7-80-3-5 kg/ha for Boro.

Table 7. Effect of long-term missing element on nutrient uptake in BRRI dhan49, T. Aman 2013, BRRI, Gazipur.

Treatment	Total nutrient uptake (kg/ha)			
	N	P	K	S
NPKSZn @138/100-7-80-3-5 kg/ha	82	20	78	8
NPSZn (-K)	59	16	53	6
NKSZn (-P)	69	15	55	7
PKSZn (-N)	57	15	47	5
CD (3 t/ha) + IPNS	87	20	78	7
NPKS (-Zn)	75	19	65	7
NPKZn (-S)	77	19	67	5
PM (2 t/ha) + IPNS	92	22	87	8
NPKSZn @ 138/100-7-60-3-5 kg/ha	72	20	71	7
OC (2 t/ha) + IPNS	81	19	89	7
NPKSZn @ 138/100-7-40-3-5 kg/ha	65	18	63	7
Control	43	11	37	4
LSD$_{(0.05)}$	8	2	8	1
CV (%)	7.8	5.8	8.6	10.7

Table 8. Effect of long-term missing element on total nutrient uptake of BRRI dhan29, Boro 2013-14, BRRI, Gazipur.

Treatment	Nutrient uptake(kg/ha)		
	N	P	K
NPKSZn@138/100-7-80-3-5 kg/ha	97	19	88
NPSZn (-K)	60	17	25
NKSZn (-P)	60	7	86
PKSZn (-N)	33	10	45
CD (3 t/ha) + IPNS	107	23	99
NPKS (-Zn)	92	21	82
NPKZn (-S)	92	18	100
PM (2 t/ha) + IPNS	108	21	131
NPKSZn @ 138/100-7-60-3-5 kg/ha	93	20	66
OC (2 t/ha) + IPNS	102	22	91
NPKSZn @ 138/100-7-40-3-5 kg/ha	83	15	65
Control	27	7	28
LSD$_{(0.05)}$	13	3	20
CV (%)	9.6	8.1	16.8

yield decrease was more with N, P and K omission. Grain yield significantly increased with increasing of K rates. Zinc and S are not deficient in BRRI farm soil.

Long-term missing element trial at BRRI regional stations

Nutrient deficiency problem is a major constraint of rice production in many soils of Bangladesh. Proper identification and management of these problems are a prerequisite for boosting production and sustaining higher yields over long period of time. The missing element trial is an effective field technique to identify the existence of limiting nutrient(s) in soil of a particular area for its correction. Therefore, trials were conducted at Barisal and Rangpur regions.

The experiments were initiated in a permanent layout at BRRI RS farm, Barisal in Boro 2009, BRRI RS farm, Satkhira in T. Aman 2010 and BRRI RS farm, Rangpur in T. Aman 2010 using six treatments: NPKSZn, PKSZn, NKSZn, NPSZn, NPKZn and NPKS in RCB design with three replications. Fertilizer rate in Barisal site was NPKSZn @ 150-15-50-10-1 kg/ha for Boro and 60-15-50-10-1 kg/ha for T. Aman. In Rangpur site it was 97-7-39-15-0.3 kg/ha and 145-10-57-15-0.6 kg/ha in T. Aman and Boro seasons respectively. In Satkhira site, fertilizer doses for Boro season were NPKSZn @ 100-15-60-10-1 kg/ha. Urea-N was applied in three equal splits at final land

preparation, at active tillering stage and at 5-7 days before PI stage. Rest of the fertilizers was applied at final land preparation. Grain yield was recorded from 5 m^2 areas at the center part of each plot and 16 hills were collected for straw yield. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis.

In Barisal, Satkhira and Rangpur sites, N was the most yield limiting nutrient both in T. Aman and Boro season. In T. Aman season, omission of P in Barisal and Satkhira significantly reduced rice yield. In Rangpur, Zn omission in both seasons and S omission in Boro season significantly reduced rice yield.

Consequences of continuous wetland intensive rice cropping

Population in Bangladesh is increasing but cultivable land is decreasing. This means that we have to produce more from less area with less water to feed our people that necessitate intensive rice cultivation. 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. The varieties tested in T. Aus, T. Aman and Boro seasons are BRRI dhan48, BRRIdhan46 and BRRI dhan50 respectively. The NPK doses used were 140-25-80, 60-15-80 and 60-10-60 kg/ha for Boro, T. Aman and T. Aus respectively. Sulfur, Zn and Cu were applied at 10, 4 and 1 kg/ha in Boro season only. This is a non-replicated trial.

Annual rice production decreased from 6.41 t/ha in 1981 to less than 2.0 t/ha in 2008 because of continuous rice cultivation without fertilizer application. However, grain yield in this treatment is showing an increasing trend since last five years (Fig. 1). In 2013, annual production in control plot was 4.45 t/ha. Grain yield with NPKS fertilizers over last 33 years showed a little bit increasing trends compared to 1981. Grain yield in control

plot was 1.29-1.67 t/ha irrespective of season during 2012-13 (Table 9). However, its reversed management (addition of NPKSZnCu fertilizer) resulted in 10.55 t/ha/yr grain production, which is similar to complete fertilization (10.58 t/ha/yr). It indicates that complete fertilization can recuperate soil productivity even after a long period of rice cultivation without fertilizer application. Moreover, additional use of Cu is not necessary. Application of Zn slightly increased annual production compared to NPKS treatment.

Grain and straw yields in control plot were 0.52 t/ha and 1.94 t/ha, respectively in Boro 2013-14. In its reversed management (addition of NPKSZnCu), grain yield was 4.58 t/ha that is comparable to complete fertilizer treatment (4.48 t/ha). The highest grain yield of 4.84 t/ha in NPKSZn treatment indicated that addition of NPKSZnCu fertilizer in a balanced way can recuperate soil fertility after a long period of continuous rice cropping without fertilizers.

Integrated nutrient management for double or triple rice cropping pattern

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 fertilizers and INM under continuous wetland culture for sustainable soil health and productivity.

The experiment was initiated in Boro 2008-09 at BRRI farm Gazipur in a clay loam soil. In Boro-Fallow-T. Aman pattern, BRRI dhan29 and BRRI dhan49 were used. In Boro-T. Aus-T. Aman pattern, BRRI dhan29, BRRI dhan43 and BR22 were included as test variety. Fertilizers used were: T_1 = Control, T_2 = STB dose (NPKS @ 160-25-60-20 kg/ha for Boro, 70-12-48-10 kg/ha for T. Aus and 84-15-54-14 kg/ha for T. Aman), T_3 = STB (50%) + MM (CD @ 2 t/ha + ash @ 1 t/ha oven dried), T_4 = FP (NPKS @ 80-10-20-10 kg/ha for Boro, 70-10-15-0 kg/ha for T. Aus and 70-10-15-0 kg/ha for T. Aman). The experiment was laid out in RCB design with three replications.

In Boro 2012-13 under triple cropping pattern, STB dose produced significantly higher grain yield than 50% STB + MM and FP (Table 10). The STB dose gave at per yield with 50% STB + MM

Annual grain yield (t/ha/yr)

y=0.049x - 87.68
R²=0.108

y=-0.072x + 148.1
R²=0.251
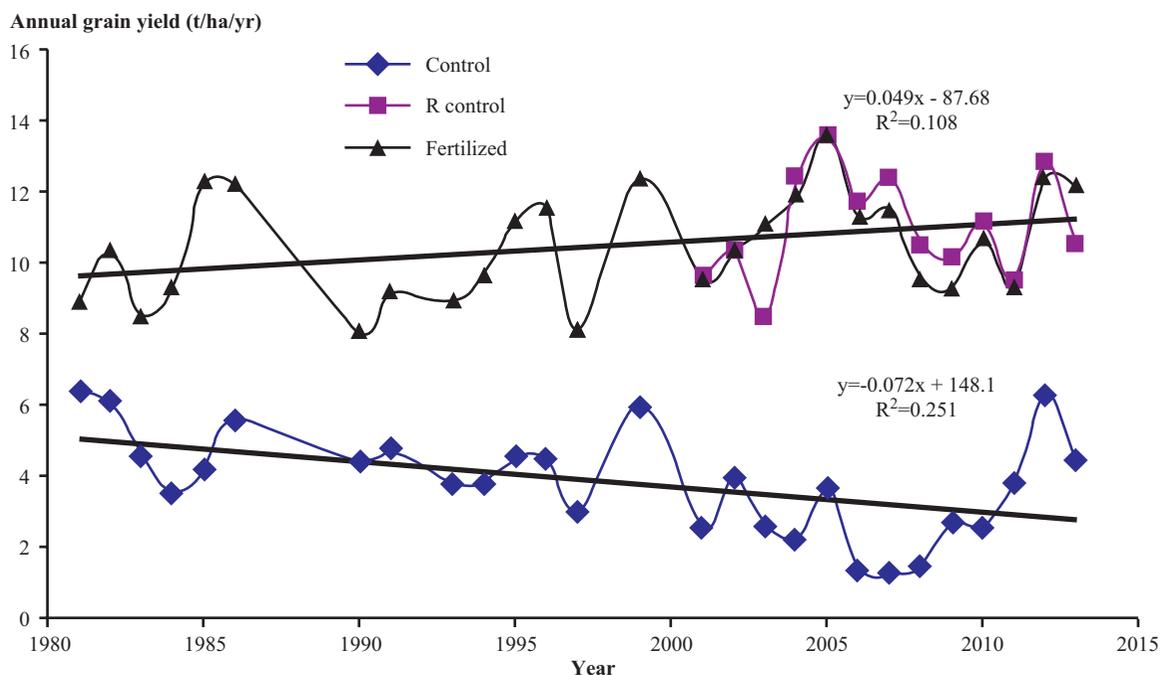
Fig. 1. Changes in annual rice production with fertilized and unfertilized perpetually wetland conditions over 33 years, BRRI, Gazipur.

Table 9. Effect of NPKSZnCu on yield of triple rice crops, BRRI-Gazipur, 2012-13.

Treatment	Yield (t/ha)			
	Boro 12-13	Aus 13	T. Aman 13	Annual
Control	1.29	1.67	1.49	4.45
Reverse control	4.88	2.92	2.75	10.55
NPK	4.26	2.53	3.22	10.01
NPKS	4.63	4.00	3.49	12.12
NPKSZn	5.12	2.91	4.13	12.16
NPKSZnCu	4.77	2.52	3.29	10.58

Table 10. Annual grain production (t/ha) of double and triple cropping patterns under continuous wetland condition, BRRI, Gazipur 2013.

Treatment	Double cropping			
	Boro 2012-13 (BRRI dhan29)	Fallow	T. Aman 2013 (BRRI dhan49)	Total yield (t/ha)
T_1 = Control	2.36	-	2.99	5.35
T_2 = STB	5.72	-	3.18	8.90
T_3 = 50% STB+MM	4.92	-	3.74	8.66
T_4 = FP	4.22	-	3.30	7.52
$LSD_{0.05}$	0.98	-	0.56	
CV (%)	11	-	8.5	
	Triple cropping			
	Boro 2012-13 (BRRI dhan29)	T. Aus 2013 (BRRI dhan43)	T. Aman 2013 (BR 22)	Total yield (t/ha)
T_1 = Control	1.70	2.54	1.89	6.13
T_2 = STB	5.80	2.47	2.79	11.06
T_3 = 50% STB+MM	5.33	3.00	3.37	11.70
T_4 = FP	3.75	2.67	2.57	8.99
$LSD_{0.05}$	0.22	NS	0.46	
CV (%)	12	12.1	8.7	

under double cropping pattern. In T. Aman 2013 under triple cropping pattern, 50% STB + MM produced significantly higher yield than STB dose and FP. In double cropping, 50% STB + MM produced significantly higher grain yield than 100% STB dose. However, cumulative yield with triple cropping was always greater than double rice crops irrespective of treatment. Maximum annual production (11.70 t/ha) was recorded with 50% STB + MM in triple cropping pattern. There was somewhat decreasing trend in grain yield of Boro rice (16th crop) compared to 13th crop under triple cropping patterns even with STB dose and STB (50%) + MM treatment. It means that intensive cropping may deteriorate soil productivity. So, STB dose and INM are good options for obtaining higher grain yields in double or triple rice cropping patterns. In T. Aus 2014, the highest grain and straw yields were recorded in 50% STB + MM, which was similar to 100% STB dose (Table 11).

Nutrient uptake in Boro 2013-14. The highest total N uptake was found in 100% STB dose, which was statistically similar with 50% STB + MM (Table 12). Total P uptake was higher with 100% STB fertilizer dose over others irrespective of cropping pattern. Total K uptake was higher with 50% STB + MM under double cropping pattern but it was identical with 100% STB under triple cropping pattern. Under both cropping patterns, total S uptake by rice plants was statistically similar with 50% STB + MM and 100% STB dose.

Nutrient uptake in T. Aus 2014. Total N, P and K uptakes were higher with 50% STB + MM, which was identical to 100% STB. Total S uptake was similar among treatments except the control (Table 13).

Table 11. Effect of STB dose and INM on yield of T. Aus rice under triple cropping pattern at BRRI, Gazipur 2014.

Treatment	Grain yield (t/ha)	Straw yield (t/ha)
T_1 = Control	1.84	1.50
T_2 = STB (100%)	2.89	3.01
T_3 = STB (50%) + MM	3.00	3.24
T_4 Farmers' practice	2.60	2.66
$LSD_{0.05}$	0.16	0.45
CV (%)	3.0	8.7

BRRI developed fertilizer management at farmers' fields (IAPP)

This study was undertaken to increase land productivity by introducing MV along with improved fertilizer management technology for rice-based cropping systems under tidal flood ecosystem (Barisal region), submergence and cold area (Rangpur region) and to increase awareness of farmers about soil management.

Tidal flood ecosystem (Barisal region). Six field experiments in T. Aus 2013, seven in T. Aman 2013 and five in Boro 2013-14 were conducted at the farmers' fields in Barisal, Jhalkathi, Patuakhali and Barguna districts (AEZ 13). Soils of the experimental fields were silty clay loam in texture with neutral reaction. Major crop cycle of that area was Pulse-T. Aus-T. Aman. Treatments were tested without replication (Table 14). Unit plot size was 8- × 6-m. Phosphorus, K, S and Zn were applied as TSP, MoP, gypsum and zinc sulphate respectively. All TSP, MoP, gypsum, zinc sulphate and cowdung were applied at final land preparation. Prilled urea (PU) was applied in two splits (FP, T_3). In T. Aus and T. Aman season, 66% PU at 15 DAT and the rest at 5-7 days before PI stage and in BRRI recom dose (T_1) and CD + IPNS (T_2), USG was applied at 12 DAT. One USG (1.8 g) was placed at the middle of four hills at 7.5-10 cm depth. BRRI dhan27 and BRRI dhan54 were used as test variety in T. Aus and T. Aman season, respectively.

In Boro, PU was applied in three equal splits in (T_3) at 15 and 35 DAT and at 5-7 days before PI stage. In T_1 and T_2, USG was applied at 15 DAT. One USG (2.7 g) was placed at the middle of four hills at 7.5-10 cm depth. BRRI dhan47 and BRRI dhan29 were used as test variety in Boro season. Two-three seedlings per hill were transplanted at 20- × 20-cm spacing. All intercultural operations were done as and when necessary. Grain yield was recorded from 5m^2 areas at the centre part of each plot and 16 hills were collected for recording straw yield. Grain yield was adjusted at 14% moisture content and straw yield as oven dry basis.

Submergence and cold prone area (Rangpur region). Six field demonstrations in both T. Aman and Boro seasons were conducted at farmers' fields Lalmonirhat, Kurigram, Rangpur

Table 12. Effect of STB and INM on total nutrient uptake (kg/ha) of BRRI dhan29 under double and triple cropping patterns, Boro 2013-14, BRRI, Gazipur.

Treatment	Double cropping pattern				Triple cropping pattern			
	N	P	K	S	N	P	K	S
Control	26	7	19	2	23	5	13	2
STB (100%)	93	24	73	8	79	25	67	9
STB (50%) + MM	84	21	82	7	78	21	76	8
FP	57	16	52	5	55	15	39	5
$LSD_{0.05}$	11	2	6	1	7	2	10	2
CV (%)	8.6	6.7	5.6	12.4	5.7	6.1	10.6	12.3

Table 13. Total nutrient uptake (kg/ha) by BRRI dhan43 as influenced by STB and INM under triple cropping pattern, T. Aus 2014, BRRI, Gazipur.

Treatment	N	P	K	S
Control	21	6	16	3
STB (100%)	48	12	37	5
STB (50%) + MM	53	12	43	6
FP	37	10	29	4
$LSD_{0.05}$	8	2	6	1
CV (%)	10.6	7.6	10.3	11.9

and Nilfamari districts (AEZ 3). Soils of experimental fields were sandy loam in texture with slightly acidic in reaction. Treatments are shown in Table 15. Unit plot size was 8- × 6-m. All TSP, MoP, gypsum, zinc sulphate and rice straw were applied at final land preparation. BRRI dhan 49 was used as test variety in T. Aman season. In Boro, BRRI dhan29 was used as test variety in all sites except Nilfamari, where BRRI dhan28 was used.

It was found that cow dung applied with IPNS based chemical fertilizer (except N) is a good practice to maximize rice yield and it might save a good amount of chemical fertilizer in tidal flood ecosystem (Barisal, Jhalkathi and Patuakhali). Rice straw applied with IPNS based chemical fertilizer maximized rice yield and it might have saved good amount of chemical fertilizer including full dose of K in submergence and cold area (Rangpur).

EVALUATION OF NEW FERTILIZER

Evaluation of N P compound (N P C) fertilizer on Boro rice

A field experiment was conducted in Boro 2013-14 at BRRI farm, Gazipur. The experimental field was clay loam in texture and deficient in soil available P (<2 mg/kg). Other nutrients status was: 1.15% organic carbon, 0.14% total N, 0.16 cmol/kg

Table 14. Treatment details of experiment in Barisal region.

Treatments	T. Aus					T. Aman					Boro				
	N*	P	K	S	Zn	N*	P	K	S	Zn	N*	P	K	S	Zn
								kg/ha							
T_1 = BRRI recom	50	11	15	3	1.0	50	15	17	4	2.0	75	30	30	5	3.0
T_2 = CD+ IPNS**	50	0	0	0	0.7	50	0	0	0	1.7	75	6	0	0	2.7
T_3 = FP	37	15	10	0	0	42	25	0	0	0	114	25	41	7	6.0

*T_1 and T_2- was applied as USG and T_3- as PU. **IPNS was followed in all elements (P, K, S and Zn) except N due to USG application. T_2: CD (3 t/ha, oven dry based) + IPNS based chemical fertilizers.

Table 15. Treatment details of experiment in Rangpur region.

Treatments	T. Aman					Boro				
	N	P	K	S	Zn	N	P	K	S	Zn
					kg/ha					
BRRI recom (AEZ basis)	80	10	33	10	3	170	20	60	15	4
RS (4.5 t/ha, sundry) + IPNS	57	6	0	6	2.8	147	15	0	11	3.8
FP	60	15	20	0	0	114	16	20	0	11

exchangeable K, 17 mg/kg available S and 4 mg/kg available Zn (DTPA extracted). Chemical composition of NPC is: 20.90% total N, 10.20% total P_2O_5 and 16.20% SO_3.

Control (T_1, no P), T_2=TSP @ 7.5 kg P/ha, T_3=NPC @ 7.5 kg P/ha, T_4=TSP @ 15 kg P/ha and T_5=NPC @ 15 kg P/ha were assigned in RCB design with three replications. All treatments received N-K-S-Zn @ 150-60-20-4 kg/ha respectively. All fertilizers except urea were applied at final land preparation. Urea was applied in three equal splits at basal, at active tillering stage and at 7 days before PI.

It was found that NPC fertilizer can produce statistically similar rice yield like TSP fertilizer. Application of NPC may alleviate N deficiency at early crop growth stages. However, more field trials are needed to compare NPC with TSP and DAP.

SOIL AND ENVIRONMENTAL PROBLEMS

Greenhouse gas emission trial at Bangladesh Rice Research Institute

Soil is considered to be one of the most important sources and sinks of greenhouse gases and thus influencing climate change. So, the experiments were conducted to study the effects of broadcast urea (BU), urea deep placement (UDP) and NPK briquette on floodwater NH_4^+-N dynamics, biomass, grain yield and total NPK uptake by rice under alternate wetting and drying (AWD) and continuous standing water (CSW) conditions, to compare the effect of BU and UDP on N_2O and NO emission under AWD and CSW conditions.

Two field experiments were set up in BRRI farm, Gazipur. Experimental field soil was clay-loam in texture. Initial soil pH was 6.22, 1.75% organic C, 0.17% total N, 16 ppm available P and 0.25 cmol/kg exchangeable K. Treatments are shown in Table 16. Rice varieties used were BRRI dhan46, BRRI dhan28 and BRRI dhan48 for T. Aman, Boro and T. Aus season respectively.

Water samples from all plots were collected for NH_4^+-N determination in acid washed plastic bottles in the morning starting from N sources application for 7 days. First water sampling was done before and immediately after application of UDP, NPK briquettes and PU. Nitric oxide was measured with a Teledyne API T200 Chemiluminescence Analyzer and N_2O was measured with a Teledyne API T320U Gas Filter Correlation Analyzer and calibration was done by a Teledyne API T700 Dynamic Dilution Calibrator.

The concentrations of NH_4^+-N in water varied depending on N sources and its application methods (Fig. 2). Under continuous standing water conditions, N_2O and NO emissions were the highest with PU application followed by urea briq and the least in control plots both in T. Aman and Boro seasons (Fig. 3 and 4).

Application of urea as broadcasting increases flood water NH_4^+-N than urea deep placement (UDP) as USG and NPK briquette in all seasons. About 25-50% N was saved with UDP compared to PU.

SOIL MICROBIOLOGY

Effect of soil nutrients on microbial population in wetland rice cultivation

Growth and colonization of soil microbes can be influenced by soil chemical, physical and biological factors. Availability of C, N, K or P can limit microbial population growth in a particular soil system. So, the study was undertaken to determine the effect of long term absence of major nutrients on microbial population in wetland rice system.

Total microbial populations were enumerated from long term missing element trial (-N, -P, -K) and compared with control and complete fertilizer treatments at BRRI, Gazipur. Nutrient agar for total bacterial population, nitrogen free medium (NfB) for NFB, NBRIP for PSB and potato dextrose agar (PDA) for fungal population were used. After 5 days of incubation, microbial population was counted following spread plate technique.

Microbes in long term missing element trial. Bacterial populations were higher than fungi. Among treatments, lower number of total bacterial populations was found in -P and -K plot. Population of free living NFB was higher in CD (4.83×10^5), PM (2.30×10^5), $NPK_{60}SZn$ ($1.08 \times$

Table 16. Treatment description for different seasons, BRRI, Gazipur.

Treatment	Description	N rate (kg/ha)		
		Boro	T. Aus	T. Aman
T_1	Control (No)	0	0	0
T_2	UDP	78	52	52
T_3	UDP	104	78	78
T_4	Prilled urea	156	104	104
T_5	UDP	156	104	104
T_6	NPK briquette	81	51	51
T_7	Prilled urea	104	78	78
T_8	NPK briquette	103	78	78
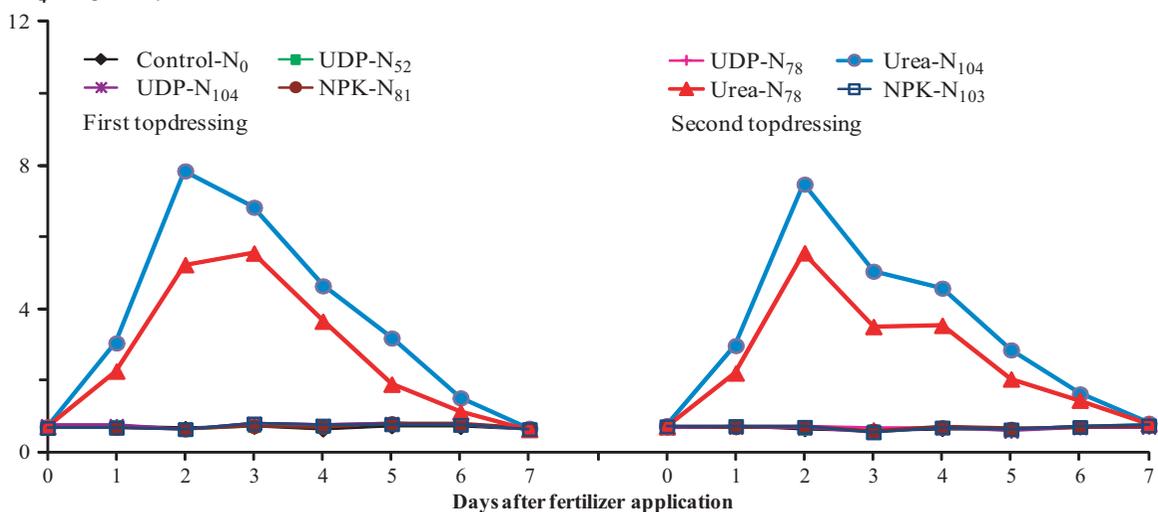
Fig. 2. Pattern of NH_4^+-N concentration in flood water, BRRI, Gazipur.
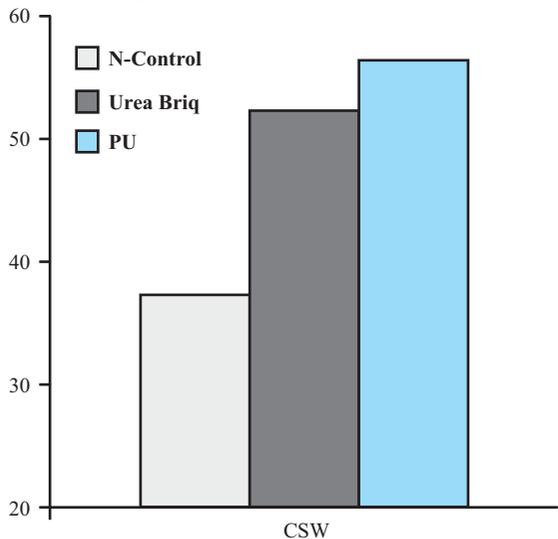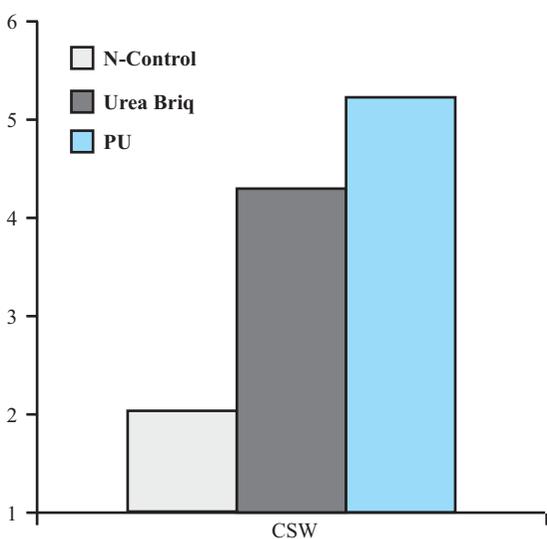
Fig. 3. Total N_2O and NO emissions under CSW conditions, T. Aman 2013, BRRI, Gazipur.
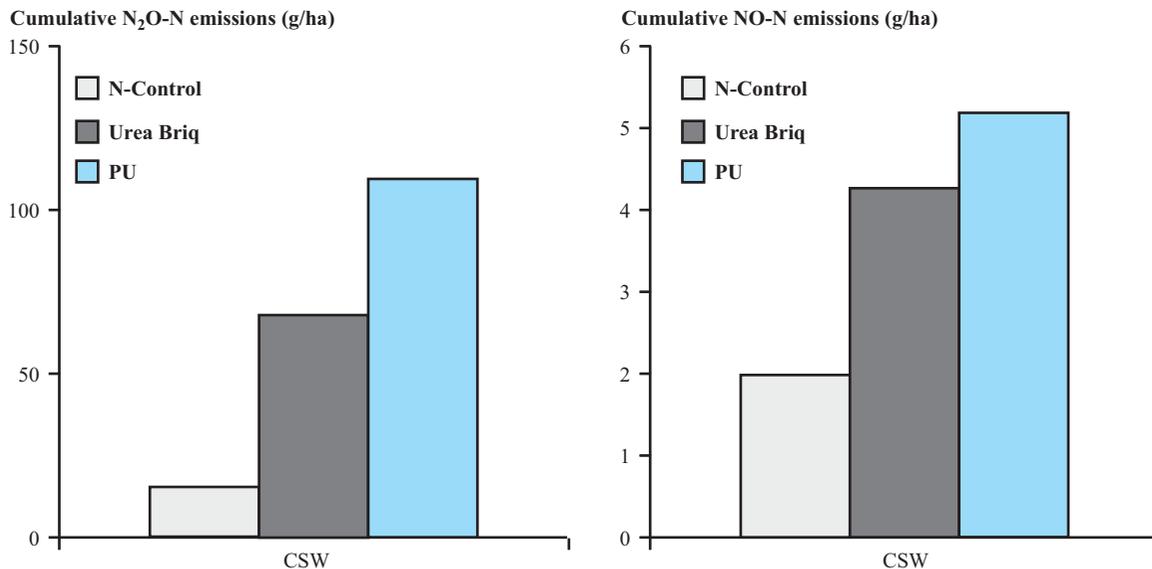
Fig. 4. Total N_2O and NO emissions under CSW conditions, Boro 2013-14, BRRI, Gazipur.

10^5), $NPK_{40}SZn$ (1.00×10^5). Cow dung applied as IPNS basis supported higher total bacteria, free living NFB and PSB compared to other treatments. There was no N fixing and P solubilizing bacteria in N and P missing plots. Moreover, fungal population was not affected by missing nutrients.

Microbes in continuous Boro-Fallow-T. Aman pattern. Total bacteria and fungi populations were high in continuous double cropping pattern experiment (Table 17). However, higher number of total bacteria and fungi population was found in STB treatment (T_2). The presence of free living NFB was found in all treatments while, but PSB was completely missing.

Microbes in continuous wetland intensive rice cropping. Comparatively higher bacterial population was found in continuous wetland

Table 17. Effect of continuous Boro-Fallow-T. Aman cropping on microbial population, T. Aman, 2013, BRRI, Gazipur.

Treatment	Microbial population (Cfu g/soil)		
	Total bacterial population	N fixing bacteria	Fungal population
T_1	9.90×10^8	6.40×10^5	9.90×10^8
T_2	1.90×10^9	2.20×10^5	1.90×10^9
T_3	5.80×10^8	3.70×10^5	2.20×10^9
T_4	1.30×10^8	2.10×10^5	3.20×10^7

Data obtained from average of two replications.

intensive rice cropping system compared to fungal population. There was no free living NFB and PSB in this long term experiment. There was no significant variation on microbial population due to treatment effects.

PROJECT ACTIVITY

Climate change and rice project
A multidisciplinary project activity on climate change and rice production was initiated for three years with the financial assistance from the Ministry of Foreign Affairs, Norway and the Royal Norwegian Embassy, Dhaka. Main focus of the project was on future climate change impacts on rice production in drought prone Rajshahi and saline prone Barisal regions of Bangladesh. Part of the activities is provided below.

Varietal adaptation and adoption in Rajshahi and Barisal regions
Varietal adoption is easier way to cope with climate change impacts. Stress tolerant varieties were introduced along with modern cultural management and compared with farmers' practices. Field performance of wheat (3.40-4.37 t/ha), mustard (1.0-1.48 t/ha) and chickpea (0.89-

1.13 t/ha) was satisfactory and farmers were interested to grow those varieties in Rajshahi region. Performance of wheat (0.89-1.98 t/ha), mustard (0.63-0.98 t/ha) was poor due to lack of land suitability, delayed planting and salinity effect in Barisal region. Cultivation of rice as direct-seeded culture may create an avenue for successful rice production in drought prone areas. Cultivation of vegetables in waterlogged soils with rice under ridge/pyramid culture was more profitable than rice alone in pre-monsoon and monsoon seasons.

Cropping patterns for drought prone Rajshahi and saline prone Barisal regions

Most of the farmers generally follow Tomato/Mustard+Boro-Fallow-T. Aman, Potato/Mustard+Boro-Fallow-T. Aman and Boro-Fallow-T. Aman patterns in Rajshahi site. They use BRRI dhan28, Swarna and Pariza etc. After project interventions, farmers are adopting low water demanding newly released wheat, mustard, chickpea etc in dry season. In Rajshahi site, maximum rice equivalent yield was recorded in Wheat-T. Aus-T. Aman pattern (13.66 t/ha) with the highest BCR (1.46) and gross margin (68,061 Tk/ha) followed by Mustard-T.Aus-T. Aman (11.91 t/ha) pattern with BCR 1.45 and gross marging Tk 58,184/ha. In Barisal site, Pulses-T. Aus-T. Aman was the dominant cropping pattern before project activities. After project activities some farmers are following Mustard/Wheat-T. Aus-T. Aman, Boro-Fallow-T. Aman and Felon/Sunflower-Fallow-T. Aman patterns using introduced varieties. In both the study sites, non-rice based cropping patterns were more profitable than Rice-Rice based patterns.

Irrigation and Water Management Division

SUMMARY

Irrigation in AWD-15 cm below ground level was the best water application method for Boro rice production and water saving was around 10% for BRRI dhan28 and 20% for BRRI dhan29 along with the higher water productivity. There was no conflict in USG application in AWD irrigation method. Based on indicators of evaluation for canopy cover and biomass and the required irrigation amounts by AquaCrop model, the AWD-15 irrigation regime appears to be the best water-saving option for rice production during the dry season in Bangladesh. The survey data in four upazilas of Rajshahi district indicates that Boro coverage is decreasing day by day due to depletion of groundwater level below suction limit of STW. Number of deep set and very deep set STWs is increasing with a increase of non-rice crop coverage. Based on the three years study results, BRRI dhan30, BRRI dhan31 and BRRI dhan40 are found more drought tolerant than the other study varieties. These varieties can be grown in drought prone areas to minimize the yield loss.

The early establishment of T. Aman through supplemental irrigation effectively mitigated the terminal drought occurred at reproductive and ripening phases during T. Aman 2013. Both short and long duration T. Aman varieties suffered less drought and showed good yield performance if they were transplanted before 24 July. So transplanting before 24 July would be medium risk period of drought and after that it would be high risk period.

Among the 10 study locations the water of Gazipur, Rangpur, Rajshahi and Kushtia as free from sodium toxicity and other six locations had slight sodium toxicity. The pH value of all samples were within the normal range. Therefore, the overall water quality was found suitable for irrigation purpose in all locations.

WATER USE EFFICIENCY IMPROVEMENT IN IRRIGATED AGRICULTURE

Validation of AquaCrop model and effect of USG in rice production under AWD water management
The field experiment was conducted at BRRI HQ farm, Gazipur, during the dry season of 2013-14 to determine the crop yield under different fertilizer and water management and validating the yield and water requirement with AquaCrop model. BRRI dhan28 and BRRI dhan29 were used as test variety. The water and nitrogen treatments were:

Water
I_1 = continuous standing water
I_2 = Irrigation when water level reached 15 cm below soil surface and
I_3 = Irrigation when water level reached 20 cm below soil surface

Nitrogen
N_0 = No nitrogen
N_1 = Pilled urea applied @220 kg ha^{-1} and
N_2 = USG applied @2.70 gm between four hills

The experiment was laid out in a split-split-plot design with three replications. The water treatments were in main plot and variety in sub plot and fertilizer management in sub-sub-plot. Forty-two-day-old seedlings were transplanted with 20- × 20-cm spacing. Transplanting was done on 2nd January in 2014 and harvested in late April for BRRI dhan28 and first week of May for BRRI dhan29. Measured quantities of irrigation water was supplied from a deep tubewell. Field water depths for different water regimes were monitored by installing a partly perforated PVC pipe of 25 and 30 cm length and 10 cm diameter.

Input to the AquaCrop model consists of climatic parameters, crop, soil, field and irrigation management data. The weather data required are daily values of maximum and minimum air temperatures, reference crop evapo-transpiration (ETo), rainfall and mean annual carbon dioxide concentration (CO_2). For crop data, canopy cover and biomass were measured in every 15 days interval. Dry biomass of the above ground plant was also obtained by weighing the total biomass of the samples collected for LAI determination, after keeping them in the oven for 48 hours at 65°C. In this study, soil layers were considered up to 0.5 m, which consists of silty-clay textured soil. In CSW, water was ponding on the soil surface continuously, whereas, in AWD, ponding water was allowed to deplete to a certain level in the two treatments.

The model was calibrated against above ground biomass and grain yield from the field experiment during the 2013-14 growth season of transplanted Boro rice for BRRI dhan28 only. Subsequently, the predicted output values were statistically compared with the observed biomass and yield data obtained from the experimental plot. The difference between model predicted and observed data was minimized using a trial and error approach in which one specific input variable was chosen as the reference variable at a time and adjusting only those parameters that influenced the reference variable the most. Statistical evaluation of the simulation results was made for calibration phases. The goodness of fit between simulated and observed values was corroborated by using various prediction error statistics. Model performance was evaluated in terms of prediction error (P_e), coefficient of determination (R^2), root mean square error (RMSE), the normalized root mean square error (NRSME), the Nash-Sutcliffe model efficiency coefficient (EF) and Willmott's index of agreement (*d*) (Raes *et al.*, 2012).

Tables 1 and 2 show field experimental results of applied irrigation water, rainfall, grain yield, above ground biomass, water productivity (WP) and harvest index under different water regimes during the growing season for model calibration (2013-14) based on three replicates. The lowest grain yield and biomass was observed to be 2.40 and 4.862 t ha^{-1} under the AWD-20 water regime

in N0 fertilizer and the highest was 4.89 and 9.79 t ha^{-1} under AWD-15 water regime with USG fertilizer for BRRI dhan28 respectively (Table 1). Water productivity ranged between 2.87-3.43 kg ha^{-1} mm^{-1} (N_0), 5.36-5.94 kg ha^{-1} mm^{-1} (Prilled urea) and 5.80-6.87 kg ha^{-1} mm^{-1} (USG), respectively (Table 1). Whereas, for BRRI dhan29, the lowest grain yield and biomass was observed to be 2.69 and 5.46 t ha^{-1} under the AWD-20 water regime in N_0 fertilizer and the highest were 5.37 in AWD-15 and 10.89 t ha^{-1} under CSW water regime with USG fertilizer respectively (Table 2). WP ranged between 2.48-3.13 kg ha^{-1} mm^{-1} (N_0), 5.30-5.43 kg ha^{-1} mm^{-1} (Prilled urea) and 4.69-5.77 kg ha^{-1} mm^{-1} (USG) respectively (Table 2). It appears that from the three irrigation regimes and fertilizer management, the AWD-15 water regime provided the best option for water productivity, ie providing high yield relative to the water use. While this option resulted in the highest yields, it used significantly lesser water than the CSW option. The AWD-20 irrigation regime caused some apparent stress to the crop, reducing both biomass and yield production noticeably. The WP of the AWD-20 option seems to be in par with that of the AWD-15 option, but there is an increased risk of crop stress with the AWD-20 option, which should be carefully considered when irrigation water is not very scarce, and maximizing yield is of more interest than maximizing water use efficiency- both in terms of water amount or its

Table 1. Irrigation water depth, grain yield, above ground biomass, water productivity (WP) and harvest index for BRRI dhan28 under different water treatments at BRRI HQ, Gazipur, Boro 2013-14.

Treatment	Irrigation water applied (mm)	Rainfall (mm)	Grain yield (t ha^{-1})	WP (kg ha^{-1} mm^{-1})	Biomass (t ha^{-1})	HI (%)
			N_0 fertilizer			
CSW	775	66	2.416	2.87	4.982	0.48
AWD-15	698	66	2.522	3.30	5.020	0.50
AWD-20	632	66	2.396	3.43	4.862	0.49
			Prilled urea (140 kg N/ha)			
CSW	775	66	4.509	5.36	8.854	0.50
AWD-15	698	66	4.535	5.94	9.071	0.50
AWD-20	632	66	4.142	5.93	8.480	0.49
USG						
CSW	775	66	4.878	5.80	9.633	0.50
AWD-15	698	66	4.895	6.41	9.790	0.50
AWD-20	632	66	4.795	6.87	9.490	0.50
LSD (5%)			0.11		0.12	

CSW=continuous standing water, AWD-15=irrigation applied when water level at 15 cm below ground surface, AWD-20=irrigation applied when water level at 15 cm below ground surface.

Table 2. Irrigation water depth, grain yield, above ground biomass, water productivity (WP) and harvest index for BRRI dhan29 under different water treatments at BRRI HQ, Gazipur, Boro 2013-14.

Treatment	Irrigation water applied (mm)	Rainfall (mm)	Grain yield (t ha⁻¹)	WP (kg ha⁻¹ mm⁻¹)	Biomass (t ha⁻¹)	HI (%)
			N_0 fertilizer			
CSW	995	120	2.768	2.48	5.582	0.49
AWD-15	812	120	2.798	2.88	5.596	0.50
AWD-20	773	120	2.688	3.13	5.462	0.49
			Prilled urea (140 kg N/ha)			
CSW	995	120	5.010	5.30	10.437	0.48
AWD-15	812	120	4.948	5.30	10.098	0.49
AWD-20	773	120	4.850	5.43	9.898	0.49
USG						
CSW	995	120	5.230	4.69	10.896	0.48
AWD-15	812	120	5.374	5.77	10.748	0.50
AWD-20	773	120	4.833	5.41	9.863	0.49
LDS (5%)			0.12		0.13	

CSW=continuous standing water, AWD-15=irrigation applied when water level at 15 cm below ground surface, AWD-20=irrigation applied when water level at 15 cm below ground surface.

cost. On the other hand, during Boro season, without N fertilizer yield should be reduced drastically, so, N fertilizer is necessary for optimum yield production.

Table 3 presents comparisons of observed and modeled grain yield and biomass. Biomass and yield estimates were slightly under and over the observed values, yielding -6.04% underestimation to 5.95% overestimation of biomass, and -5.31 underestimation to 8.28% overestimation in yield estimates, depending on the irrigation regime and fertilizer doses. The differences in biomass vs yield in the observations and the simulations indicate that the final HI value that the model used differed slightly from the observations, but the difference in HI remained at 1%.

The AquaCrop model was calibrated to predict biomass and crop grain yield under three irrigation water regimes. Based on indicators of evaluation for biomass and the required irrigation amounts, the AWD-15 irrigation regime appears to be the best water-saving option for rice production during the dry season in Bangladesh. Regardless, the obtained season-end metrics in terms of simulated biomass and crop yield are suggesting high potential for the AquaCrop model to be reliably used in irrigation scheduling, yield prediction or potentially in climate related scenario studies in Bangladesh. After validation of the model the probabilistic yield will be estimated under AWD method for similar climatic condition.

Development of Soil moisture declination model for alternate wetting and drying (AWD) irrigation for Rice cultivation

Experiment was set up in BRRI HQ farm, Gazipur, in Boro season 2014 to study the soil water dynamics for development of irrigation scheduling model. The experiment contains six treatments and each of them was replicated thrice. The treatments were-

T_1= Continuous standing water (CSW),

T_2= CSW with polythene protection around the field and levee,

Table 3. Calibration results of biomass and grain yield under different water regimes for BRRI dhan28 at BRRI HQ, Gazipur, Boro 2013-2014.

Treatment	Yield (t ha⁻¹)		P_e	Biomass (t ha⁻¹)		P_e
	Obs.	Sim.	(±%)	Obs.	Sim.	(±%)
CSW×N_0	2.768	2.621	-5.31	5.582	5.245	-6.04
AWD-15×PU	4.948	4.762	-3.76	10.098	9.548	-5.45
AWD-20×USG	4.833	5.233	8.28	9.863	10.450	5.95

CSW=continuous standing water, AWD-15=irrigation applied when water level at 15 cm below ground surface, AWD-20=irrigation applied when water level at 15 cm below ground surface.

T_3= Irrigation when water level 15 cm below GL,

T_4= T_3 with polythene protection around the field and levee,

T_5= Irrigation when water level 30 cm below GL and

T_6= T_5 with polythene protection around the field and levee.

RCB design was followed. BRRI dhan28 was the tested variety. Seeding was done on 30th November 2013. Fifty-day-old seedlings were transplanted on 20 January 2014. Individual plot size was 5- × 4-m and each plot was separated from others with one m buffer area. A spacing of 20- × 20-cm was maintained. Recommended fertilizer management and cultural practices were followed. To protect seepage losses polythene sheets were placed around the plots and levees of treatment T_2, T_4 and T_6. Irrigations were applied by measuring with a flow meter.

Soil samples were collected from different depths to determine the moisture content under different water level conditions. In the continuous standing water plots, a closed bottom cylinder (steel drum) was placed to determine the daily evapotranspiration. A slopping gauge was installed in the drum to measure the daily water level in the drum. Partially perforated PVC pipe were installed in each plots to measure the daily water level. PVC pipe of 25 cm height and 15 cm perforation were installed below soil surface in treatment T_1, T_2, T_3 and T_4. PVC pipe having 40 cm height and 30 cm perforation were below soil surface installed in treatment T_5 and T_6. Water levels in the plots were measured daily. Daily temperature, relative humidity, sunshine hours, wind speed and rainfall data were collected from Plant Physiology Division, BRRI. Daily reference of crop evapotranspiration (ET_0) was calculated using Aquacrop model. Seepage and percolation rate was assessed from the daily water level fluctuation data of polythene protected and unprotected plots.

The experimental soil type is silty clay loam. Soil samples were collected from different layers having 5 cm depth. In T_3 and T_4 samples were collected from 0-15 cm depths when water level in the PVC pipe reached different levels. In T_5 and T_6 samples were collected from 0-30 cm depths when the water level in the PVC pipe reaches different levels below the ground surface. Soil moisture content was determined by gravimetric method. Graphs were plotted for different layers with the soil moisture content and water level data. A relationship is also developed between parched water level below ground surface and soil moisture content in different layers.

Figure 1 shows the soil moisture content at different layers for different perched water level below the ground surface in treatment T_6. It shows that even near saturation, the soil moisture content decreases with soil profile depths. At the water level of 6 cm the soil moisture content in the 1st, 2nd, 3rd, 4th, 5th and 6th layers are 40.0, 33.5, 34.5, 30.0, 28.0 and 29.6 percent respectively. It also shows that soil moisture content in the 1st, 2nd, 3rd, 4th, 5th and 6th layers reaches to 22.5, 23.1, 23.4, 23.5, 23.6 and 23.8 percent respectively when the parched water level reached at 30 cm below the ground surface. Figure 4 also indicates that soil water holding capacity decreases with depth. This is due to compaction in the lower layers which increases the bulk density.

Figure 2 shows different conditions that plant experienced during water depletion. When parched water level remains within 15 cm below ground surface the soil moisture content in the effective rootzone (0-30 cm) is greater than the field capacity and no stress is observed. When parched water level falls at 20 cm below ground surface the soil moisture content in the upper part (0-15 cm) of the effective rootzone is less than the field capacity and slight stress is observed. When parched water
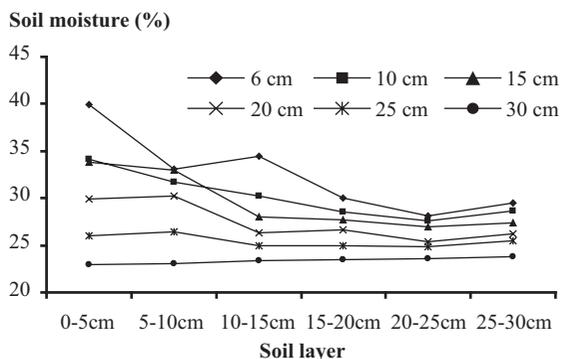
Soil moisture (%)

Fig. 1. Soil moisture content in different soil layers (0-30 cm) for different parched water level in the field.
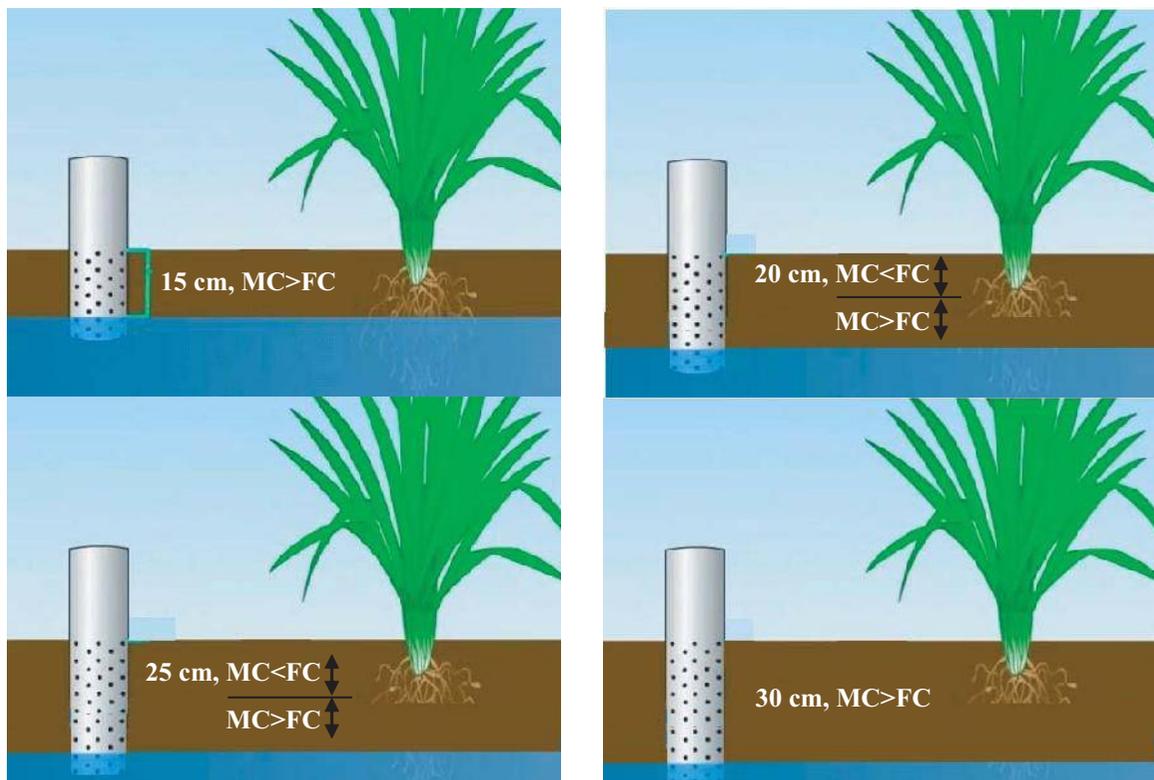
Fig. 2. Soil moisture condition in the effective rootzone of rice for different parched water level in the field.

level falls at 30 cm below ground surface the soil moisture content in the effective rootzone is less than the field capacity and moderate stress is observed.

Different water regimes maintained in the treatments during the growth duration. The field growth duration was 100 days. In treatment T_1 and T_2 continuous standing water was maintained for 90 days and below saturated condition for 10 days (before harvest). Plots were remained in standing water condition for 61, 62, 46 and 49 days in T_3, T_4, T_5 and T_6 respectively.

Table 4 shows the number and amount of irrigation applied under different treatments. For land preparation (LP) 210 mm irrigation water was applied in the field. The number of irrigation was the highest in T_1 (17) and the lowest in T_6 (10). Total amount of irrigation applied in T_1, T_2, T_3, T_4, T_5 and T_6 during the growth season were 700, 584, 539, 482, 405 and 356 mm respectively. A total of 90 mm rainfall was recorded during the field growth span. Table 4 also shows that irrespective

of treatments polythene protected plots saves more water than the non-protected plots. This result also indicates that polythene protection could be an effective measure for saving irrigation water in rice field.

Table 5 shows the yield of BRRI dhan28 under different irrigation treatments. Yield data showed that among the treatments, the highest yield was obtained from continuous standing water plots (T_1=5636 kg/ha, T_2=5563 kg/ha) followed by 15 cm (T_3=4951 kg/ha, T_4=4894 kg/ha) and 30 cm (T_5=4896 kg/ha, T_6=4676 kg/ha) AWD plots. Yield were much lower in T_3 and T_4 plots compared to T_1 and T_2 plots for uncontrolled water stress occurred during the reproductive phase due to problem of irrigation pump (DTW). Irrespective of treatment, higher yield was obtained from non-protected plots compared to the polythene protected plots. This may be due to the obstruction of the border plants to extract nutrients from adjacent areas. Table 5 shows the relative yield loss compared to the continuous standing water

Table 4. Number of irrigation, water applied and total water used for BRRI dhan28 under different treatments, Boro 2014, BRRI HQ farm, Gazipur.

Treatment	No. of irrigation applied	Water applied for LP (mm)	Irrigation during growing (mm)	Rainfall (mm)	Total water used (mm)	Total water requirement (mm)	Irrigation water saved over T_1 (%)
T_1	17	210	700	90	1000	631.1	-
T_2	14	210	584	90	874	631.1	16.6
T_3	13	210	539	90	839	631.1	23.0
T_4	12	210	482	90	782	631.1	31.1
T_5	11	210	405	90	705	631.1	42.1
T_6	10	210	356	90	656	631.1	49.1

Table 5. Yield, yield loss and water productivity of BRRI dhan28 under different treatments, Boro 2014, BRRI HQ farm, Gazipur.

Treatment	No. of irrigation applied	Total water used (mm)	Grain yield (kg/ha)	Yield loss over T_1 (%)	Water productivity (kg/ha-mm)
T_1	17	1000	5636	-	5.636
T_2	14	874	5564	1.28	6.366
T_3	13	839	4951	12.15	5.901
T_4	12	726	4894	13.16	6.741
T_5	11	675	4896	13.13	7.253
T_6	10	646	4676	17.03	7.238

treatment (T_1). Water productivity was the highest for treatment T_5 (7.25 kg/ha-mm) and the lowest for T_1 (5.63 kg/ha-mm). Yield loss was the highest in T_6 (17%) and the lowest in T_2 (1.3%). Therefore, considering yield loss, water productivity and water saving T_2 and T_4 are found better than the others for irrigated rice cultivation.

The study will be continued to determine soil moisture characteristics curve at different layers. Further analysis will be done to complete the work. Soil moisture characteristics curve at different layers will be developed to evaluate the field capacity, permanent wilting point and available soil water content to develop a model for soil moisture dynamics. Prediction of irrigation schedule will be possible after development of the model.

Delineation of areas having water shortage during Boro rice cultivation in northwest Bangladesh

The study was conducted in Pabna and Rajshahi districts of Bangladesh to locate STW areas facing water scarcity during Boro season and finding possible remedies in crop production.

The survey was conducted at three upazilas (Chatmohor, Bhangura and Faridpur) of Pabna district and four upazials (Mohanpur, Bagmara, Durgapur and Puthia) of Rajshahi district (Fig. 3).

A pre-structured questionnaire was used for the survey. Information was collected from ten STWs in each upazila.

The groundwater level in Chatmohor, Bhangura and Faridpur upazilas of Pabna district declines to 30-35 ft below the ground surface during April-June (Fig. 4a). Whereas the groundwater level in Mohanpur, Bagmara, Durgapur and Puthia upazilas of Rajshshi district declines to 21-35 ft below the ground surface during April-June (Fig. 4b). Because of water level declination performance of STW hampers significantly and Boro coverage is decreasing day by day. In some places STWs were converted to DSSTW (Deep Set Shallow Tubewell) and VDSSTW (Very Deep Set Shallow Tubewell). But it reduced the discharge as a result cost of irrigation and its reliability hampered significantly. The Boro area of these upazilas has been converted to Rabi crops (wheat, maize, grasspea, onion, garlic etc.) area. On average 2,139 ha and 608 ha Boro area has been decreased in the upazilas of Pabna and Rajshahi district respectively.

Average ground water level during dry period remains within 21-35 ft in Pabna and Rajshahi district. Therefore, the pump of STW has to be set 6-15 ft and 5-20 ft below ground surface to reduce suction head in Pabna and Rajshahi district respectively.

| a. Upazila of Pabna district | b. Upazila of Rajshahi district |

Fig. 3. Location of surveyed area.

Fig. 4. STW placed at different depth below the soil surface at (a) Pabna and (b) Rajshahi.

USE OF WATER RESOURCES IN RAINFED ENVIRONMENT

Effect of drought on different T. Aman varieties

The experiment was conducted to evaluate the relative drought tolerance of some T. Aman varieties for assessing suitable cultivar for drought prone area. A total of 12 popular T. Aman varieties were grown under irrigated and rainfed environment. The varieties were: BR11, BR23, BR25, BRRI dhan33, BRRI dhan39, BRRI dhan31, BRRI dhan49, BRRI dhan30, BRRI dhan40, BRRI dhan41, BRRI dhan44 and BRRI dhan46*. These varieties were classified into three categories based on the growth duration. There were two short duration, three medium duration and seven long

duration varieties. Two water management treatments were as follows-

T_1= Rainfed condition and

T_2= Supplementary irrigation when water stress is observed.

A 25 cm long PVC pipe having 15 cm perforation at the bottom end was installed in the plot to assess the water stress condition. The soil inside the pipe was removed to monitor the perched water level. No water in the pipe indicated water stress for the crop and immediately supplementary irrigation was applied in T_2 plots.

The seeding was done on 2 July 2013 and transplanting on 5 August 2013. TSP, MP, gypsum and zinc sulphate were applied during the last ploughing. Urea were top dressed twice during the

vegetative growth. Weeding were done after Urea applications. The rainfed plots were separated from the irrigated plots with one m buffer area. The outer sides of the levee in rainfed plots were covered with polythene sheet to protect seepage from irrigated plots. The perched water level status in the plots was monitored by installing perforated PVC tubes. Supplemental irrigation was applied in the irrigated plots when water level reaches 15 cm below the ground surface.

Table 6 shows the growth duration, yield and yield reduction due to drought stress in the selected T. Aman varieties. Mean yield of the varieties were from 2.86 to 4.18 t/ha under rainfed condition and 3.50 to 5.94 t/ha under supplementary irrigated condition. It shows that yield reduction is lowest in BRRI dhan31 (9.4%) and highest in BRRI dhan41 (38.0%). The results show that BRRI dhan30, BRRI dhan40 and BRRI dhan41 also have drought tolerance compared to the other tested varieties. The highest yield reduction was found in BR41 followed by BR11, BRRI dhan46 and BR23 with yield loss of 38, 32, 30 and 28 percent respectively. Three years' results indicate that BRRI dhan30, BRRI dhan31 and BRRI dhan40 are more drought tolerant than the other varieties.

Figure 5 shows three classes of varieties as-sensitive, moderately tolerant and tolerant. BRRI dhan31, BRRI dhan30, BRRI dhan40 and BRRI dhan44 are tolerant to drought. BRRI dhan39, BR 25 and BRRI dhan49 are moderately tolerant to drought. BR 11, BR 23, BRRI dhan33, BRRI

Table 6. Growth duration, yield and yield reduction due to drought stress in T. Aman varieties at BRRI HQ farm, Gazipur 2013.

Variety	Growth duration (day)	Yield (kg/ha)		Yield reduction (%)
		Rainfed	Supp. irrigated	
BR11	145	3336	4891	31.8
BR23	154	3715	5130	27.6
BR25	138	3558	4682	24.0
BRRI dhan30	146	4181	5010	16.5
BRRI dhan31	140	3129	3454	9.4
BRRI dhan33	120	2860	4089	30.1
BRRI dhan39	122	3572	4698	24.0
BRRI dhan40	148	3618	4407	17.9
BRRI dhan41	152	3451	5567	38.0
BRRI dhan44	146	3654	4471	18.3
BRRI dhan46	154	4178	5944	29.7
BRRI dhan49	140	3365	4544	25.9

dhan41 and BRRI dhan46 are sensitive to drought stress.

Based on the three years study results, BRRI dhan30, BRRI dhan31 and BRRI dhan40 are found more drought tolerant than the other study varieties. These varieties can be grown in drought prone areas to minimize the yield loss.

Terminal drought mitigation adopting transplanting dates in T. Aman 2013

The experiment was conducted to determine the effect of drought for different transplanting dates in different growth stages of T. Aman rice. A long duration variety (BR11) and a short duration one (BRRI dhan33) were tested during T. Aman season. There were six treatments with three replications in the experiment and the treatments were- seedlings transplantation on 10 July (T_1), 17 July (T_2), 24 July (T_3), 31 July (T_4), 7 August (T_5) and 14 August (T_6).

Thirty-day-old rice seedlings were transplanted with 20- × 20-cm spacing. Individual plot size was 5- × 3-m with 60 cm buffer zones. A USWB Class A evaporation pan and a rain gauge were installed near the experimental field to determine rainfall and evaporation amounts during the rice growing season. Data were recorded at 9:00h daily to determine seepage and penetration, rainfall and evaporation from the experimental field. The historical rainfall data were collected from the Department of Agricultural Extension, Kushtia. Drought amount (deficit water in soil) was calculated using drought model (developed by Dr Towfiqul Islam).

Table 7 shows the drought amount at different rice growth stages for different dates of transplantg. BRRI dhan33 suffered comparatively less drought than BR11 due to its shorter growth duration. From the drought pattern of the previous year in case of BRRI dhan33 drought in reproductive and ripening phases increased with delay transplanting (Fig. 6). In 2013, drought in reproductive phase for transplanting after 31 July rapidly increased (Fig. 7) but ripening phase faced fewer droughts due to sufficient rainfall in October. Thus, short duration variety suffer drought both reproductive and ripening stages if it is transplanted after 24 July. In other word, when

Fig. 5. Yield of Aman varieties under rainfed and supplementary irrigation treatments, BRRI HQ farm, Gazipur during 2013.

Table 7. Yield and yield components for different transplanting dates, T. Aman 2013.

Treatment	Transplanting date	Plant ht (cm)	Panicle /m^2	Filled grain/ panicle	1000-grain wt (gm)	Yield (t/ha)
			BRRI dhan33			
T_1	10 July	112	250	132	24.16	4.6
T_2	17 July	114	253	129	24.36	4.9
T_3	24 July	113	289	129	24.40	5.1
T_4	31 July	109	276	130	23.67	5.0
T_5	07 Aug	109	236	129	24.07	4.6
T_6	14 Aug	109	232	115	23.26	4.5
			BR11			
T_1	10 July	112	275	132	24.36	5.6
T_2	17 July	123	234	142	23.32	5.3
T_3	24 July	118	298	131	24.40	**5.9**
T_4	31 July	120	276	117	24.84	5.4
T_5	07 Aug	118	268	123	23.75	5.1
T_6	14 Aug	117	255	125	24.44	5.1

Fig. 6. Average drought pattern (2009-13) for BRRI dhan33.

Fig. 7. Drought pattern in 2013 for BRRI dhan33.

short duration variety transplanted before 24 July it can escape terminal drought. For long duration variety, drought amount increased with late transplanting. Figure 8 presents terminal drought over transplanting dates for different growth phases in the previous years and Figure 9 shows that in 2013 for long duration BR11. Drought in vegetative phase shows a decreasing trends over transplanting dates, and it has a rising trends after transplanting on 24 July during reproductive period but drought amount has started increasing at ripening phase just after 17 July transplanting date. In 2013, reproductive phase shows decreasing trend on delay transplanting. But in ripening phase severe drought occur if the crop transplanted after
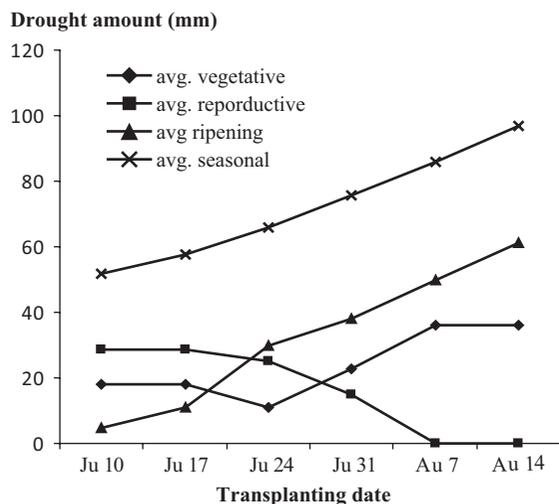
24 July. The analysis shows that long duration variety faces less drought during critical stages (reproductive and ripening stages) when it is transplanted not beyond 17 July. But it suffers more drought during critical stages if it is transplanted beyond 24 July.

BRRI dhan33 yielded highest (5.1 t/ha) if it was transplanted on July 24. Lowest yield was found 4.5 t/ha if it was transplanted on 14 August. For BR11, the highest yield was found for July 24 transplanting (5.9 t/ha). The lowest yield was observed in case of 14 August (5.1 t/ha) transplanting. In both the cases yield decreased after transplanting on 24 July.

Drought is an unpredictable phenomenon and it reappears after 5-10 years. But we can't forecast the year of occurrence. Short duration variety faced fewer droughts due to its shorter growth duration. But both short and long duration variety faced fewer droughts if they transplanted before 24 July. So, transplanting before 24 July would be medium risk period of drought and after that that would be high risk period.

Drought amount (mm)

Fig. 8. Average drought pattern (2009-13) for BR11.

Drought amount (mm)

Fig. 9. Drought pattern in 2013 for BR11.

SUSTAINABLE MANAGEMENT OF GROUND WATER

Monitoring of groundwater fluctuation and safe use in different geo-hydrological regions
The study was conducted to monitor the water level fluctuations and water quality to assess the availability and suitability for agriculture. Available water level recorder was used for measuring groundwater fluctuation. Water samples were collected from all BRRI RSs and HQ for quality analysis.

The study was conducted at BRRI HQ farm Gazipur, Comilla, Rajshahi, Habiganj, Kushtia, Bhanga, Rangpur, Satkhira. Sonagazi and Barisal. Figure 10 shows the maximum and minimum groundwater level at different BRRI stations during 2013-14. During the reporting period maximum lowering of groundwater table was observed in March/April and minimum in September/October. Among the BRRI RSs the highest depth (11.5 m) was observed in Comilla and the lowest (0.82 m) in Satkhira area. The above information indicates that

Location

Comilla 4.6 11.5
Rajshahi 4.5 11.4
Habiganj 5.12 8.49
Kushtia 1.2 7.49
Bhanga 1.62 5.95
Rangpur 1.8 4.8
Satkhira 0.82 3.95
Sonagazi 2.2 3.77
Barisal 1.29 2.33

■ Min
■ Max

Max and min GWL (m)
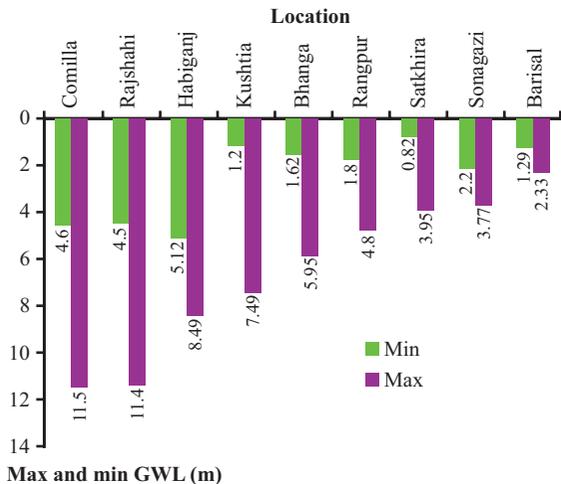
Fig. 10. Fluctuation of groundwater level at different BRRI RSs during 2013-14.

out of nine BRRI RSs, five (Bhanga, Rangpur, Satkhira, Sonagazi and Barisal) are suitable for operating shallow tubewell (STW) and the rest four (Comilla, Rajshahi, Habiganj and Kushtia) are not suitable for using STW during the critical period (March/April) of Boro season. But during wet season all of the nine sites are suitable for STW use as the water table depth is within the suction limit (8 m). Figure 11 presents the maximum and minimum groundwater table depth from 1998 to 2014. The results showed that both maximum and minimum groundwater level at BRRI HQ farm Gazipur is declining day by day and it is not fully recharged after the monsoon. In 1998 the maximum groundwater level was about 11.68 m (Fig. 11) from the ground surface which is 33.61 m in 2014. So the lowering is about 22 m in 16 years. During the initial five years the lowering rate was not so high and it was only 3 m (14-11m). But during the last five years (2009-2014) the lowering was about 10 m (2 m/year) which is more than three times of the initial declination rate. So, the present high rate of declination is very alarming. The lowering is due to increased pumping demand due to establishment of many factories and industries surrounding BRRI HQ. The minimum groundwater level is also declining every year which indicate that the groundwater level is never fully recharged after the monsoon.

Water quality and its suitability for irrigation use
The quality analysis of water, collected from different BRRI RSs showed that the water in Satkhira had slight salinity problem and all other samples had no salinity problem (Table 8). Out of 10 samples only three (Bhanga, Barisal and Satkhira) had slight boron toxicity problem and the other seven had no boron problem. Among the 10

Year

1998 11.68
1999 15.93
2000 14.95
2001 15.83
2002 14.57
2003 14.68
2004 15.98
2005 17.15
2006 19.35
2007 20.92
2008 21.56
2009 23.38
2010 26.34
2011 28
2012 30.16
2013 32.48
2014 33.61

■ Max
■ Min

Max and min GWL BRRI HQ (m)
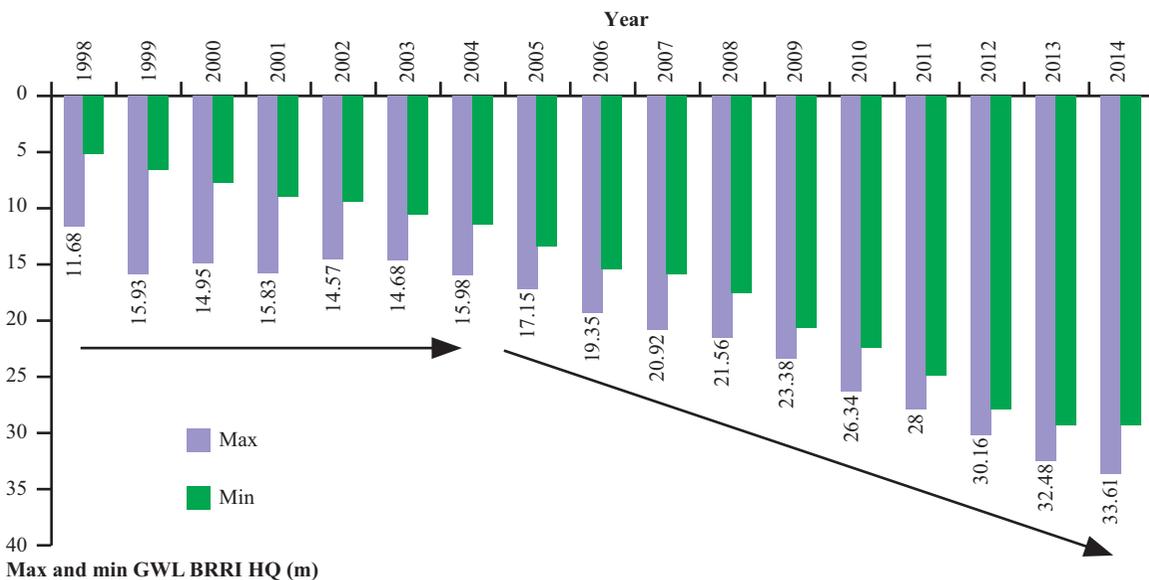
Fig. 11. Maximum and minimum GWL at BRRI HQ during 1998-2014.

Table 8. Quality Classification of water for irrigation use collected from different BRRI RSs during April 2014.

Location	Potential irrigation problem					Degree of restriction			
	Salinity	Toxicity		Miscellaneous		Salinity	Toxicity		Others
	(dS/m)	Na (SAR)	B (ppm)	HCO$_3$ (ppm)	pH	(dS/m)	Na (SAR)	B (ppm)	pH
Gazipur	0.3	2.02	0.55	288	6.8	None	None	None	Normal
Sonagazi	0.5	3.31	0.5	242	7.5	None	Slight	None	Normal
Comilla	0.26	3.75	0.38	130	7.7	None	Slight	None	Normal
Habiganj	0.2	3.97	0.57	204	7.8	None	Slight	None	Normal
Rangpur	0.26	2.15	0.50	118	7.2	None	None	None	Normal
Rajshahi	0.28	2.28	0.67	531	7.2	None	None	None	Normal
Kustia	0.19	2.20	0.47	139	7.2	None	None	None	Normal
Bhanga	0.18	6.97	0.85	399	7.3	None	Slight	Slight	Normal
Barisal	0.5	3.88	0.87	545	7.5	None	Slight	Slight	Normal
Satkhira	1.5	3.36	0.97	160	7.69	Slight	Slight	Slight	Normal
Range	0.18-1.5	2.02-6.97	0.38-0.97	118-545	6.8-7.8				
		Recommended normal range (After FAO, 1985) :				<0.7	<3	<0.7	Normal
					None	0.7-3.0	3-9	0.7-3.0	6.5-8.4
				Slight to moderate		>3.0	>9	>3.0	
					Severe				

study locations the water of Gazipur, Rangpur, Rajshahi and Kushtia were free from sodium toxicity and the other six locations had slight sodium toxicity. The pH value of all the samples were within normal range. Therefore, overall the water quality was found suitable for irrigation purpose in all locations.

RENEWABLE ENERGY

Effectiveness of solar pump for irrigated rice
The study was conducted to evaluate the suitability of solar pump for irrigation and multiple use. A solar irrigation system was installed at BRRI HQ farm. The panel size was 1.5 m^2 × 8 = 12 m^2 and the capacity was 1600 watts. Submersible pump was used and the capacity was one kw. Pumping water has been started since September 2014. Surface water is being pumped from a pond at 3 m head. The maximum volume of pumped water during September was 8.2 m^3/hr (Fig. 12) which is equivalent to137 litre/min. The highest discharge was observed from 12 noon to 2 pm. The average rate of pumping during September was 45.5 m^3/day which can irrigate 3.5 bigha (0.5 ha) of land. The highest discharge during this month was observed 64 m^3/day (Fig. 13).

It will be needed to conduct the study with different type of pumps for economic analysis of solar energy.

Discharge (m^3/hr)
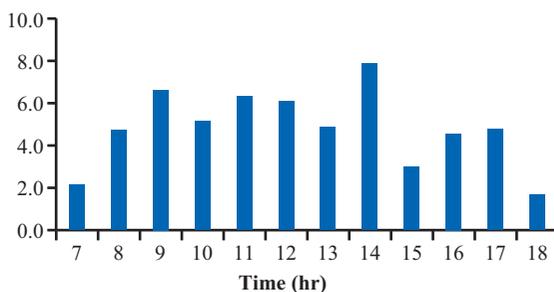
Fig. 12. Discharge in m^3/hr during September 2014.

Discharge (m^3/day)
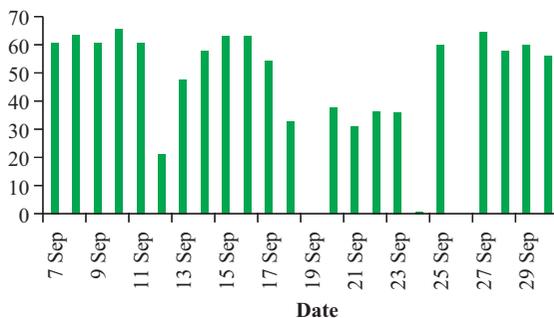
Fig. 13. Daily discharge (m^3/day) during September 2014.

Plant Physiology Division

SUMMARY

Plant Physiology Division mainly worked on abiotic stress (salinity, submergence, drought, heat and cold), growth studies and weather parameters during the reporting year. Genotypes from different sources (INGER materials, anther cultured lines, advanced breeding lines and germplasm) were screened for salinity tolerance at the seedling stage. Out of 483 genotypes, 63 genotypes were found tolerant to moderately tolerant. Horkuch showed two physiological mechanisms ie tissue tolerance and high K^+ absorption for salinity tolerance. Out of 24 only four QTLs in chr. 8, chr. 11 and chr. 12 for the trait K^+/Na^+ ratio could govern the tolerances of Horkuch by maintaining better K^+/Na^+ ratio in the shoot. For submergence tolerance 138 genotypes were considered and only 12 genotypes were found tolerant to moderately tolerant. Out of 46 genotypes, four genotypes performed better having good tillering ability, taller stature and better yield at medium stagnant condition. Four ALART and one PVT materials were tested for drought tolerance at net house condition. Among them two ALART materials performed better compared to the check BRRI dhan56. Out of 22 genotypes tested for deep rooting ability onlyone ALART material performed well but Chao Med Nyay produced the longest (70.30 cm) root compared to check Morichboti (60.37 cm). About 200 germplasms were screened for cold tolerance under natural low temperature condition and only 41 germplasms were selected at the seedling stage. Two advanced breeding lines showed better cold tolerance at seedling stage as well as vegetative stage compared to check variety. All BRRI Boro and Aus varieties, drought tolerant donors and 12 germplasms were tested for heat tolerance in artificial high temperature condition. Only three germplasms (Acc. no. 97, 102 and 133) and two known heat tolerant checks Dular and Kasalath were found moderately heat tolerant. A gel based genotyping system for SNP markers was established for introgression of spikelet fertility QTL. Five and eight BC_1F_1 progenies were identified having two spikelet fertility QTLs (*qSF4.1* and *qSF4.2*) in BRRI dhan28 and BRRI

dhan29. Two NERICA genotypes NERICA-L-8 and NERICA-L-36 yielded better than that of BRRI dhan56. Seedbed amended by the mixture of rice husk and NaCl-priming influenced most of the phenotypic traits compared to control. Rice grain yield under double and normal transplanting was similar with subsequent reduction of field duration. Whereas, higher yield was recorded in BRRI dhan28 and BRRI dhan29 under double transplanting over normal transplanting during Boro season. BRRI dhan54 was found as strong photoperiod-sensitive variety and BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan56 and BRRI dhan57 as weakly sensitive.

SALINITY TOLERANCE

Screening for salinity tolerance of INGER material at the seedling stage

To identify salt tolerant genotypes at seedling stage forty-one INGER materials were considered namely- IR83417-6-B-10-1-1AJY1-B, IR8340-4-B-11-2-1-1-AJY1-B, IR83459-7-B-11-1-1-2AJY1-2-B, IR83460-4-B-4-1-2-1-AJY1-B, IR83465-6-B-102-2-1-AJY1-B, IR8410702-B-AJY1-1-3-AJY1-2-B, IR84645-311-58-1-B-AJY1-1-B, IR85922-4-1-1-AJY1-2-B, **IR85924-11-1-1-AJY1-B, IR85924-12-1-1-AJY1-B, IR85924-5-1-1-AJY1-B, IR85927-8-2-1-AJY1-B, IR86337-B-AJY1-B, IR87853-9-AJY1-B,** IR87915-5-2-2-B, IR87923-2-2-1-B, **IR88344-8-1-2-B,** IR86376-27-1-1-B, IR86384-93-3-1-B, **IR86385-116-1-1-B, IR86385-165-1-1-B,** IR86385-48-1-1-B, IR886385-84-1-1-B, IR886385-84-1-1-B, IR86385-85-2-1-B, IR88339-8-B-3-1-B, A 69-1, **AGAMI MI, AT 401,** CSR 28, IR28, IR29, IR45427-2B-2-2B-1-1, IR55179-3B-11-3, **IR66946-3R-178-1-1(Fl478), NONA-BOKRA, POKKALI (ACC108921), BRRI dhan47,** BRRI dhan61, **BR7100-6-6, IR78794-B-Sal 29-1, IR59418-7b-21-3** along with standard tolerant FL478 and sensitive check IR29 were screened under salinity (12 dS/m) stress. Out of 41 genotypes, 17 (bold markings) showed visual score 4-5 that is tolerant to moderately tolerant. Screening was done as per Gregorio *et al*., 1997.

Screening of advanced breeding lines for salinity tolerance at the seedling sage

Forty-one advanced breeding lines as IR78761-B-SATB1-28-3-24, **IR78761-B-SATB1-28-3-26,** IR78761-B-SATB2-4-25-3, IR85920-11-2-1-AJY1-2-B, IR85920-11-2-1-AJY1-3-B, IR85921-9-2-1-AJY1-1-B, IR86341-B-AJY1-B, IR87856-10-AJY1-B, **IR87856-7-AJY1-B,** IR87938-1-1-1-2-B, IR87938-1-1-1-3-B,IR87938-1-1-2-1-B, IR87938-1-1-2-2-B, IR87938-1-1-2-3-B, IR88300-2-2-1-B, IR88304-B-AJY1-B, IR88314-1-AJY1-B, IR88320-B-AJY1-B, IR89609-8-2-B, IR86376-47-3-1-B, **A69-1,** AGAMI MI, **AT401,** CSR28, IR28, IR29, **IR45427-2B-2-2B-1-1,** IR55179-3B-11-3, IR66946-3R-178-1-1 (FL478), **NONA BOKRA, POKKALI (Acc. 108921),** BRRI dhan53, BRRI dhan54, IR83439-4-B-11-3-2-1-AJY1-3-B, IR85865-B-2-1-AJY1-B, IR85897-B-B-AJY1-B, Jataibalam, Subulkua, Shulidhan, Akundi, Dhaldata along with standard tolerant and sensitive check FL478 and IR29 were screened for salinity tolerance under salinity (12 dS/m) stress. Out of41 genotypes, only seven (bold markings) showed visual score 5 that are moderately tolerant. Among them only one genotype scored 3 that is tolerant compared to check. Screening was done as per Gregorio et al., 1997.

Screening for salinity tolerance of some anther culture lines at the seedling stage

Fifteen anther culture lines as Bio-AC1B-19-2-1-1-2, Bio-AC1B-19-2-1-1-3, Bio-AC1B-19-2-1-2-1, Bio-AC1B-19-2-1-2-2, Bio-AC1B-19-2-1-2-3, **Bio-AC1B-19-2-1-2-4,** Bio-AC1B-19-2-1-3-1, **Bio-AC1B-19-2-1-3-2,** Bio-AC1B-19-2-1-5-1, **Bio-AC1B-19-2-1-5-2,** Bio-AC1-10-2, Bio-2B-3, Bio-2B-6, Bio-2-2-1-2, Bio-2B-30, BRRI dhan41, FL378 (Tolerant ck), BRRI dhan27 (Std. ck), BRRI dhan29 (Susceptible ck) were screened for salinity tolerance under salinity (12 dS/m) stress. Among15 lines, only three (bold markings) showed visual score 5 that is moderately tolerant. Screening was done as per Gregorio et al., 1997.

Screening for salinity tolerance of rice germplasm at the seedling stage

Two hundred rice germplasm from BRRI genebank namely Acc. no-468, 470, 471, 472, 473, 475, 486, 487, 489, 490, 492, **494,** 496, 502, 504, 507, 508, 512, 513, 514, 515, 516, 518, 519, 520, 521, 522, 523, 525, 529, 531, 532, 534, 536, 537, 540, 543, 544, 546, 549, 550, 576, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 597, 598, 599, 600, 604, 612, 614, 616, **621,** 623, 626, **627,** 628, 630, 631, **632,** 633, 634, 635, 637, 638, 639, 640, 641, **642,** 643, 644, 645, 646, 659, 661, 662, 663, 664, 665, 666, 667, 668, 670, 671, 672, 673, 674, 675, 676, 678, 679, 680, 683, 684, 685, 686, 689, 692, 694, 697, **698,** 699, 700, 701, 703, 704, 706, 707, 708, 709, 710, **711,** 712, 713, 714, **715,** 716, 717, 718, 719, 720, 721, 722, 723, **724,** 725, 726, 727, 728, 729, 731, 732, **733,** 736, 737, **740, 742,** 743, 747, 748, 749, 750, 751, **752, 753,** 754, 755, 756, 757, 758, 759, 761, 762, 764, 765, **766,** 767, 768, 770, 771, 773, 774, 775, 776, 777, 778, 779, 780, 781, 783, **784,** 785, 787, 788, 789, 790, 791, 793, 794, 795, 796, 797, 798, 799, 800, 803, 804, 806, 810 along with standard tolerant FL478, Pokkali and sensitive check IR29 were screened for salinity tolerance under salinity (12 dS/m) stress. Among 200 germplasms, only 16 germplasms (bold markings) showed visual score 4 to 5 that is tolerant to moderately tolerant. Survivability ranged from 45 to 90% for the tolerant genotypes. Screening was done as per Gregorio et al., 1997.

Screening for salinity tolerance of some deep water rice varieties at seedling stage

The present study aims to judge the salt tolerant capacities of DWR varieties into controlled net house condition in the hydroponic culture for seedling stage tolerance. Fifty deep water accessions from BRRI Genebank and 23 deep water varieties and advanced lines from BRRI RS, Habiganj were considered for this experiment. All the genotypes were tested along with standard tolerant check FL478, FL378 and sensitive check IR29 in hydroponic culture by the method as per Gregorio et al. 1997 at seedling stage in the Plant Physiology Nethouse, BRRI. Only SES score was used to find out the level of tolerance at seedling stage among the tested deep water genotypes and lines. Only three deep water genotypes namely, Noakhali (acc. no. 6379), Jota bhaulia (acc. no. 6380) and Kartiksail 2 (acc. no.

6348) were found moderately tolerant at seedling stage.

Mapping QTLs for salinity tolerance of Horkuch at seedling stage

A study was carried out to genetic dissection and mapping loci contributing tolerances of a Bangladeshi salt tolerant landrace Horkuch. $F_{2:3}$ mapping strategy was employed to map QTLs of Horkuch, where 100 F_2 populations of Horkuch/IR29 were genotyped by 49 polymorphic SSR markers distributed throughout the rice genome. The 49 SSR markers covered about 957.92 cM of Horkuch genome with an average genetic distances between markers are 19.55 cM which ranges 10.64 to 29.54 cM. Phenotypic characterization of 100 F_3 progenies for seedling stage salinity tolerance was carried out according to the IRRI standard protocol described by Gregorio *et al.,* 1997. Phenotypic traits such as SES score, Na^+ and K^+ concentration and ratios, relative water content of shoots and roots, chlorophyll a and b content and ratios of leaves, stomatal conductance, seedling height and root length, dry mass of shoot and root were recorded and computed for judging seedling stage tolerance. Linkage analysis and QTL mapping were done through Inclusive Composite Interval Mapping method v4.0 software. Significant QTL was declared when LOD value exceed the threshold LOD 3.0.

A total of 15 phenotypic traits were measured and recorded for observing the variations of tolerances among parents and segregating populations. ANOVA showed significant variations only for seven traits ie Na^+ and K^+ concentrations and ratios; shoot and root length and dry weights (Table 1). The concentration of Na^+ and K^+ was significantly higher for the tolerant parent Horkuch than sensitive IR29 and subsequently the ratio of K^+/Na^+ was significantly higher for Horkuch, this is indicative of greater uptake of K^+ and maintaining healthy ratios of K^+/Na^+ by Horkuch (Table 1). Results of Na^+ and K^+ concentrations and ratios of Horkuch and IR29 suggesting the clues of possible physiological mechanisms governing the tolerances of Horkuch. Here, two physiological mechanisms could be hypothesized for the tolerances of Horkuch ie (i) tissue tolerance (Horkuch maintained higher Na^+ concentration) and (ii) better K^+ absorption/uptake (higher K^+ improves the healthy K^+/Na^+ ratio). Correlation study among the traits showed a very strong, significant and negative relationship of SES to K^+ concentration, K^+/Na^+ and shoot dry weight. These relationships clearly explain the tolerance of Horkuch at seedling stage that could be governed significantly by K^+ absorption/uptake and subsequent better balance of K^+ to Na^+ in the shoot.

Linkage analysis was done based on average recombination conversion on actual physical position of each marker ie 250 kb=1 cM. Mapping through ICIM method identified 24 putative QTLs for five traits ie K^+/Na^+ ratio, chlorophyll a/b ratio, root relative water content, root length and root dry weight (Fig. 1). However, out of 24 QTLs only four were identified for the trait 'K^+/Na^+ ratio' in chr.8, 11 and 12 (Fig. 1). The LOD and R-square values of the identified QTLs ranging from 3.01-7.44 and 18.30-30.62% respectively, which are indicative of major QTLs for salinity tolerance at seedling stage. However, additive genetic effects showed negative allelic effects for the two QTLs of chr.11 and positive effects for rest of the two QTLs (Fig. 1). The opposite directions of the allelic effects for the identified four QTLs indicates that both parents contributed for the tolerances at seedling stage of the progenies.

Screening for salinity tolerance of some introgression lines from Boilam at seedling stage

Mapping for tolerance at seedling stage of Boilam identified four putative QTLs in chromosome 1, 4, 9 and 12. A major QTL effect in chromosome 9 (*qSES9*) for overall tolerance judged by SES score, which is tightly linked to the In Del marker R9M30 with R^2 14% was targeted for use in breeding for salinity tolerance. The present investigation was undertaken for quantification of *qSES9* to the seedling stage salinity tolerance in rice. A total of 133 advanced backcross breeding lines derived from 14 introgression lines from BRRI dhan27/Boilam were tested along with standard tolerant and sensitive checks and parents

Table 1. Summary statistics of the phenotypic traits of parents (Horkuch and IR29) and F_3 populations. Each value is the mean of three replications.

Trait	Parent			Population					
	Horkuch	IR29	p-value	Max	Min	Mean	Standard deviation	Heritability	p-value
SES score	5.46	6.53	0.17	8.50	2.67	5.59	1.14	0.55	0.00
Na$^+$ concentration (mmol/g dry mass)	0.63	0.26	0.00	1.10	0.05	0.52	0.19	0.51	0.00
K$^+$ concentration (mmol/g dry mass)	0.20	0.05	0.00	0.34	0.01	0.15	0.07	0.76	0.00
K$^+$/Na$^+$ ratio	0.32	0.19	0.00	1.36	0.08	0.31	0.16	0.31	0.01
Stomatal conductance [mmol/(m²·s)]	805.97	721.43	0.28	1567.90	19.70	707.07	324.66	0.00	0.77
Chlorophyll a (mg/g fresh wt)	1.64	2.85	0.17	5.96	0.22	1.94	0.53	0.02	0.35
Chlorophyll b (mg/g fresh wt)	1.73	3.03	0.15	5.04	0.24	2.08	0.50	0.01	0.43
Total chlorophyll (mg/g fresh wt)	3.38	5.89	0.16	9.55	0.46	4.01	1.00	0.01	0.40
Chlorophyll a/b ratio	0.94	0.94	0.67	1.80	0.83	0.93	0.08	0.17	0.10
Shoot relative water content (%)	90.67	92.23	0.44	139.55	29.20	78.01	11.28	0.17	0.13
Root relative water content (%)	83.06	84.73	0.21	415.52	27.28	97.15	24.82	0.21	0.09
Shoot length (cm)	47.54	30.45	0.00	63.67	25.00	42.52	6.88	0.86	0.00
Root length (cm)	16.91	13.28	0.00	40.00	6.33	15.55	3.82	0.42	0.00
Shoot dry weight (g/plant)	0.63	0.32	0.00	1.18	0.13	0.59	0.18	0.77	0.00
Root dry weight (g/plant)	0.10	0.07	0.00	1.00	0.03	0.12	0.09	0.18	0.11
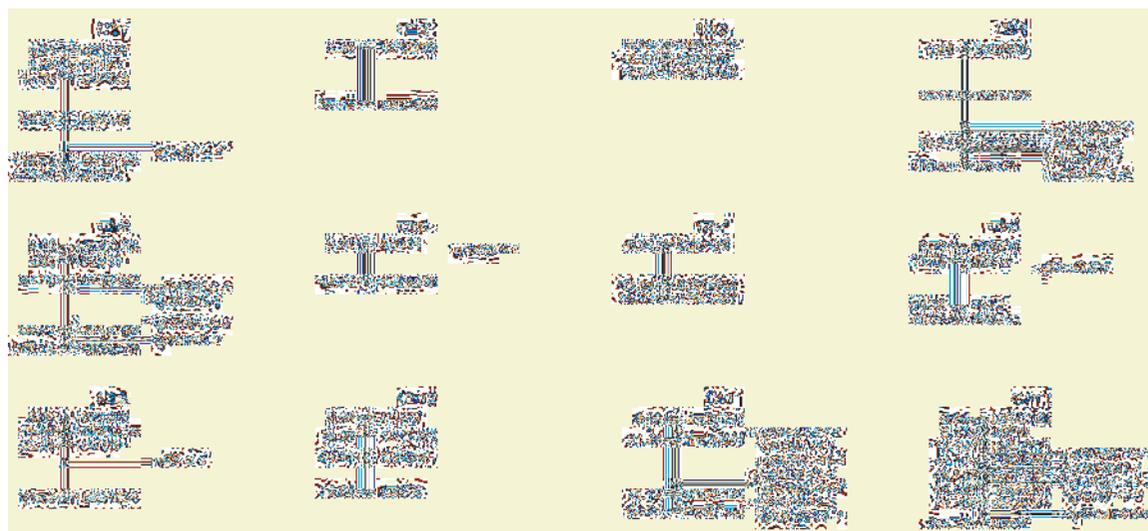
Fig. 1. Linkage map with identified significant QTLs across Horkuch genome.

Pokkali, IR29, BRRI dhan27 and Boilam in hydroponic culture according to the method described by Gregorio *et al.*, 1997 at seedling stage. All 133 introgression lines were evaluated for tolerance only by SES score. The SES varied from 3.80 to 8.70 among the tested lines. However, the parents and checks were scored 5.89 to 6.83 ie Boilam (6.10), BRRI dhan27 (6.67), IR29 (6.83) and BRRI dhan47 (5.89).

The distribution of the SES scores of the tested 133 introgression lines was shown to continuous variation for salinity tolerance at

seedling stage (Fig. 2). This continuous distribution confirmed that the trait is still segregating and also its quantitative nature and again indicating that there should be other factors contributing for the tolerance at seedling stage.

Screening for salinity tolerance of some local and exotic genotypes at seedling stage
Ninety-six salt tolerant genotypes collected from IRRI, India and BRRI through DANIDA-Planning Commission Project were evaluated at seedling stage along with standard tolerant checks FL378

Frequency
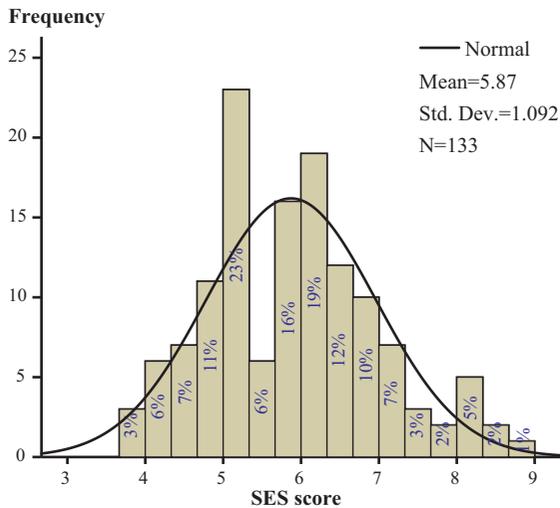
Fig. 2. Histogram showing the distribution of lines according to the SES score (overall salinity tolerance at seedling stage).

and sensitive check IR29. The experiment was conducted in hydroponic culture by the method described by Gregorio *et al.* 1997 at seedling stage. Seven phenotypic parameters were measured and recorded to evaluate the level of tolerance of the tested genotypes. Based on SES 3 out of 96 genotypes tested were found tolerant with SES value ranging 3.85-4.00. Fourteen genotypes showed SES score less than the tolerant check FL378 (5.73) and sensitive check IR29 (6.56) (Table 2). However, the selected 17 genotypes showed 100% survivability in a high salinity stress in hydroponic culture for 2 weeks. Correlations among the traits showed SES has very strong, significant and positive relationship to Na^+/K^+ ratio but negative to rest of the traits (Table 3). These strong and significant relations (r = 0.75**) of SES vs Na^+/K^+ indicating the tolerance at seedling stage should be controlled mainly by the lower balance of Na^+/K^+ in to the shoot.

SUBMERGENCE TOLERANCE

Confirmation of performance regarding survival and recovery ability of previously screened rice germplasms
Seventy-six germplasms- Acc. no. 24, 82, 83, 84, 85, 86, 88, 89, 90, 91, 92, 93, 95, 97, 99, 10, 103,

108, 109, 110, 113, 114, 119, 120, 121, 123, 127, 128, 130, 131, 135, 136, 143, 146, 165, 166, 171, 173, 217, 230, 237, 248, 250, 252, 412, 416, 440, 444, 449, 450, 451, 453, 454, 456, 457, 458, 459, 460, 461, 462, 463, 465, 466, 407, 1838, 3950, 4206, 4217, 4218, 4398, 4399, 4548, 4578, 4096, 4398, 4399 and two checks namely FR13A (Res. ck), BR5 (Sus. ck) were tested to identify tolerant germplasm at the seedling stage under complete submergence condition. Fourteen-day-old seedling was transplanted in the Plant Physiology submergence tank. At 14 days after transplanting, the crop was allowed to complete submergence maintaining 75 cm water depth for 14 days. During submergence period, the water of the tank was made turbid twice daily and the light intensity in upper level (normal), mid-level (30 cm below the water surface) and lower level (75 cm below the water surface) of the tank water were measured through light meter (LI-250). The light intensity was 570-1541, 224-445 and 74-105 µ mole/m^2/s at upper, mid and lower level respectively before turbidity. After turbidity light intensity was 82-166 and 0.4-1.5 µ mole/m^2/s at mid and lower level respectively. The water pH was 7.30-8.00 and temperature was 28-31°C during the growing period. At 14-day-after submergence, the water drained out from the submergence tank. The survival data was taken at 5- and 30-day-after desubmergence. Survival scoring was done by SES. Recovery status was also evaluated at 30 days of desubmergence.

Among the tested genotypes, four genotypes namely Acc. 1838, Acc. 4206, Acc. 4399 and Acc. 4096 were identified having good survivability and excellent recovery (Table 4). These genotypes can be used for further investigation to get donor materials for crossing.

Characterization of some promising genotypes under submergence condition
Eighteen genotypes (IR09F147, IR09F177, IR09F189, IR09F226, IR09F236, IR09F253, IR84645-312-11-1-B, IR84649-308-24-1-B, IR77092-B-14-8-3-1, Chiherang-Sub1, IR64-Sub1, PSBRC82-Sub1, Kalojoma, DGI-349, BRRI dhan33, BRRI dhan39, BRRI dhan40, BRRI dhan49) and four checks namely BRRI dhan51,

Table 2. Phenotypic parameters measured for tolerance at seedling stage. Each value is the mean of three replications. Parameters of tolerant and moderately tolerant genotypes were shown below.

Genotypic code #	SES score	Survivability (%)	Na+/K+ ratio	Seedling ht (cm)	Root length (cm)	Shoot dry wt (mg/seedling)	Root dry wt (mg/seedling)
15	3.85	100.00	3.39	32.20	19.25	214.50	34.79
14	4.00	100.00	2.22	32.10	19.55	165.00	31.11
52	4.00	100.00	2.71	29.75	16.70	229.50	30.89
13	4.65	100.00	2.70	29.25	20.85	163.50	29.55
95	4.70	100.00	4.17	49.20	17.40	326.50	37.37
16	4.75	100.00	3.33	28.80	17.05	247.50	27.80
18	4.75	100.00	3.35	25.35	11.80	200.00	22.27
09	4.80	100.00	3.33	29.40	20.45	192.50	27.73
77	4.95	100.00	3.09	37.50	12.15	270.00	26.84
19	5.00	100.00	3.06	28.25	13.30	169.00	26.63
39	5.00	100.00	3.36	33.35	11.90	176.50	33.18
75	5.05	100.00	6.66	32.95	17.60	207.00	28.28
11	5.10	100.00	3.17	30.00	18.60	207.50	20.15
51	5.15	100.00	3.51	27.95	14.15	215.50	27.47
22	5.25	100.00	3.55	30.50	16.15	200.00	25.56
67	5.25	100.00	4.79	34.45	14.75	207.00	29.54
50	5.35	100.00	4.44	28.55	15.95	170.00	28.33
FL378 (ck)	5.73	95.00	4.75	28.18	13.11	173.31	25.23
IR29 (ck)	6.56	78.75	5.85	27.53	12.99	188.54	19.43
Sig.	**	**	**	**	**	**	**
LSD$_{0.05}$	0.76	21.00	1.88	2.47	2.45	57.36	4.07
CV (%)	7.50	15.10	21.00	5.40	11.40	23.80	12.40

**Significant at the 1% level of probability.

Table 3. Correlations (Pearson) among the seven phenotypic traits measured.

	SES	SUR	Na+/K+	SH	RL	SDW	RDW
SES score	1						
Survivability	-0.78**	1					
Na+/K+ ratio	0.75**	-0.62**	1				
Seedling height	-0.46**	0.37**	-0.29**	1			
Root length	-0.54**	0.35**	-0.36**	0.38**	1		
Shoot dry weight	-0.56**	0.34**	-0.45**	0.57**	0.38**	1	
Root dry weight	-0.74**	0.46**	-0.47**	0.64**	0.59**	0.64**	1

**Significant at the 1% level of probability; ns=not significant.

Table 4. Elongation (%), survivability (%), dry matter increased (%) and SES score of some promising genotypes.

Accession no.	Elongation (%)	Survivability 5 DAS (%)	Survivability 30 DAS (%)	SES score	Dry matter increased (%)
1838	35.00	85.70	85.70	3	81.00
4206	27.00	78.50	78.50	4	80.00
4399	43.00	71.40	71.40	4	58.00
4548	34.00	33.30	33.30	8	26.00
4096	43.00	71.40	71.40	4	76.00
4399	26.00	16.70	16.70	9	69.00
FR13A (R. ck)	11.00	100.00	100.00	1	79.00
BR5 (S. ck)	42.00	17.00	17.00	9	63.00
Standard deviation	11.04	32.28	32.28		18.40

DAS=Days after submergence.

BRRI dhan52, FR13A and BR5 were tested during the period from March 2013 to June 2013. The methodology and submergence condition was same as previous experiment.

Among the tested genotypes, two genotypes namely IR09F177 and IR64-*Sub1* were identified as tolerant to 14 days of complete submergence having good survivability (83.3-91.7%) and

excellent recovery (2-3). Rests of the genotypes were also non-elongating type but survivability percentage was poor. From the results three genotypes should be considered for further investigation.

Screening for flash flood submergence tolerance
Forty-eight genotypes (BR7937-28-1, IR09F173, IR10F198, IR10F339, IR10F365, IR10F558, IR10F616, IRRI119, IRRI154, IR10F187, IR09F169, IR10F548, IR10F550, IR10F668, IR09F175, IR09F130, IR09F165, IR09F117, IR09F181, IR09F186, IR09F187, IR09F188, IR09F202, IR09F203, IR09F220, IR09F222, IR09F224, IR09F117, IR09F147, IR09F116, IR09F171, IR09F226, BR9157-12-2-37-13-15, BR9157-12-2-37-13-17, BR9157-12-2-37-13-71, IR84649-308-24-1-B,　IR77092-B-14-8-3-1, IR7867-4R, IR72046-B-14-8-3-1, IR77092-B-2R-B-10**,** IR84645-2-11-1-B, BR9377-6-3-6, BR9377-9-14-7, IR84645-312-11-1-B, BRRI dhan33 (S. ck), BRRI dhan40, BRRI dhan41, BRRI dhan44 (S. ck),) and two checks namely BRRI dhan51, BRRI dhan52 were tested during the period from July 2013 to October 2013. The methodology was same as previous experiment. The light intensity was 430-1512, 214-345 and 71-95 μmole/m^2/s at upper, mid and lower level respectively before turbidity. After turbidity light intensity was 82-156 and 0.20-1.30 μmole/m^2/s at mid and lower level respectively. The water pH was 7.1-7.8 and temperature was 28.5-31.0°C.

Among the tested genotypes, five genotypes namely IR09F202, IR7867-4R, IR72046-B-14-8-3-1, IR77092-B-2R-B-10 and BR9377-9-14-7 appear to be tolerant to 14 days of complete submergence having good survivability and excellent recovery.

Screening of performance regarding survival and recovery ability of some advanced breeding lines
Nine genotypes (IR84649-308-24-1-B, IR77092-B-14-8-3-1, IR7867-4R, IR72046-B-14-8-3-1, IR77092-B-2R-B-10, IR84645-2-11-1-B, BR9377-6-3-6, BR9377-9-14-7, IR84645-312-11-1-B) and four varieties (BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan51) were tested during the period from July 2013 to October 2013.

The methodology was same as previous experiment. The light intensity was 430-1552, 214-345 and 71-95 μ mole/m^2/s at upper, mid and lower level respectively. The water pH was 7.1-7.8 and temperature was 28.5-31.0 °C

Among the tested genotypes, four genotypes namely IR7867-4R, IR72046-B-14-8-3-1, IR77092-B-2R-B-10 and BR9377-9-14-7 were also identified as tolerant to 14 days of complete submergence having good survivability and excellent recovery.

Characterization of some advanced breeding lines for medium water stagnation environment in T. Aman season
Eleven genotypes (IR09F147, IR09F177, IR09F189, IR09F226, IR09F236, IR09F253, Chiherang-Sub1, IR64-Sub-1, PSBRC82-Sub1, Kalojama, DGI-349) and five varieties (BRRI dhan33, BRRI dhan39, BRRI dhan49, BRRI dhan51, BRRI dhan52) were characterized against medium stagnation environment during the period from March 2013 to October 2013. At 20 DAT, water stagnation was started at 15 cm depth and it was increased up to 60 cm by increasing water depth 15 cm with 10 days intervals. Water stagnation condition was maintained at 60 cm depth up to 65-day-after transplanting.

Among the tested genotypes only two IR lines IR09F236 and IR09F253 were produced tall plant, good number of tiller per hill and grain yield at water stagnant condition. These two IR lines might be used as medium stagnant rice for further investigation.

Screening of medium stagnant water tolerant rice genotypes
Thirty-five genotypes (BR7937-28-1, IR09F173, IR10F198, IR10F339, IR10F365, IR10F558, IR10F616, IRRI119, IRRI154, IR10F187, IR09F169, IR10F548, IR10F550, IR10F668, IR09F175, IR09F130, IR09F165, IR09F117, IR09F181, IR09F186, IR09F187, IR09F188, IR09F202, IR09F203, IR09F220, IR09F222, IR09F224, IR09F117, IR09F147, IR09F116, IR09F171, IR09F226, BR9157-12-2-37-13-15, BR9157-12-2-37-13-17, BR9157-12-2-37-13-71) and four varieties (BRRI dhan33, BRRI dhan44,

BRRI dhan51, BRRI dhan52) were characterized during the period from July 2013 to December 2013 against medium stagnation environment. The methodology was same as previous experiment.

All genotypes were non-elongating type at water stagnant condition. None of the tested genotypes were suitable for medium water stagnant condition.

DROUGHT TOLERANCE

Performance of some genotypes under drought stress at reproductive stage
Four ALART and one PVT materials were evaluated under control drought condition in Plant Physiology net house BRRI HQ, Gazipur during T Aman 2013. Twenty-five-day-old seedlings were transplanted in drum (56- × 43-cm) containing 110 kg puddled soil in two sets where 1st set was grown in well-watered conditions and 2nd set under stress condition. At panicle initiation stage water was drained out from the 2nd set so that the plants experiences drought stress from the reduction division stage. The water table depth and soil moisture was recorded. At severe drought stress some life saving water was applied. The amount of life saving water was calculated as follows:

The amount of life saving water (ml) = P r^{2}h
Where, r = 56/2 = 28 cm (The radius of the circumference of pot at the base of the hill.); h = 0.5 cm/day (the approximate evapotranspiration at the period of Nov-Dec.

Due to water stress plant height significantly reduced in all the variety (Table 5). The straw yield was remarkably reduced in stress condition in all the varieties indicating growth was affected by water stress (Table 5). The growth duration was almost same under control and stress condition in all the varieties except IR87707-446-B-B-B and IR82589-B-B-84-3 in which the growth duration under stress condition was five days and seven days less respectively (Table 5). The panicle number was reduced drastically due to water stress in all the genotypes except IR82589-B-B-84-3. In IR82589-B-B-84-3 although the panicle number under control and stress condition was not statistically similar but the reduction was less than other varieties (Table 5).

Under stress condition, the lowest percent yield reduction was found in IR87707-446-B-B-B (71.6%) followed by IR82589-B-B-84-3(75.9%) and IR83373-B-B-27-4 (76.7%) but in other varieties it was more than 80%. Similarly under stress condition the highest filled grain number was found in IR87707-446-B-B-B followed by IR82589-B-B-84-3 and IR83373-B-B-27-4 and the lowest sterility percentage was found in IR82589-B-B-84-3 followed by IR87707-446-B-B-B and IR83373-B-B-27-4. The thousand grain weight and harvest index (HI) was also significantly reduced under stress condition. So, the yield reduction was possibly attributed to the reduction of filled grain number per plant and thousand grain weights as well as the percent increase in the sterility (Table 6).

Screening for deep rooting ability
To identify genotypes having deep rooting ability 22 genotypes including 14 donor materials, four

Table 5. Plant height, straw yield, panicle number and growth duration of tested genotypes as affected by water stress at reproductive stage.

Designation	Plant ht (cm)		Straw yield (g/plant)		Panicle no.		Growth duration (day)		
	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Increase/decrease
IR83383-B-B-129-4	111.4	86.9	53.2	50.5	26.7	15.2	112	111	-1
IR83373-B-B-27-4	102.1	88.2	41.29	37.18	23.5	16.0	112	109	-3
IR87707-446-B-B-B	109.8	93.2	48.0	41.57	25.6	21.2	111	106	-5
IR82589-B-B-84-3	127.7	113.2	51.5	35.8	14.7	11.9	109	102	-7
BRRI dhan56	116.8	102.9	46.7	39.1	19.2	16.1	104	101	-3
IR82635-B-B-75-2	117.4	103.1	53.0	37.9	16.3	12.9	103	101	-2
LSD (0.05)	3.1		6.14		2.6		2.3		-
CV (%)	11.4		10.8		11.1		1.7		-

Table 6. Grain weight, and filled grain number and sterility percentage of tested genotypes as affected by water stress at reproductive stage.

Designation	Grain wt (g/plant)			Filled grain no./plant		% sterility		1000-grain wt (g)		Harvest index (HI)	
	Control	Stress	% red.	Control	Stress	Control	Stress	Control	Stress	Control	Stress
IR83383-B-B-129-4	59.91	5.36	91.10	2531.4	318.0	16.90	83.5	24.32	17.06	0.51	0.09
IR83373-B-B-27-4	39.52	9.22	76.70	1595.1	563.3	31.40	67.5	25.12	19.15	0.45	0.17
IR87707-446-B-B-B	54.01	15.36	71.60	2284.0	777.1	17.20	68.3	23.52	19.66	0.50	0.23
IR82589-B-B-84-3	49.67	11.95	75.9	2088.4	673.5	14.20	65.7	23.74	17.18	0.47	0.22
BRRI dhan56	48.17	8.51	82.30	2218.9	500.9	18.00	72.1	21.73	18.03	0.48	0.16
IR82635-B-B-75-2	53.20	8.55	83.90	2442.1	519.8	12.30	73.2	22.73	16.82	0.48	0.16
LSD (0.05)		4.99	-	222.8		6.6		1.47		0.41	
CV (%)		12.9	-	12.7		11.5		5.6		9.9	

ALART, one PVT, BRRI dhan39, BRRI dhan56 and a local upland variety Morichboti were tested following BRRI, 2006. Considering root length, CRL and root shoot ratio, the ALART IR82589-B-B-84-3 performed well and genotypes Chao Med Nyay produced 70.3 cm long root which could be used further breeding programme (Table 7).

Table 7. Seedling height, root length, cumulative root length (CRL) and root shoot ratio of 22 genotypes.

Designation	Shoot ht (cm)	Root length (cm)	CRL (cm)	Root shoot ratio (mg/g)
SEE Deuan	90.26	46.83	1298.17	107.10
Chao khaw	71.77	45.67	1064.67	112.40
Intok Hoy	88.44	55.70	1163.67	86.9
Eaoy	87.55	46.40	880.50	101.1
Chao Med Nyay	98.55	70.3	1534.83	105.6
MakBouap	90.22	52.93	1064.50	82.0
ThibNgan	91.55	51.50	1304.33	115.2
Eakhaw	74.66	47.70	782.93	92.1
Kam	90.22	52.77	1007.83	112.7
EaNoi	90.77	55.20	1147.83	121.3
Makeu	85.66	52.87	1102.50	124.2
Tainan15	88.33	47.70	1318.33	130.8
Do Nang Nouan	81.11	47.03	902.77	97.1
Tia	89.33	47.17	1512.67	92.1
BRRI dhan39	60.22	50.00	1215.63	130.4
BRRI dhan56	63.55	63.27	1063.03	141.2
IR83383-B-B-129-4	61.22	44.70	923.80	101.3
IR83373-B-B-27-4	60.27	42.40	791.00	105.8
IR87707-446-B-B-B	74.77	53.53	1101.50	85.6
IR82589-B-B-84-3	82.77	67.23	1776.33	130.1
IR82635-B-B-75-2	74.44	63.23	1481.33	122.4
Morichboti	88.00	60.37	1330.00	130.9
LSD (5%)	11.91	12.82	490.65	42.32
CV (%)	8.9	14.7	25.4	23.3

HEAT TOLERANCE

Screening for heat tolerance of some Bangladeshi rice germplasms and advanced breeding lines

A total of 53 BRRI gene germplasms along with checks were considered for this study. Plants were grown in pots and were transferred to polythene made heat house during flowering period for seven days.

Among the 34 germplams, 11 showed spikelet sterility less than 40% which is very much comparable to the moderately heat tolerant IR64 and Dular. Interestingly N22, the heat tolerant check showed 68% spikelet sterility. Sterility was found much higher for all breeding lines; only 3 lines showed sterility ~70%, rest of the lines showed >80-90% sterility (Fig. 3). Pollen viability showed very high variation among the tested entries. Six germplams (acc. 3, 86, 116, 194 and 206) showed pollen viability ~90% including moderately tolerant check Dular (Fig. 4). Among the tested breeding lines four showed pollen viability ~90%. Based on lower percentage of spikelet sterility and greater pollen viability, five genebank accessions 96, 97, 100, 131 and 133 were selected for using as parents for future heat tolerant breeding in Bangladesh.

Development of heat tolerant BRRI dhan28 and BRRI dhan29 by introgressing spikelet fertility QTLs (*qSF4.1* and *qSF4.2*) through marker-assisted backcrossing

A marker assisted breeding programme was undertaken for improving the spikelet fertility of BRRI dhan28 and BRRI dhan29 by introgressing

Spikelet sterility (%)
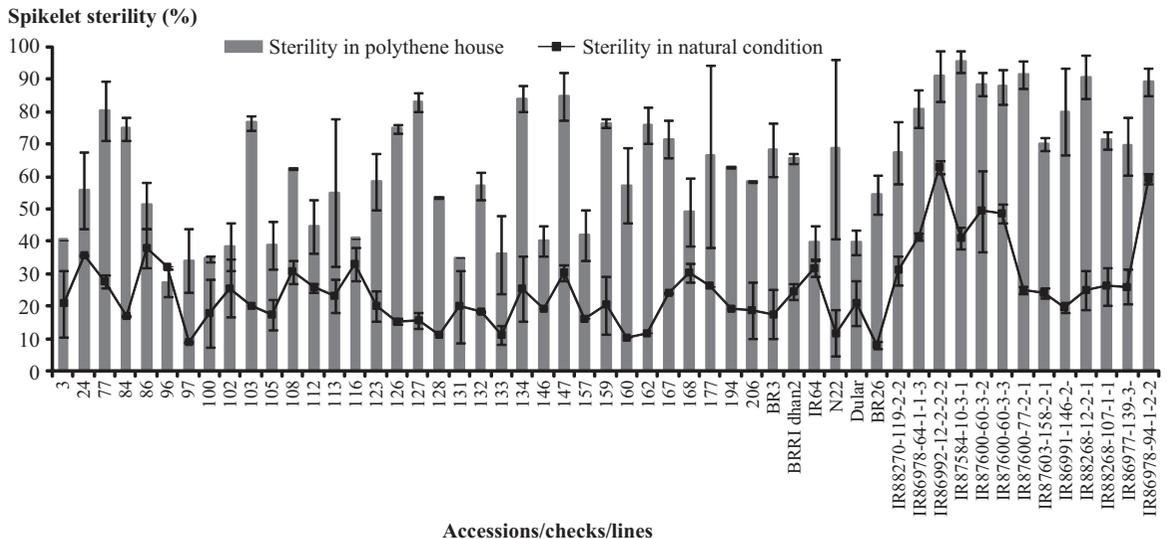
Fig. 3. Spikelet sterility of 53 tested entries under controlled high temperature polythene house (grey bars) and natural condition (lines). Each bar and marker point is the mean of two replicates and error bars are the ±SD.

Pollen viability (%)   **Total pollen count (no.)**
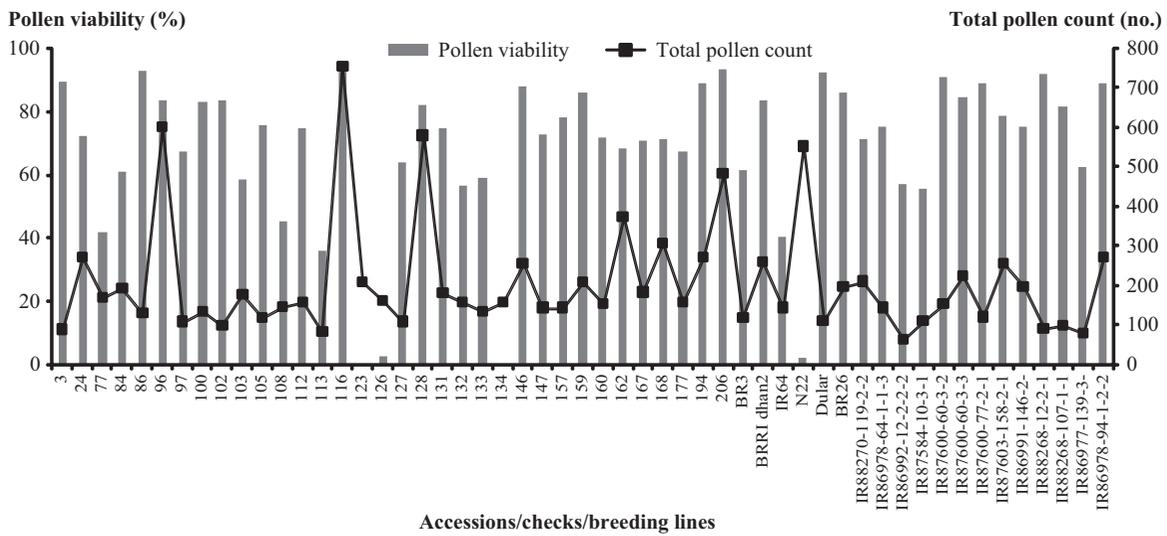
Fig. 4. Pollen viability of 53 tested entries under controlled high temperature polythene house (grey bars) and total pollen count (lines).

spikelet fertility QTLs (*qSF4.1 and qSF4.2*) from N22. A two-step (genotype-phenotype) marker-assisted backcrossing approach was employed to introgress two spikelet fertility QTL, where markers were used to confirm the presence of the QTL in to backcross progenies while a stringent phenotypic selection was employed for selecting best genotype analogous to the recipient parent. Two spikelet fertility QTL (*qSF4.1 and qSF4.2*)

corresponding to two SNPs (id4005120 and id4011562) were targeted for introgression first by selecting an InDel and 5 SSRs based on their physical position and later confirmed by CAPS markers digested with *AluI* (Table 8). BRRI dhan28 and BRRI dhan29 were crossed with N22 (IRGC19379) to produce F_1. Thirty-five and 32 F_1s were confirmed both phenotypically (by comparing plant height, growth duration and

Table 8. List of InDel, SSR and CAPS markers used as foreground markers for introgression of spikelet fertility QTLs (*qSF4.1* and *qSF4.2*).

Chr. no.	Primer	Position (bp)	Product size (bp)	Tm (°C)	Motif	Marker type
4	R4M30	18220000	173	55	--	InDel
4	RM185	18579760	197	61	(AGG)9	SSR
4	RM2439	22912308	152	55	(AT)27	SSR
4	RM3820	27623764	122	55	(GA)20	SSR
4	RM3648	33121369	186	55	(GA)14	SSR
4	RM127	34529722	223	55	(AGG)8	SSR
4	4005120STSF	4005120	--	--	--	CAPS
4	4005120STSR	4005120	--	--	--	CAPS

spikelet shape and black spot on grain tip) and genotypically through PCR with a robust SSR marker RM493 (by observing double bands on the heterozygous progenies). A total of 107 and 178 BC_1F_1 seeds were produced from F_1/BRRI dhan28 and F_1/BRRI dhan29 cross combination respectively. All BC_1F_1 seeds produced from both crosses were genotyped through an InDel and SSR marker R4M30 (18.22 Mb) and RM185 (18.57 Mb) and then by two SSR RM3648 (33.12 Mb) and RM127 (34.52 Mb) to confirm the presence of N22 genomic segment around the QTLs (*qSF4.1* and *qSF4.2*) (Fig. 5). Again the selected progenies were genotyped by two SSR, RM2439 (22.91 Mb) and RM3820 (27.62 Mb) in between the genomic regions of the two QTLs to identify recombinant progenies. A total of 19 and 37 BC_1F_1 progenies were selected based on the presence of N22 genomic segments in and

around the two QTLs in different combinations. For final confirmation of the presence of the major QTL (*qSF4.1*), a designed CAPs marker digested with *AluI* was used to genotype the selected 19 and 37 BC_1F_1 progenies from both the crosses (Fig. 6). Selected progenies were further characterized phenotypically specific for the traits ie days to flowering, plant stature, leaf characters and grain shape, size and colour for quick recovery of the recipient background. Finally the best matched 5 and 8 BC_1F_1 progenies from both crosses were selected for second round of backcrossing.

Development of heat tolerant varieties through conventional pedigree selection in controlled high temperature condition

F_2 segregating progenies from five crosses (BRRI dhan29/N22, BRRI dhan28/N22, BRRI dhan29/
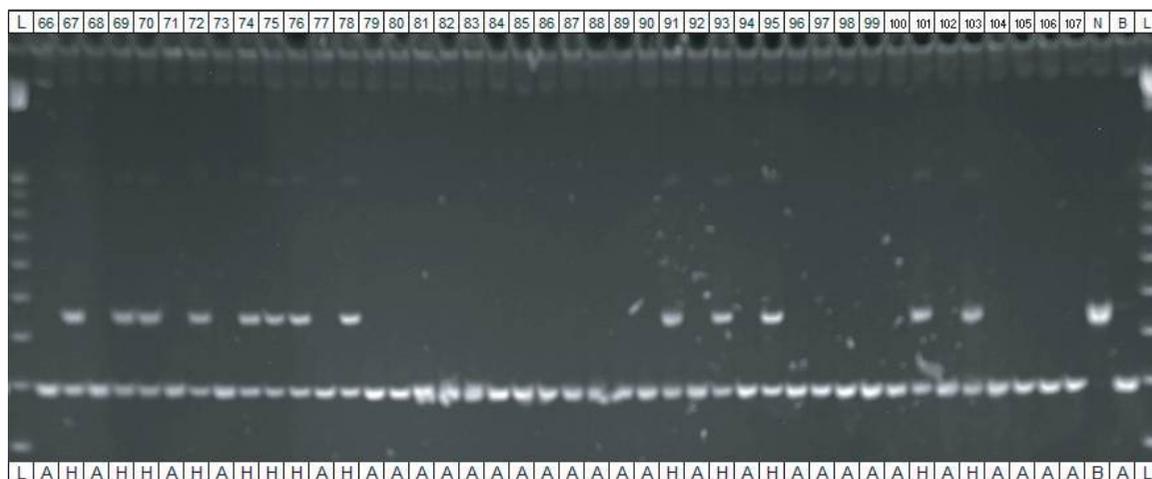
Fig. 5. PCR product of InDel marker R4M30 in 8% PAGE showing patterns of DNA bands of BC_1F_1 progenies (denoted as serial number), parents (N=N22 and B=BR28) and L indicate Ladder (25 bp). Double and single bands indicate heterozygotes (H) and homozygotes of BR28 (A) respectively.
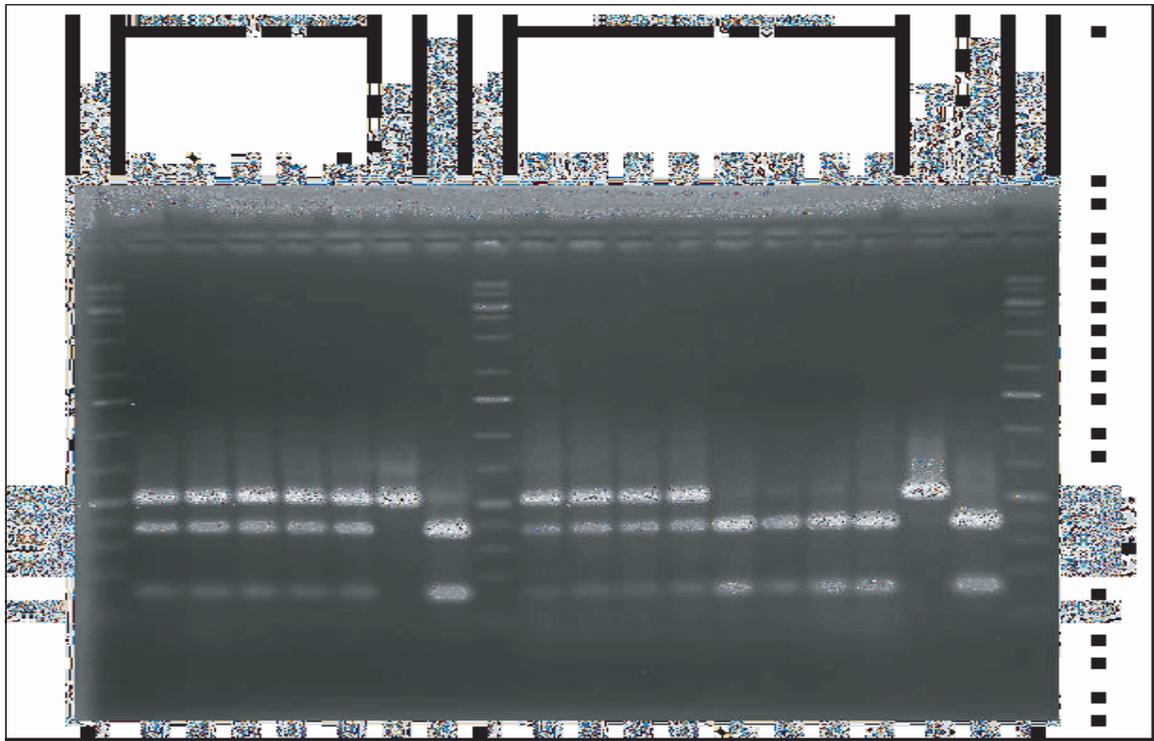
Fig. 6. PCR product of CAPs digested with *AluI* in 2% Agarose gels showing patterns of DNA bands of BC$_1$F$_1$ progenies (denoted as serial number), parents (N22, BR28 and BR29) and Ladder (1 kb+). Triple and double bands indicate heterozygotes (H) and homozygotes of BR28 (A) and BR29 (A) respectively.

Dular, BRRI dhan48/Kachalath and BRRI dhan49/Kachalath) were sown to the pots for their evaluation and selection against high temperature condition (>35-38°C) during flowering in April to May 2014. A total of 100 F$_2$ segregating progenies from each cross were tested for selection in high temperature condition. Only 11 progenies from the tested five cross combination were selected for further advancement in the high temperature condition for next generation (Table 9).

Table 9. Selected segregating progenies from five crosses in the high temperature condition.

Crosses	*Number of tolerant progenies selected in the artificial high temperature condition (35-38°C)
BRRI dhan28/N22	1
BRRI dhan29/N22	7
BRRI dhan29/Dular	1
BRRI dhan49/Kasalath	1
BRRI dhan48/Kasalath	1

COLD TOLERANCE

Screening for cold tolerance at seedling stage under natural condition

Sprouted seeds of 200 rice germplasms collected from BRRI genebank along with three check varieties namely BR18, BRRI dhan28 and BRRI dhan36 were screened for cold tolerance in perforated netted bed attached with Styro-foam sheet floating in a tray containing full strength culture solution in the net house of Plant Physiology Division. The pH level of culture solution was maintained at 5.0 throughout the experimental period. Seedlings were grown up to 40 days and scored following the SES for cold tolerance of rice.

Among 200 tested genotypes 40 genotypes (Acc no. 208, 210, 212, 217, 222, 233, 244, 247, 253, 254, 255, 256, 271, 273, 275, 288, 296, 305, 306, 307, 311, 318, 319, 330, 331, 335, 337, 339, 363, 367, 369, 389, 395, 400, 415, 439, 441, 471,

472, 473) were selected for further studies. Above all, acc no-472 was the most tolerant which showed mean score 3.

Evaluation of two cold tolerant advanced rice genotypes for whole growth periods under natural condition

Studies were carried out in BRRI HQ farm, Gazipur during Boro 2013-14 season to observe the cold tolerance as well as other parameters of advanced rice genotypes namely IR7749-31-2-1-3-1 and IR2266-42-6-2. These two breeding lines were evaluated along with BRRI dhan28 (standard Boro variety) and BRRI dhan36 (cold tolerant only at vegetative stage). There were four seeding dates from October to November (10 October, 20 October, 30 October and 15 November) 2013 so that the crop suffers from cold both at seedling and reproductive stages.

Seedling vigour of all tested genotypes in October seeded rice seedlings was significantly higher than November seeded seedlings. Both the advanced rice genotypes (IR7749-31-2-1-3-1, IR2266-42-6-2) showed significantly higher vegetative vigour than the tolerant check BRRI dhan36 and standerd check BRRI dhan28 when seeds were sown on 15 November (Table 11).

October seeded rice plants suffered from cold at reproductive phase and after increasing temperature in March those plants again produced new tillers resulting more number of tillers in later stage of reproductive phase. However, in 15 November seeded plants, number of tillers were increased and reached to a peak level at maximum tillering stage or before PI and then reduced at reproductive stage. (Fig. 7).

The crop growth rate on 10 October and 20 October seeded plants in all rice genotypes after booting stage was stunted due to cold and panicles did not come out properly (Fig. 8). The panicle growth rate (PGR) was slightly higher in BRRI dhan28 than other tested rice genotypes in 10 October and 20 October seeded plants. However, it was comparable among all tested rice genotypes on 30 October seeded plants. In November seeded plant, PGR was higher in BRRI dhan28 during PI to flowering stage but it was significantlly higher in both the advanced lines

IR7749-31-2-1-3-1, IR2266-42-6-2 at flowering to maturity stage (Fig. 9).

The last leaf sheath length of October seeded crop was significantly shorter than November in all the genotypes. In 10 October seeded crop, it was significantly longer in BRRI dhan28 than all other tested genotypes. (Table 10). The shortest length of the last internode was recorded in all varieties when seeds were sown in 10 October. Last internode length was not differed significantly among tested rice genotypes on 30 October and 15 November seeded plants. However, when seeds were sown in 10 October and 20 October, it was significantly higher in BRRI dhan28 followed by IR7749-31-2-1-3-1, IR2266-42-6-2 and BRRI dhan36 (Table 10). Panicle emergence was affected badly on 10 October and 20 October seeded plants. It was significantly higher in BRRI dhan28 followed by IR7749-31-2-1-3-1, IR2266-42-6-2 and BRRI dhan36. When seeds were sown on 10 October BRRI dhan36 emerged less than 50% of its panicle. Panicle emergence in both the advanced lines was comparable. However, there was no significant difference in panicle emergence among different rice genotypes on 15 November seeded plants (Table 10). Panicle length was reduced significantly in October seeded plants than November. The lowest panicle length was recorded on 10 October seeded plants and reduction was about 20% on 10 October seeded plants than 15 November (Table 10).

Duration from seed sowing to panicle initiation and flowering were decreased in October seeded plants than November and they were the lowest in 10 October seeding in all rice genotypes. However, growth duration was increased in October seeding than November. The highest growth duration was recorded also in 10 October seeding. Among the tested rice genotypes BRRI dhan28 had significantly the lowest growth duration than the other tested rice genotypes. Growth duration of all other varieties was comparable. Duration from PI to crop maturity was significantly higher in October seeded plants than that of November and it was the longest in 10 October seeded plants followed by 20 October, 30 October and 15 november (Table 10).
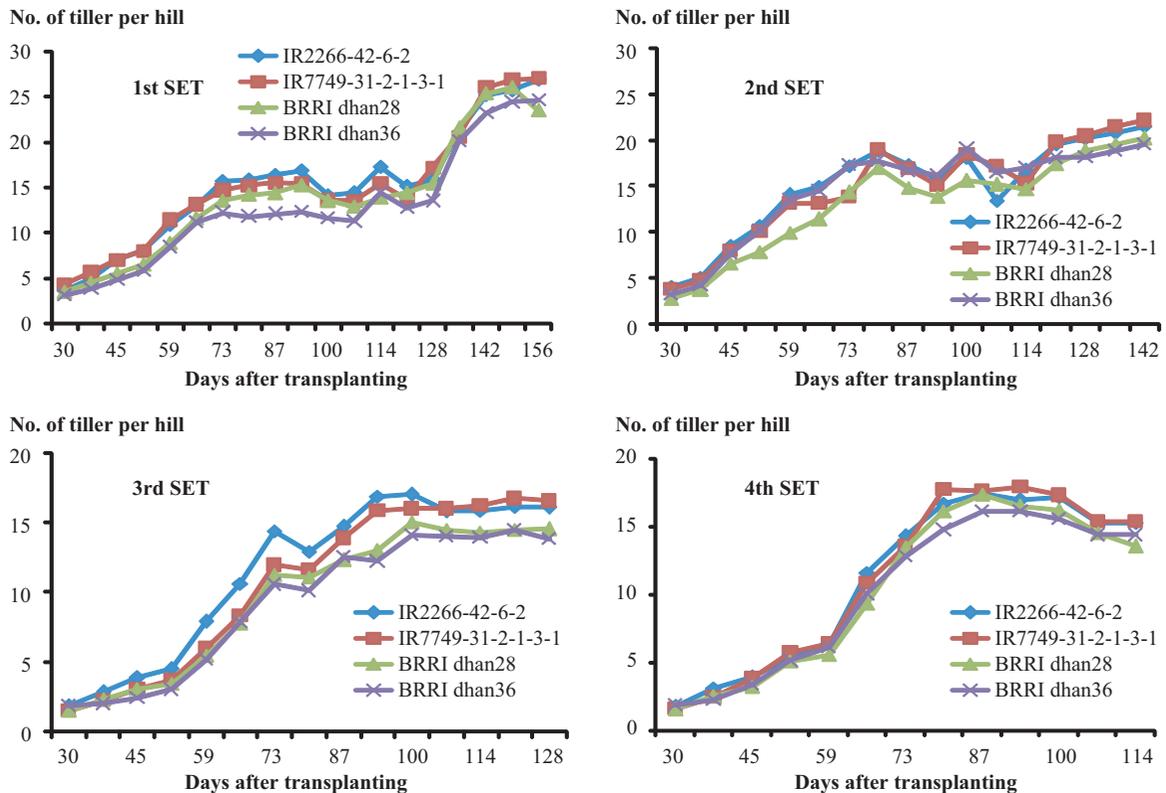
Fig. 7. Tillering pattern of four rice genotypes as affected by different sowing times.

All the genotypes sown in October produced lower yield than sown in November. In 15 November seeding, both the advanced rice genotypes IR7749-31-2-1-3-1 and IR2266-42-6-2 yielded significantly higher yield than the checks. The advanced rice genotype IR7749-31-2-1-3-1 produced higher yield around 26% than BRRI dhan28 and 30% than BRRI dhan36. However, there was no significant yield difference among all the tested rice genotypes on 10 October, 20 October and 30 October seeding. Panicle per hill was significantly higher in October seeded plants than November seeding. Significantly higher filled grains per panicles were recorded in IR7749-31-2-1-3-1 than BRRI dhan36 on 15 November seeded plants. Sterility was significantly lower in IR7749-31-2-1-3-1 than the checks on 20 October seeding. Lower filled grain/ panicle, higher percentage of sterility and reduced grain weight resulted in lower harvest index (HI) in October seeding than that of November. Harvest index was significantly higher

in IR7749-31-2-1-3-1 than BRRI dhan36 in 15 November seeding (Table 10).

International temperate rice observational nursery (IRTON, 2013)
Twenty-eight genotypes (IRTON materials) from IRRI and two local cheeks, BRRI dhan28 and BRRI dhan36 (moderately cold tolerant at seedling stage) were tested in Rangpur, Bangladesh. Vegetative vigour (Vg) and tillering ability were observed at the vegetative stage and other parameters except heading (Hdg) were measured at the maturity stage.

Growth duration of all the tested entries was significantly higher than BRRI dhan28 but closer to BRRI dhan36. Among the tested genotypes nine entries (HANAREUM, IR 05K106, IR10K152, IR 87322-65-2, IR 02K101, IRRI 142, JINMIBYEO, MILYANG 240 and GAYABYEO) were selected as moderately tolerant to cold with other good agronomic characteristics specially yield. Rice
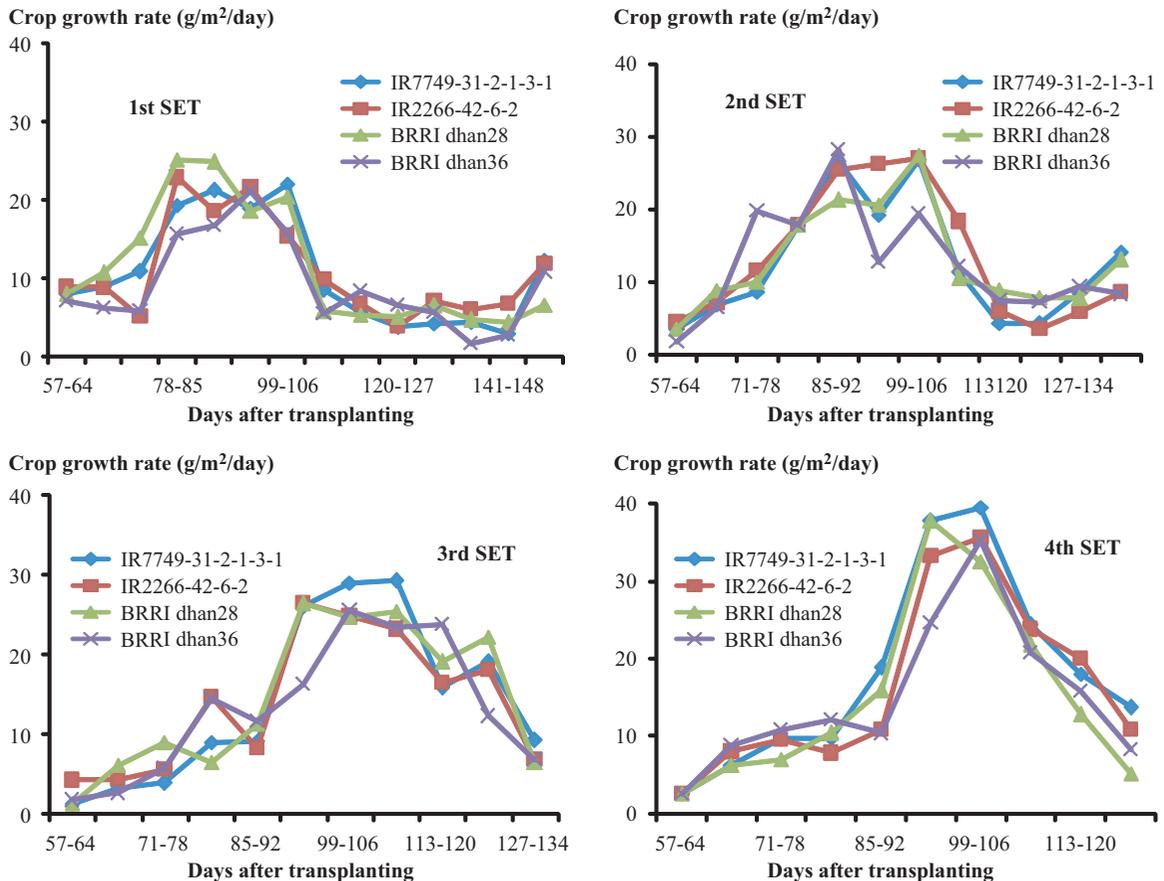
Fig. 8. Changes of crop growth rate of rice genotypes from tillering to maturity stage.

genotypes IR87322-65-2 showed the best performance in relation to cold tolerance and yield.

GROWTH STUDIES

Study on performance of some NERICA rice genotypes in T. Aman season

Eight NERICA lines along with two checks namely BRRI dhan49 and BRRI dhan56 were used. Thirty-day-old seedlings were transplanted at 20- × 20-cm spacing. BRRI recommended fertilizer and cultural practices were done. RCB design with three replication were followed. The data were analyzed by using CropStat 7.2.

All the parameters differed significantly among rice genotypes except leaf area index. The growth duration of all NERICA lines were

significantly lower than BRRI dhan49 but higher than BRRI dhan56. The 1000 grain weights of all NERICA lines were significantly higher than the checks. None of the NERICA genotypes yielded more than the check variety BRRI dhan49 (4.3 t/ha) but two NERICA genotypes NERICA-L-8 (3.68 t/ha) and NERICA-L-36 (3.57 t/ha) exceed yielded than the check variety BRRI dhan56 (3.22 t/ha) (Table 11).

Development of field-based seedling raising technique for low temperature condition in the Boro season

Two experiments were carried out to develop a field-based seedling raising technique for low temperature condition in Boro season. In study 1, seedbeds were amended by rice husk, ash, cow dung, mixture of rice husk and mud and a seedbed prepared only by mud considered as control. Seed
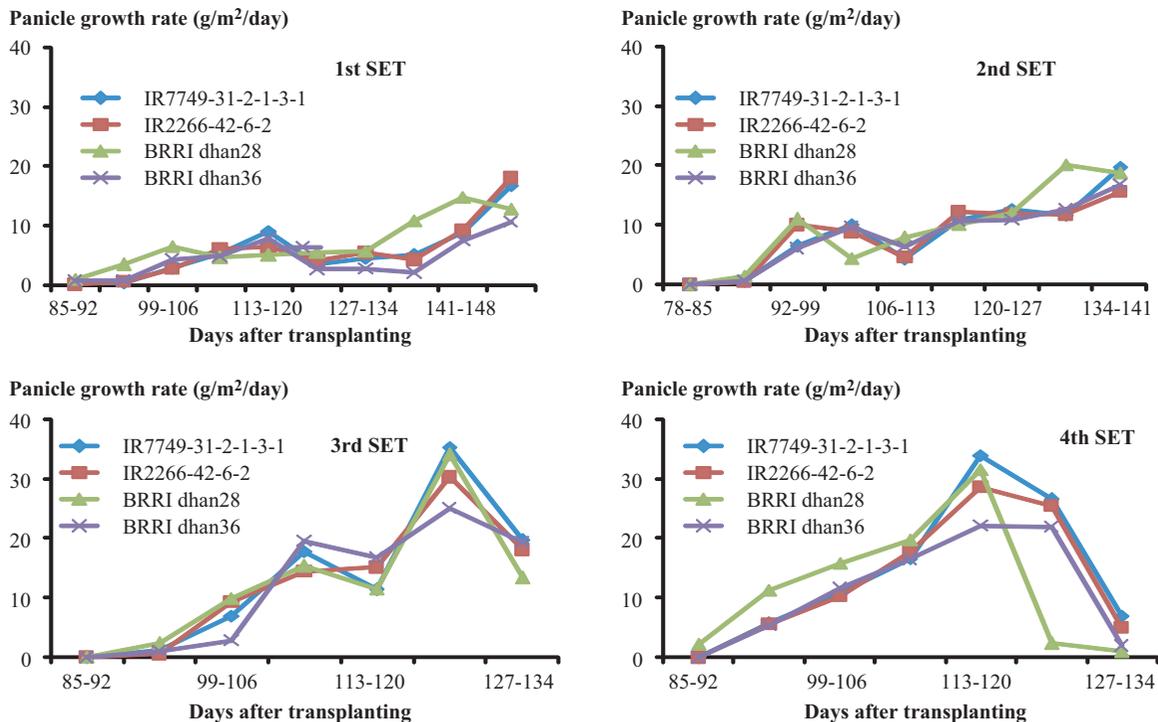
Fig. 9. Changes of panicle growth rate of rice genotypes from PI to maturity stage.

Table 10. Seedling vigour, days to PI, flowering and maturity and some morpho-physiological parameters, yield and yield components of four rice genotypes as affected by sowing time induced natural cold.

Genotype	Seedling vigour	Day to PI	Day to flower	Day to maturity	Last LShL (cm)	LIL (cm)	Panicle length (cm)	Panicle emergence (%)	Yield (t/ha)	Panicle/ hill	Filled grain/ panicle	Sterility (%)	1000-grain wt (g)	HI
					Sowing time, 10 Oct 2013									
IR7749-31-2-1-3-1	3	96.33	119.66	178.00	18.54	11.53	17.54	58.63	3.22	32.33	24.40	63.20	21.83	0.33
IR2266-42-6-2	3	95.66	120.00	179.00	18.97	11.09	17.94	57.34	3.27	29.33	22.96	61.96	21.35	0.32
BRRI dhan28	3	89.00	114.00	171.00	20.76	13.27	18.35	63.72	3.15	29.00	25.31	56.36	20.57	0.41
BRRI dhan36	3	96.66	119.33	177.33	18.91	8.18	17.95	43.6 4	2.25	32.66	19.34	74.74	21.86	0.30
					Sowing time, 20 Oct 2013									
IR7749-31-2-1-3-1	3	99.00	123.00	170.00	20.24	15.48	19.76	75.57	3.34	25.00	38.78	46.37	21.78	0.36
IR2266-42-6-2	3	98.33	120.33	169.66	20.39	15.31	19.31	75.08	3.31	26.00	28.68	52.59	21.60	0.35
BRRI dhan28	3	92.66	115.00	165.66	21.91	18.45	19.5	84.68	3.13	21.00	32.83	59.47	20.14	0.42
BRRI dhan36	3	98.00	123.00	171.33	20.33	13.82	19.2	68.39	3.13	27.00	24.71	62.23	21.79	0.37
					Sowing time, 30 Oct 2013									
IR7749-31-2-1-3-1	3	102.0	125.00	170.00	23.15	22.27	22.48	96 .12	4.44	14.33	73.94	36.88	22.37	0.44
IR2266-42-6-2	3	101.3	125..0	170.66	23.43	22.32	22.3	95.34	4.48	16.66	65.83	32.29	22.51	0.44
BRRI dhan28	3	96.66	116.33	165.00	23.51	22.99	21.13	100.00	4.31	14.66	66.59	35.63	20.22	0.44
BRRI dhan36	3	103.3	126.00	170.66	22.62	21.15	21.23	93.54	4.41	16.00	70.34	38.31	22.44	0.44
					Sowing time, 15 Nov 2013									
IR7749-31-2-1-3-1	3	106.0	130.66	159.66	28.05	27.91	23.11	100.00	6.10	14.66	92.85	24.79	24.16	0.51
IR2266-42-6-2	3	107.0	132.33	159.66	27.82	27.67	23.15	100.00	5.26	13.00	89.30	23.85	24.69	0.50
BRRI dhan28	5	103.3	129.00	154.66	28.44	28.35	22.7	100.00	4.84	12.66	82.34	22.47	21.57	0.50
BRRI dhan36	4	106.0	131.00	159.33	27.52	27.41	22.75	100 .00	4.69	12.66	75.91	26.38	23.17	0.48
LSD at 5%	0.46	1.87	2.34	0.83	1.71	2.32	2.11	5.46	0.41	4.96	13.69	11.13	1.30	0.033

Table 11. Mean performance agronomical traits of 10 rice genotypes.

Genotypes	Day to 50% flower	Plant ht (cm)	Panicle length (cm)	Productive tiller/hill	Leaf area Index	Panicle /m²	Growth duration (day)	Spike fertility %	Filled grain/ pan	1000-grain wt (g)	Grain yield (t/ha)	Harvest index
NERICA-L-1	87.00	85.11	23.00	9.00	3.17	225.00	115	64.79	62.63	24.82	2.3	43.95
NERICA-L-8	87.00	106.78	23.83	9.00	3.64	225.00	119	71.43	74.47	25.63	3.68	40.77
NERICA-L-16	83.00	114.33	23.50	8.33	2.77	208.33	115	35.28	37.20	24.22	1.38	26.63
NERICA-L-33	87.00	104.11	26.43	10.55	2.83	263.83	114	54.95	70.11	23.45	2.6	44.57
NERICA-L-36	93.00	113.66	25.63	9.67	3.39	241.67	120	67.93	70.61	25.13	3.57	43.24
NERICA-L-49	81.00	114.44	24.90	7.66	2.99	191.58	110	42.06	55.62	24.97	2.67	39.93
NERICA-L-32	95.00	106.66	23.87	9.11	2.81	227.67	123	56.15	57.93	24.75	2.53	37.4
NERICA-L-54	78.00	108.44	22.50	9.00	4.13	225.00	113	64.13	63.19	27.05	2.42	38.67
BRRI dhan49	102.00	118.44	25.77	12.56	2.80	300.00	129	72.43	94.56	21.00	4.3	48.04
BRRI dhan56	87.00	116.83	23.85	10.96	3.82	274.08	105	67.56	91.15	19.50	3.22	39.71
Means	88.00	108.88	24.33	9.58	3.24	238.22	116	59.67	67.75	24.05	2.87	40.29
CV %	5.14	4.1	3.7	9	16.9	8.8	6.94	11.8	11.4	4.6	20.6	13.2
LSD$_{(0.05)}$	0.422	7.675	1.545	1.484	0.937	39.748	0.527	12.033	13.552	1.908	1.012	9.190
Probability	**	**	**	**	ns	**	**	**	**	**	**	**

**=significant at P<0.01, ns=non significant.

priming was used in 2nd study where seeds were primed by distilled water and NaCl solution and non-primed seed served as control. At 30-day-old, seedlings were sampled for leaf number, seedling height, root length, shoot and root fresh weight and dry weight, chlorophyll a, b and a/b as well as seedling strength etc. All recorded and calculated data were analyzed for ANOVA and Principal Component through CropStat 7.2 and breeding view of GCP respectively.

Both the studies reveal that both of the techniques have some sort of benefit in raising seedling at low temperature condition. Though there were only few traits varied significantly (Tables 12 and 13) but it is evident that seedbed amended by the mixture of rice husk and mud and NaCl-priming influenced most of the phenotypic traits (Figs. 10 and 11). Therefore, these two treatments could be recommended for further evaluation before recommending it to farmers. Moreover in future, it should be recommended to combine NaCl-priming treatment in seedbed like mixture of rice husk and mud could give more better and significant result for raising healthy seedlings in the low temperature condition.

Comparative physiological study on some BRRI varieties under normal transplanting and double transplanting system

A comparative study was done on growth, physiological parameters, yield and yield components of some Aman and Boro varieties under different transplanting methods. For Aman season, sprouted seeds of BR22, BRRI dhan46 and

Table 12. Phenotypic traits recorded to compare the treatment effects of the first study. Each value is the average of 90 seedlings.

Treatment	Leaf no.	Shoot length (cm)	Root length (cm)	Shoot fresh wt (mg/ seedling)	Shoot dry wt (mg/ seedling)	Root fresh wt (mg/ seedling)	Root dry wt (mg/ seedling)	Chlorophyll a (mg/g fresh wt)	Chlorophyll b (mg/g fresh wt)	Chlorophyll a/b ratio	Seedling strength (mg/cm)
T$_1$ (Control)	5.54	12.18	12.59	168.22	34.78	141.78	17.44	1.05	1.34	0.78	2.85
T$_2$ (Rice husk)	4.99	11.21	9.36	157.89	31.00	173.33	22.11	1.11	1.38	0.80	2.77
T$_3$ (Ash)	5.44	12.59	10.66	188.22	36.56	147.56	19.00	0.99	1.32	0.75	2.88
T$_4$ (Cow dung)	5.20	11.30	6.79	178.89	36.78	101.33	17.83	1.21	1.51	0.80	3.25
T$_5$ (Husk+mud)	5.21	13.46	12.98	223.56	42.78	185.00	22.11	1.14	1.42	0.80	3.15
Significance	ns	ns	**	ns	ns	*	ns	*	ns	ns	ns
LSD$_{0.05}$	1.04	1.89	1.56	63.20	10.00	53.89	8.22	0.12	0.18	0.06	0.19
CV (%)	10.40	8.30	7.90	18.30	14.60	19.10	22.20	5.90	6.70	3.70	8.70

*, ** and ns indicates significance at the 5%, 1% level and not significant.

Table 13. Phenotypic traits recorded to compare the treatment effects of the second study. Each value is the average of 90 seedlings.

Treatment	Leaf no.	Shoot length (cm)	Root length (cm)	Shoot fresh wt (mg/ seedling)	Shoot dry wt (mg/ seedling)	Root fresh wt (mg/ seedling)	Root dry wt (mg/ seedling)	Chlorophyll a (mg/g fresh wt)	Chlorophyll b (mg/g fresh wt)	Chlorophyll a/b ratio	Seedling strength (mg/cm)
T_1 (control)	4.86	14.59	10.11	212.42	49.90	104.08	23.17	0.86	1.14	0.75	3.38
T_2 (Hydro-primed)	5.10	14.88	10.69	200.92	47.92	82.42	14.32	0.87	1.15	0.75	3.20
T_3 (NaCl-primed)	4.90	14.96	10.70	230.92	53.38	84.58	16.67	0.88	1.16	0.75	3.57
Significance	*	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
$LSD_{0.05}$	0.18	1.96	2.46	66.52	15.43	38.99	5.68	0.07	0.07	0.02	0.72
CV (%)	2.10	7.70	13.60	17.90	17.70	24.90	18.20	4.70	3.70	1.20	18.80

*, ** and ns indicates significance at the 5%, 1% level and not significant.

Fig. 10. Principal component biplot for study 1.

Fig. 11. Principal component biplot for study 2.

BRRI dhan49 were sown in the seedbed and transplanting was done with the seedling age of 30, 45 and 60-day-old and double transplanting with the seedlings of (30 + 30) days. However, for Boro season BRRI dhan28, BRRI dhan29 and BRRI dhan45 were used and seedling age were 40, 60 and 80 days for transplanting and (40 + 40) days for double transplanting.

Aman season. Total dry matter did not differ significantly with the transplanting method at 60 DAT, 80 DAT and harvest (Fig. 12). Days to flowering varied significantly in case of both the varieties and planting methods (Fig. 13). No significant yield differences were observed between double transplanting and normal transplanting methods during T. Aman season for three varieties as BR22, BRRI dhan46 and BRRI dhan49 (Fig. 14). But double transplanting could give benefits for subsequent reduction of field duration.

Boro season. Total dry weight of double transplanting was similar with normal transplanting with 60-day-old seedling for BRRI dhan28 and BRRI dhan29 but it was lower in BRRI dhan45 (Fig. 15). The highest total dry weight was observed at normal transplanting with 40-day-old seedlings and the lowest in 80-day-old seedlings for all the variety except BRRI dhan45. Days to flowering varied significantly with rice varieties but not with the planting method (Fig. 16). Grain

Fig. 12. Total dry weight of three T. Aman varieties under different transplanting method at different growth stages.

Fig. 13. Day to flowering of some T. Aman varieties under different transplanting methods. Error bar represents ±SD.

Fig. 14. Yield of some T. Aman varieties under different transplanting methods. Error bar represents ±SD.

Fig. 15. Total dry weight of three Boro varieties under different transplanting methods at maturity stage.

Fig. 16. Day to flowering of some Boro varieties under different transplanting methods. Error bar represents ±SD.

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Fig. 12. Total dry weight of three T. Aman varieties under different transplanting method at different growth stages.

Fig. 13. Day to flowering of some T. Aman varieties under different transplanting methods. Error bar represents ±SD.

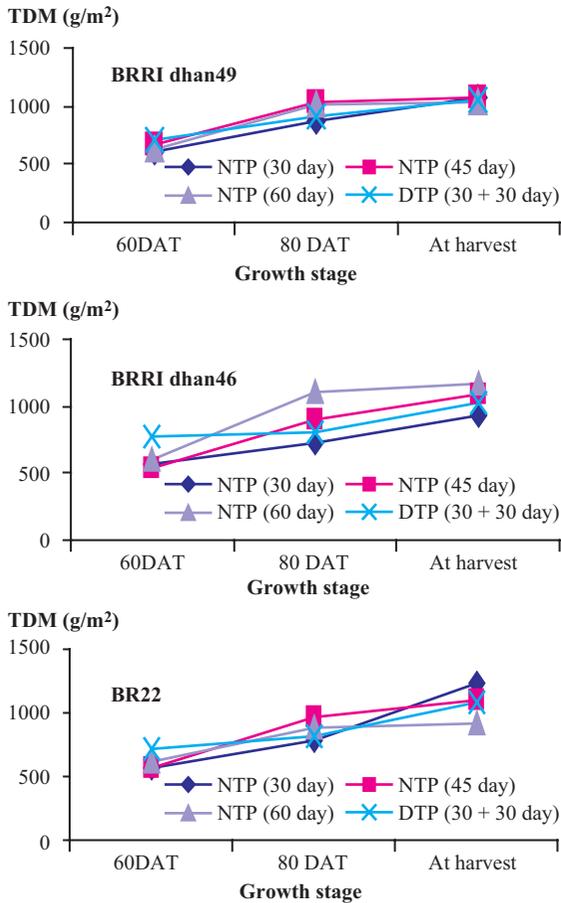**Fig. 14.** Yield of some T. Aman varieties under different transplanting methods. Error bar represents ±SD.

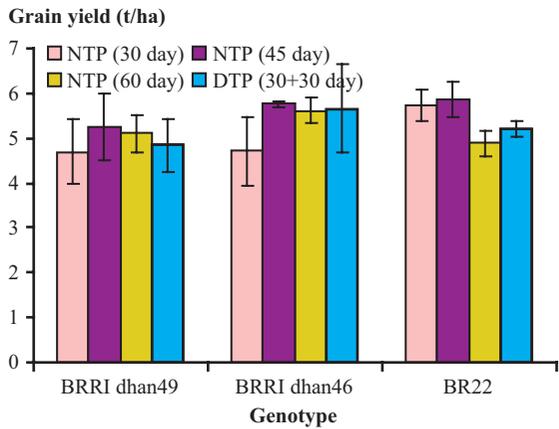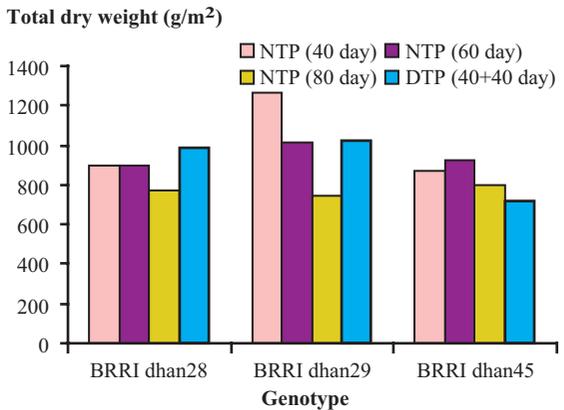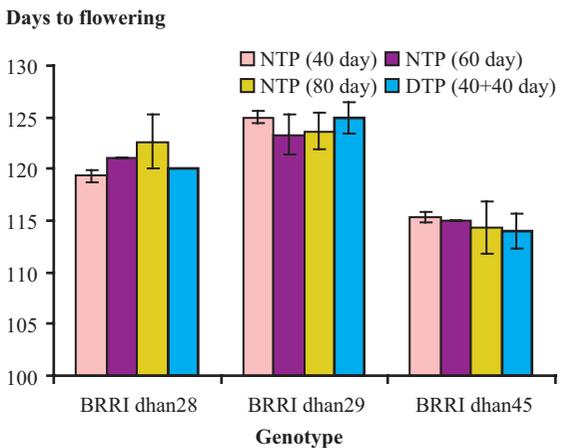**Fig. 15.** Total dry weight of three Boro varieties under different transplanting methods at maturity stage.

Fig. 16. Day to flowering of some Boro varieties under different transplanting methods. Error bar represents ±SD.

yield did not differ significantly among the rice varieties. The yield of normal transplanting with 60 and 80-day-old seedling and double transplanting were statistically similar. But the grain yield differed significantly in normal transplanting with 40-day-old seedling than other transplanting method for all the variety except BRRI dhan45. In BRRI dhan45, yield was comparable between normal transplanting and double transplanting (Fig. 17). However, double transplanting method reduced field duration in Boro season.

Photo-sensitivity test of BRRI released modern T. Aman varieties

The present investigation aims at studying the response of some BRRI released modern T. Aman varieties in recent times to photoperiodic treatments. BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan56, BRRI dhan57, BRRI dhan62 and as Check BR11 and Nizersail. Ten hour photoperiodic treatment was started from seed sowing. One set were grown at natural day length. On the basis of basic vegetative phase and

Grain yield (t/ha)

Fig. 17. Yield of some Boro varieties under different transplanting methods. Error bar represents ±SD.

photoperiod sensitive phase BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan56, BRRI dhan57 are weakly photoperiod sensitive, BRRI dhan54 is strongly photoperiod sensitive and BRRI dhan62 is photoperiod insensitive variety.

Determination of growth stages of some rice varieties as affected by sowing time

A field experiment was conducted to find out the required degree-days for determination of panicle initiation of short and long duration rice varieties. Seedlings of BRRI dhan28, BRRI dhan29, BRRI dhan55 and BRRI dhan58 were transplanted in the field at five-leaf stage. All fertilizers were applied as per BRRI recommendation. Seed sowing schedule was from 15 December to 31 January at an interval of 15 days. The study was laid out in RCB design with three replications.

At seedling stage, the time required for tiller formation was the highest when seeds were sown during mid-December and the lowest when seeded at the end of January. Irrespective of variety there was a decrease in the duration of the transplanting to panicle initiation stage with delay of sowing time. When seeds were sown at the mid-December the growth duration was the highest. As sowing dates advanced, the growth duration (GD) gradually decreased irrespective of varieties. With the advancement of sowing dates the elevated temperature on rice crop affects the crop duration by attaining the phenological stages earlier.

The degree days (°Cd) requirements for panicle initiation were 639±43.6, 851±24.8, 696 ± 37.6, 752±23.3 for BRRI dhan28, BRRI dhan29, BRRI dhan55 and BRRI dhan58 respectively.

The simple calculation of degree days of rice varieties may aid the prediction of the dates of occurrences of the crop developmental phases.
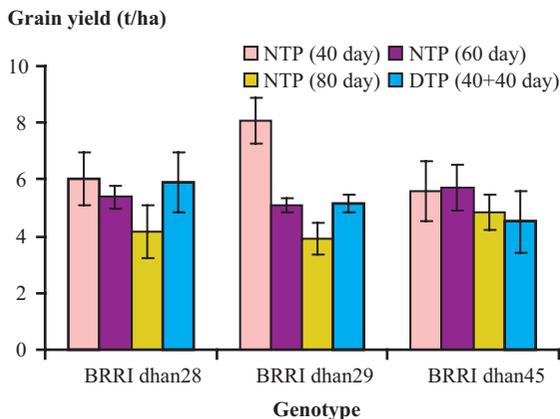
Entomology Division

SUMMARY

The rice fields and seedbeds of BRRI HQ farm, Gazipur harboured green leafhopper (GLH), white leafhopper (WLH) and grass hopper (GH) in high numbers. Spider, damsel fly, ladybird beetle (LBB) and carabid beetle (CDB) were the dominant predators in all the habitats. From weekly rice hill counts, stem borers (SB), GH, GLH, long-horned cricket (LHC), rice leaffolder (RLF) and whorl maggot (WM) damages were observed throughout the year.

The highest incidence of GLH was observed at BRRI HQ, Gazipur in the light trap followed by Barisal. Peak brown planthopper (BPH) and GLH incidence was found in November at Gazipur and yellow stem borer (YSB) in October at Barisal. The highest catches of the natural enemies in the light trap was recorded at Gazipur.

The light trap data of Tarash upazila revealed that planthopper adults occurred in the early of March and peaked in May. Another peak population was observed in November to December.

Aerial sticky trap placed during off-rice season at different heights, indicates that BPH landed in the rice seedbed mostly from the eastern direction and higher number was caught at 2.44 m height traps than the other heights.

Farmers adopting the selected technology and got 5.93% higher economic benefit than their usual management practices in case of brown planthopper management.

Least number of natural enemies and rate of parasitism observed in rice field where prophylactic use of insecticides. Prophylactic application of insecticides at 15-days intervals failed to show any significant yield advantage in Barisal and Rangpur regions. Therefore, indiscriminate use of pesticide should be avoided.

Leaffolder and rice stemborer appeared below the economic threshold level both in vegetative and reproductive stage in all the entries except GR2-R and also did not find any new insect pest.

A total of 159 commercial formulations of insecticides from 36 generic group were evaluated against BPH and 44 from 17 generic group against YSB of which 151 were found effective against BPH (showing more than 80% mortality) and 13 against YSB (reduced dead heart 80% or above over control) and recommended for registration by the Pesticide Technical Advisory Sub-Committee (PTASC). New or mixed formulations were more effective for BPH than YSB.

Out of 307 entries 27 were moderately resistant to resistant against BPH, eight against white-backed planthopper (WBPH) and none were found against GLH. The tested two F_2 materials, showed moderately resistant reaction against BPH. A total of 54 IRBPHN materials were tested and 13 were found to moderately resistant to resistant against BPH. Out of 153 entries/varieties, BR10 and BRRI dhan38 were moderately resistant against gall midge. Among 56 OT materials, four (OT-1, OT-3, OT-4 and OT-29) were recorded as resistant against gall midge. Only the line BR7642-62-1-2-3, out of 19 rice germplasm, was found resistant against gall midge. Besides, among 14 differential materials, OB677 and Vellutha Cheera showed moderately resistant reaction against gall midge.

SURVEY AND MONITORING OF RICE ARTHROPODS

Pest and natural enemy incidence at BRRI HQ farm, Gazipur

Weekly monitoring of rice insect pests, their natural enemies and crop damage intensities due to insect pests were conducted in seed bed, rice ratoon, grass fallow, irrigated rice, and upland rice at BRRI HQ farm, Gazipur. One hundred complete sweeps (CS) were taken from each of the habitats and the collected pest and natural enemies were counted. Damage intensity, due to some major insect pests and their populations, was also estimated from 20 randomly selected hills in each week.

The overall insect pest incidence was low. Higher incidences were found in Aus and T. Aman seasons than the Boro season (Tables 1, 2 and 3). The rice fields of Aus, T. Aman seasons and seedbeds of all the seasons harboured higher populations of GLH, GH and WLH (Tables 1, 2 and 3). The highest populations of GLH and WLH were found in Aus seedbed but GH population

Table 1. Incidence of insect pests and natural enemies in rice and non-rice habitats (collected by sweep net), Aus 2013, BRRI HQ farm, Gazipur.

Arthropod	Seed bed	Ratoon	Grass fallow	Irrigated rice	Upland rice
Insect pests (no./week)					
YSB	2	0.64	0.23	0.6	0.92
GLH	63.4	2.7	2.64	2.5	8.5
WLH	13.4	0.18	2.9	1.8	2.3
SWC	0.2	3.54	3.54	0.84	0.76
GH	14.4	7.8	11.69	14.7	13.5
RB	0.4	2.27	2.27	0.4	2.07
RH	0.2	0.54	0.3	0.1	0.76
Total	94	17.67	23.57	20.94	28.81
Natural enemies (no./week)					
LBB	2	3.9	3.9	0.8	2
SPD	2.6	3.63	4.46	2.7	3.76
CDB	4	1.27	1.69	1.3	6.38
Dam fly	6	1.18	5.46	3	4.9
Total	14.6	9.98	15.51	7.8	17.04

CDB=Carabid beetle, Dam fly=Damsel fly, GLH=Green leafhopper, GH=Grass hopper, LBB=Ladybird beetle, RH=Rice hispa, RB=Rice bug, YSB=Yellow stem borer, SPD=Spider, SWC=Swarming caterpillar, WLH=White leafhopper.

Table 2. Incidence of insect pests and natural enemies in rice and non-rice habitats (collected by sweep net), T. Aman 2013, BRRI HQ farm, Gazipur.

Arthropod	Seed bed	Ratoon	Grass fallow	Irrigated rice
Insect pests (no./week)				
YSB	0.91	0.21	0.24	2.17
WBPH	0.58	0.21	0.47	2.0
GLH	11.17	2.84	5.53	25.25
WLH	5.08	2.21	3.29	9.5
GH	14	8.21	18.41	21.92
RLF	0.5	0.05	0.06	0
Total	32.24	13.73	28	60.84
Natural enemies (no./week)				
LBB	0.5	1.32	0.41	1.73
SPD	3.42	3.10	0.12	7.16
CDB	2.17	0.21	0.14	3.5
Dam fly	2.17	0.84	1.88	4.3
Total	8.26	5.47	2.59	16.69

CDB=Carabid beetle, Dam. Fly=Damsel fly, GLH=Green leafhopper, GH=Grasshopper, LBB=Ladybird beetle, LHC=Long-horned cricket, RLF=Rice leaffolder, YSB=Yellow stem borer, SPD=Spider, WLH=White leafhopper.

occurred in higher number in T. Aman rice. The lowest numbers of insect pests were found in rice ratoon habitat in all seasons (Tables 1, 2 and 3).

Spider (SPD), dam fly, ladybird beetle (LBB) and carabid beetle (CDB) were the dominant predators (Tables 1, 2 and 3) in all the habitats except in a few cases. The highest number of dam fly and LBB was found in the seedbed of Aus and

Table 3. Incidence of insect pests and natural enemies in rice and non-rice habitats (collected by sweep net), Boro 2014, BRRI HQ farm, Gazipur.

Arthropod	Seed bed	Ratoon	Grass fallow	Irrigated rice
Insect pests (no./week)				
YSB	0.25	1.44	1.88	0.31
GLH	14.5	2.89	3.2	4.88
WLH	4.25	2.22	4.84	2.06
GH	3.91	3.44	6.88	2.69
RLF	0	0	0.08	0.56
RH	0	0	0.08	0.88
LHC	0	0	0.04	0.18
Total	22.91	9.99	17	11.56
Natural enemies (no./week)				
LBB	5.17	3.44	3.36	2.4
SPD	1.41	1.89	3.28	0.75
CDB	0.67	0.33	0.12	0.94
Dam. Fly	1.25	0.67	2.72	2.75
TB	0.66	0	0.16	0.06
Total	9.91	6.55	9.64	6.9

CDB=Carabid beetle, Dam fly=Damsel fly, GLH=Green leafhopper, GH=Grasshopper, LBB=Ladybird beetle, LHC=Long-horned cricket, RLF=Rice leaffolder, RH=Rice hispa, YSB=Yellow stem borer, SPD=Spider, TB=Tiger beetle, WLH=White leafhopper.

Boro seasons respectively (Tables 1 and 3).

The insect population and their damage were below the economic threshold level (ETL) in weekly hills count. GLH, GH and RLR were the most abundant pests in hill counts (Table 4). The highest damage was found in T. Aman season (Table 4). Damages caused by SB, GH, RLF and WM were observed throughout the year. Spider (SPD), dam fly and LBB were the dominant natural enemies (Table 4).

Monitoring pest and natural enemy incidence using light trap

Rice insect pests and their natural enemies were monitored by light trap from July 2013 to June 2014 at the BRRI HQ, Gazipur and BRRI RS-Comilla, Habiganj, Barisal and Rajshahi.

The incidence of insect pests was higher at Gazipur followed by Barisal, Rajshahi, Habiganj and Comilla. The highest peak of GLH was in October and an additional peak in May at Gazipur. (Table 5) and that was for BPH in November except Comilla and Habiganj and the 2nd peak was observed at Gazipur in May. The highest peak of YSB was observed at Barisal in October (Fig. 1). The highest CW recorded at Gazipur in September,

Table 4. Insect pest and natural enemy incidence, and damage levels in rice Aus, T. Aman 2013 and Boro 2014, BRRI, Gazipur.

Pest and natural enemy[1]		Aus				T. Aman		Boro	
		Upland rice		T. Aus					
		No./20 hill/week	Damage (%)	No./20 hill/week	Damage (%)	No./20 hill/week	Damage (%)	No./20 hill/week	Damage (%)
Insect pests									
SB	DH	0.38	0.75	0	1.66	0.33	0.64	0.06	0.02
	WH		0.27		0		0		0.38
GLH		1.46	0	0.4	0	3.25	0	2.19	0
GH		4.15	2.44	5	1.58	4.08	2.88	3.06	1.40
RH		0	0	0	0	0.17	0	0.43	0
RLF		0.31	0.42	0.9	0.62	3.08	0.56	2.13	0.46
LHC		0	0.27	0.1	0.02	0.42	0.45	0.19	0.04
WM		0	1.27	0	0.76	0	1.81	0	3.95
RB		0.92	0	0	0	0	0	1.31	0
Total		7.22	5.42	6.4	4.64	11.33	6.34	9.37	6.25
Natural enemies (no./20hills/week)									
LBB		1.23		0.8		0.17		2	
SPD		4.38		4		4.58		4.13	
CDB		2		1.5		0.92		1.44	
Dam. Fly		1.61		1.5		1.75		1.81	
Total		9.22		7.9		7.42		9.39	

[1]Populations and damage based on weekly direct count of 20 hills/plot. CDB=Carabid beetle, DH=Dead heart, Dam fly=Damsel fly, GLH=Green leafhopper, GH=Grass hopper, LHC=Long horned cricket, LBB=Ladybird beetle, RLF=Rice leaffolder, RH=Rice hispa, RB=Rice bug, SB=Stem borer, SPD=Spider, STPD=Staphylinid beetle, WM=Whorl maggot, WH=White head.

Table 5. Major insect pests and natural enemies caught in light trap at BRRI HQ farm, Gazipur and regional stations during July 2013-June 2014.

Insect pest	Gazipur	Comilla	Barisal	Rajshahi	Habiganj	Total
GLH	18727	389	5997	5791	4544	35448
WLH	2319	215	644	1046	0	4224
OHLH	373	0	222	0	0	595
ZLH	4506	0	884	1	0	5391
Emposca	2807	0	554	112	0	3473
BPH	18398	0	3338	444	0	22180
WBPH	5574	12	1278	90	0	6954
Atrovenosa	5913	0	444	5	0	6362
YSB	7664	1796	10223	509	301	20493
DHB	322	415	985	0	382	2104
PB	90	0	0	270	0	360
GM	89	0	0	0	0	89
RLF	358	0	1040	9	0	1407
CW	1569	128	37	466	0	2200
Naranga	176	42	36	3	0	257
GH	7	0	0	0	27	34
SHG	3	378	33	0	88	502
LHG	6	26	57	0	0	89
LHC	1034	279	546	0	311	2170
MC	843	0	354	0	0	1197
FC	884	0	0	6	0	890
SWC	4	0	0	1230	0	1234
RB	125	0	22	0	46	193
Scp. B	0	0	0	212	0	212
Total	71791	3680	26694	10194	5699	118058
Natural enemy						
LBB	167	174	18	17	180	556
CDB	1448	59	486	80	343	2416

Table 5. Continued.

Insect pest	Gazipur	Comilla	Barisal	Rajshahi	Habiganj	Total
STPD	1504	0	0	11	0	1515
GMB	15812	11	4235	0	0	20058
Dam. Fly	35	0	51	6	0	92
SPD	149	258	82	3	27	519
EW	698	0	0	287	0	985
TB	7	0	0	0	0	7
EB	383	0	0	0	0	383
Dam.fly	1	12	0	21	0	34
Total	20204	514	4872	425	550	26565

BPH=Brown Planthopper, CDB=Carabid beetle, CW=Caseworm, Dam fly=Damsel fly, DHB=Dark headed borer, GH=Grass hopper, GLH=Green leafhopper, GM=Gall midge, GMB=Green mirid bug, LBB=Lady bird beetle, LHC=Long horned cricket, OHLH=Orange headed leafhopper, PB=Pink borer, RB=Rice bug, RLF=Rice leaffolder, SPD=Spider, STPD=Staphylinid beetle, TB=Tiger beetle, WBPH=White-backed planthopper, WLH=White leafhopper, YSB=Yellow stem borer, ZLH=Zigzag leafhopper, SHG=Short horn grasshopper, LHG=Long horned grasshopper, MC=Mole Cricket, FC=Field cricket, SWC=Swarming caterpillar, RB=Rice bug, Scp.B= Scotinophara bug, EW=Ear wig, EB=Elaterid beetle.
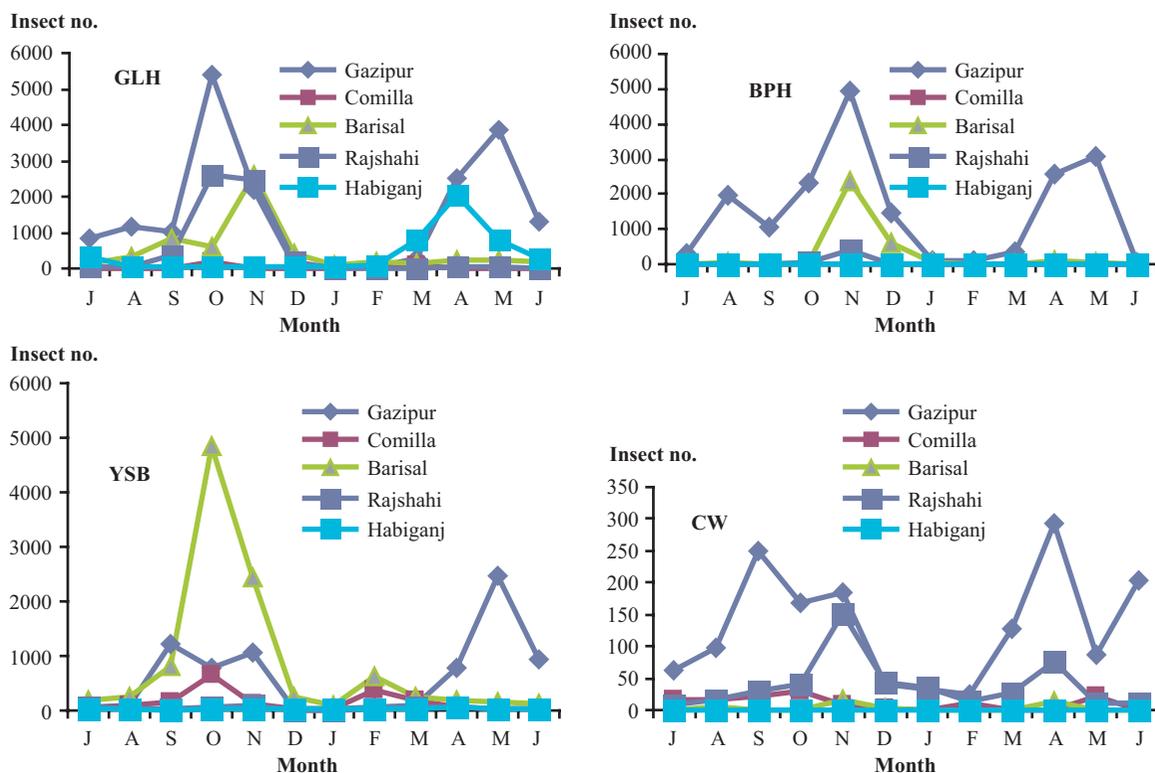
Fig. 1. Incidence pattern of major insect pests in light trap, BRRI HQ and regional stations, July 2013- June 2014.

November, April and June. However, CW was the highest in November and April at Rajshahi (Fig. 1).

The highest catches of natural enemies in light trap were recorded at Gazipur followed by Barisal (Fig. 2). The natural enemy caught in Comilla, Habiganj and Rajshahi were almost similar. However, GMB population was higher in Barisal and two peaks were in April and November at Gazipur and only one peak in November at Barisal. The predators, LBB, CDB and SPD were the dominant population at all the locations. The highest peak of CDB was in May at Gazipur. However, STPD was the dominating predator in March at Gazipur (Fig. 2).
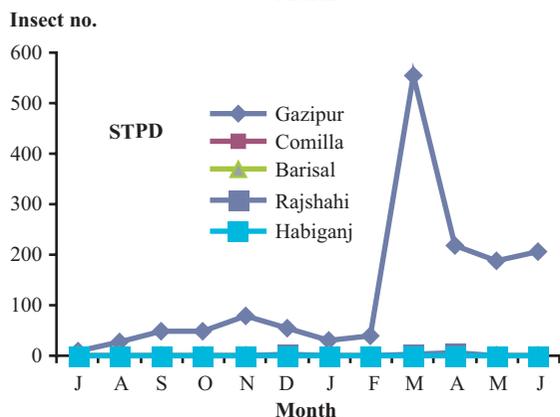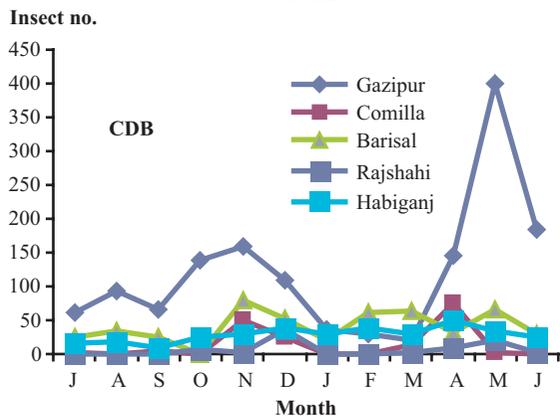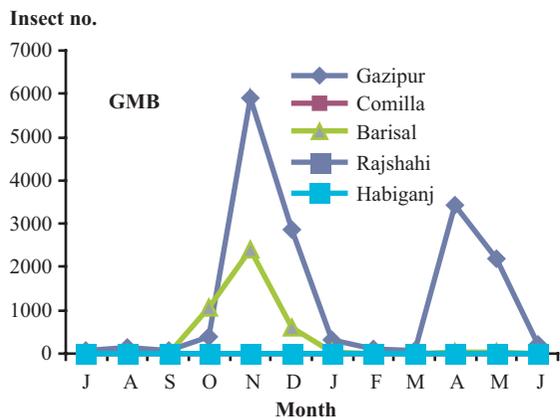
Fig. 2. Incidence pattern of natural enemies of rice insect pest in light trap, BRRI HQ and regional stations, July 2013- June 2014.

Survey and monitoring of BPH and its natural enemies in Sirajganj (AFACI project)

Planthoppers and their natural enemies were monitored weekly in field using by yellow sticky trap (15.24- × 25.4-cm) at Kanchaneswar, Aurangail, Vogholman and at Dobila, Hamkuria and Washin of Tarash upazila during T. Aman 2013 and Boro 2014 seasons respectively. Trapping was done diagonally at 10 randomly selected spots of the each field. The trapped insect pests and natural enemies were sorted identified, counted and recorded in a data sheet.

Peak incidence was found at Kanchaneswar on 9 October and that was from 2 October to 6 November at Vogholman, and 23 October to 6 November at Aurangail. Like planthoppers, natural enemy population was also caught during the observation period. Among the natural enemies, green mirid bug population was higher in Aurangail on 30 October than the other locations, and the population was comparatively lower in kanchaneswar than Vogholman. Spider population was almost similar during the observation period (from September to November 2013) in the above mentioned locations.

In Boro 2014, BPH and WBPH population increases at Dobila, Hamkuria and Washin from the 4th week of March and the peak population was in the early May.

Light trap incidence of BPH and natural enemies in Sirajganj (AFACI project)

Pennsylvanian light traps were operated at three locations namely Washin, Dobila and Kanchaneswar (Tarash, Sirajganj) from June 2013 to May 2014 to monitor the abundance and incidence pattern of planthoppers and their natural enemies. The traps were operated from dusk to dawn and the insect pests and natural enemies caught in the trap were collected, sorted, counted and the numbers were recorded in the data sheet every day.

In T. Aman 2013, planthoppers population started to build-up from the 3rd week of July and peak incidence occurred during August to September and again in mid-October to mid-November in Washin. The natural enemies were trapped from the 2nd week of June and the peak incidence was in mid-August to the end of September in Dobila and that was almost similar in different weeks from September to November 2013 in Kanchaneswar except lady bird beetle which happened to be caught in the last week of September 2013.

Dissemination of BPH management technologies through integrated approach

Dissemination trials of selected BPH management technologies were conducted in farmer's field during T. Aman 2013 season to popularize improved management practices for controlling BPH. Two demonstrations at Kanchaneswar, and one each in Aurangail and Vogolman were conducted. The treatments were- (i) Use of single nozzle sprayer (need based spray) (ii) Use of double nozzle sprayer (need based spray) (iii) Farmer practices (farmers own BPH management practices) and (iv) Control (no measure). The test variety was BRRI dhan49 and the design was RCB factorial with four replications. Direct count of BPH was recorded from 20 randomly selected hills diagonally at 10-day intervals. Grain yield estimated from 10 m^2 area from each plot and data were analyzed using crop stat v 4.0 software.

Field scouting in T. Aman 2013. Field scouting was done from mid-October to November 2013 at Kanchaneswar 1, Kanchaneswar 2, Aurongail and Vogholman. Among the planthoppers, WBPH infested the rice field earlier than BPH and its number was almost similar to that of BPH in Kanchaneswar 1 but slightly higher in the three other sites. Spider population was higher in Kanchaneswar while the GMB population was higher in Aurongail and in Vogholman than the other locations. The high population of GMB had probably suppressed the hoppers population successfully in Aurongail.

Yield of BPH management dissemination plots. On-farm trial at Kanchaneswar1, Kanchaneswar2, Aurongail and Vogholman showed that the percent yield difference among the treatments was very low due to the low incidence (<ETL) of BPH and WBPH. Therefore, the differences in yield among the treatments were very low although the plots sprayed by the double nozzle sprayer gave consistently higher yields than the other treatments in all the four experiments.

Pest and natural enemy incidence in different rice based cropping patterns

Two cropping patterns ie, Aman-Fallow-Boro and Aman-Rabi-Boro were established in BARI HQ farm, Gazipur under Cereal Systems Initiative for South Asia (CSISSA) to determine the incidence and abundance patterns of insect pests and their natural enemies. Insect monitoring was done fortnightly from hill counts and complete sweeps during T. Aman 2013 season.

Insect infestation was below the ETL in both the cropping patterns. Leaf damage by leaf folder, grasshopper and long horned cricket was observed (Fig. 3). Leaf damage was observed as the highest in T_1 for grasshopper while it was also found highest in T_2 for leaf folder. Natural enemies namely LBB and SPD were found highest in T_2 (Fig. 4).
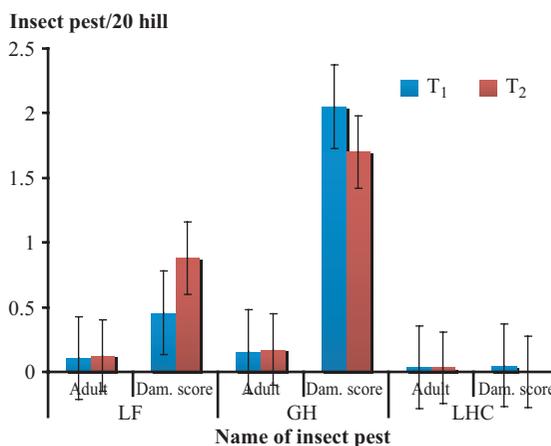
Fig. 3. Insect pests incidence/20 hill in different rice based cropping patterns, T. Aman 2013, BARI farm, Gazipur. Error bar indicates standard errors.
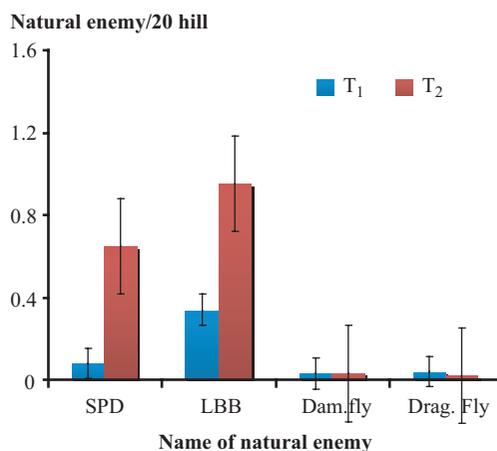
Fig. 4. Natural enemies incidence/20 hill in different rice based cropping patterns, T. Aman 2013, BARI farm, Gazipur. Error bar indicates standard errors.

STUDIES ON THE RICE INSECT PEST AND NATURAL ENEMY BIO-ECOLOGY

Conservation of natural enemies through ecological engineering approaches

The experiment was conducted in a large field having three block and four plots in each block. Marigold was planted on bunds to conserve natural enemies through different ecological engineering approaches. The treatments were T_1=One meter away from the flowering plants of rice bunds, T_2=Four meter away from the flowering plants of rice bund, T_3=Prophylactic insecticide use (carbofuran 5G @ 10.0 kg/ha) and T_4=Control. Parasitism was determined from retrieval method.

The results showed that the highest number of grasshopper (GH), green leafhopper (GLH) and white leafhopper (GLH) were found in T_1 but the incidence was below the ETL (Fig. 5). The highest number of spider, dam fly and LBB were found in T_1 (Fig. 6). In T_3, used insecticide was fourth time but yield was similar to that of T_1 and T_2. Lower yield was observed in T_4 where no insectiside applied and no flowering plants grown in rice bunds. Moreover, continuously insectiside treated plot had the lowest parasitism of *Trichogramma zahiri* (Fig. 7) where as it was the highest in the rice field of nectar-rich flowering plants. No yield reduction was observed in rice field surrounded by flowering plants.
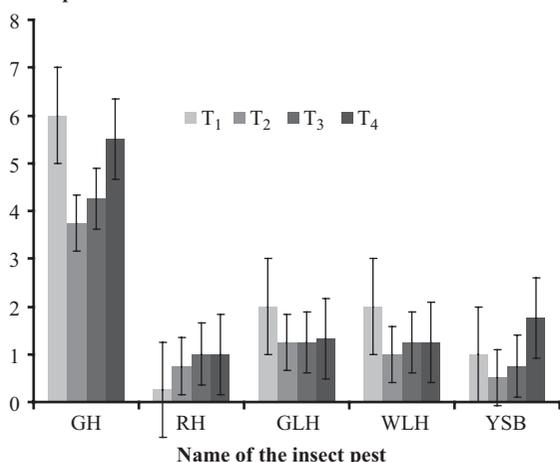
Fig. 5. Insect pest number per 20 complete sweep in different treatments. Error bar indicates standard errors.
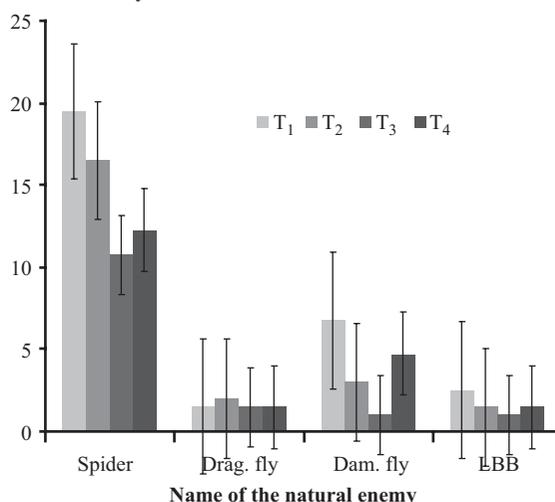
Fig. 6. Natural enemies number per 20 complete sweep in different treatments Error bar indicates standard errors.
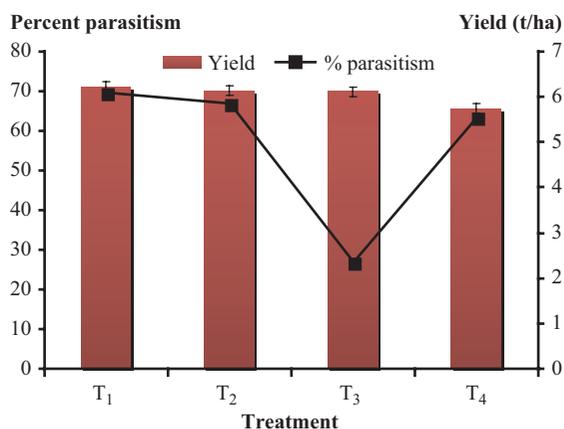
Fig. 7. Percent parasitism by *Trichogramma zahiri* and yield in different treatments

INTEGRATED PEST MANAGEMENT

Validation of BRRI recommended practices for the management of major insect pests of rice (IAP Project)

Demonstration experiment on BRRI recommended practices for successful management of rice insect pests was conducted in farmer's fields having at least 44 decimal lands. Location and fields for the component treatments was selected based on land type, variety cultivated and transplanting time. The treatments were- T_1=Prophylactic use of

insecticide, T_2=Perching+ Sweeping+ Need based insecticide application, T_3=Perching and T_4=Respective farmers' supervision without any intervention. The experiment was assigned in four farmers' fields at Taraganj and four at Pirganj upazila. The insect infestation was monitored fortnightly by 20 hill count and 20 complete sweeps. The experiment was conducted both in T. Aman 2013 and Boro 2013-14 in Rangpur region and only in Boro 2013-14 season at Barisal region with same procedure. BRRI dhan52 and BRRI dhan58 was cultivated during Aman and Boro season respectively at Rangpur region and BRRI dhan29 in Barisal region. The insect infestation, yield and yield contributing characteristics of the different treated plots of each field was compared by one way analysis of variance by Turkeys' Post hoc Test.

Insect pest and natural enemy status, T. Aman. During the experimental period insect infestation in both Taraganj and Pirganj was below the economic threshold level (ETL). Yellow stemborer (YSB), rice leaf roller (RLR), long horned cricket (LHC), grasshopper (GH), green leafhopper (GLH), brown planthopper (BPH) and white backed planthopper (WBPH) were found at Taraganj in fortnightly sweeping and hill counting. Gall midge and rice bug (RB) were not found in Taraganj during sweeping. On the other hand deadheart/whitehead symptom was not observed in Pirganj during hill counting. No significant differences were observed for insect infestation among the treatments in both the locations.

Among the natural enemies SPD, LBB, drag fly, dam fly and CDB were noticed both in Taraganj and Pirganj. In 20 hill count study CDB was not found in both the locations of Pirganj and Taraganj where continuously insecticide was used.

Plant characteristics, yield component and yield. No significant difference was observed among the treatment for tiller, leaf and panicle/hill and also plant height at the experimental field of Taraganj and Pirganj. Significantly lower yield was observed at treatment T_4 (farmers practices) in both the location at Taraganj and Pirganj (Table 6). It was found that continuous use of insecticide

had no effect on yield and yield contributing characters of rice when insect infestation below the ETL. So farmers can avoid indiscriminate use of insecticide which ultimately save production cost and save the environment from insecticidal pollution.

Insect pest and natural enemy incidence at Rangpur region, Boro season. During the experimental period insect infestation in both Pirganj and Taraganj was below the economic threshold level (ETL). Grasshopper (GH), long horned cricket (LHC), yellow stemborer (YSB), white stemborer (WSB), green leafhopper (GLH), rice leaf roller (RLR) and rice bug (RB) were found in Pirganj in fortnightly sweeping and hill counting. In addition brown planthopper (BPH), gall midge (GM) and onion shoots (OS) were observed in Pirganj. No significant differences were observed for insect infestation among the treatments for both the locations.

Among the natural enemies spider (SPD), ladybird beetle (LBB) adult (A), LBB grub (G), carabid beetle (CDB), staphylinid beetle (STB), damsel fly (dam fly) and dragon fly (drag fly), were found in both the locations.

Plant characteristics, yield component and yield. There was no significant differences were observed among the treatments T_2, T_3 and T_4 for tiller, leaf and plant height at the experimental field of Taraganj. Though significantly highest tiller, leaf and plant height were observed in T_1 compared to T_2 and T_3 but no difference was observed in case of panicle/hill. Significantly, lower panicle and yield was observed at treatment T_4 in both the location (Tables 7 and 8). In Pirganj, there was no significant differences were observed among the treatments T_1, T_2 and T_3 for different plant and yield components except leaf/hill.

Insect pest and natural enemy incidence at Barisal region. During the experimental period insect infestation was below the economic threshold level (ETL) in all the locations. Yellow stemborer (YSB) and deadheart, onion shoot (OS), rice leaf roller (RLR) rice hispa adult RH (A) and RH grub (G) with their damages, long horned cricket (LHC), grasshopper (GH), green leafhopper (GLH), brown planthopper (BPH) and rice bug

Table 6. Plant characteristics, yield component and yield of different treatments in Taraganj and Pirganj, T. Aman 2013.

Treatment	Tiller/hill (no.) (Mean ±SE)	Leaf/hill (no.) (Mean ±SE)	Plant ht (cm) (Mean ±SE)	Panicle/hill (cm) (Mean ±SE)	Yield (t/ha) (Mean ±SE)
			Taraganj		
T_1	14.03±0.30	63.44±1.64	110.20 ± 0.89	10.49 ± 0.18	5.32 ± 0.70a
T_2	14.39±0.28	66.05±1.50	110.61 ± 0.80	10.74 ± 0.24	5.42 ± 0.73a
T_3	14.60±0.34	69.70±1.95	110.54 ± 0.79	10.79 ± 0.19	5.26 ± 0.67a
T_4	14.55±0.32	69.20±1.43	108.99 ±0.87	9.79 ±0.18	4.80 ± 0.63b
	ns	ns	ns	ns	*F-value:17.12* *P<0.05*
			Pirganj		
T_1	16.52±0.84	71.78±3.03	116.70 ± 0.11	10.05 ± 0.13	5.53 ± 0.15a
T_2	16.35±0.80	73.15±3.14	117.10 ± 0.13	10.30 ± 0.12	5.44 ± 0.06a
T_3	16.27±0.74	71.52±2.56	116.70± 0.09	10.10 ± 0.09	5.34 ± 0.07a
T_4	15.93±0.67	69.63±2.40	115.95 ± 0.10	9.85 ± 0.09	4.84 ± 0.11b
	ns	ns	ns	ns	*F-value:16.32* *P<0.05*

T_1=Prophylactic use of insecticide, T_2=Perching+ sweeping + need base insecticide application, T_3=Perching, T_4=Farmers' practice. Data were analyzed using one-way ANOVA; ns=not significantly different at the 5% level of Tukey's post hoc Test.

Table 7. Plant characteristics, yield component and yield of different treatments at Taraganj, Boro 2013-14.

Treatment	Tiller/hill (no.) (Mean ± SE)	Leaf/hill (no.) (Mean ± SE)	Plant ht (cm) (Mean ± SE)	Panicle/hill (no.) (Mean ± SE)	Yield (t/ha) (Mean ± SE)
T_1	17.41 ± 0.36a	69.83 ±1.53 a	97.67 ±0.60a	12.43 ± 0.29a	7.01 ± 0.22a
T_2	16.01 ± 0.29b	63.85 ±1.31b	94.91 ± 0.48ab	12.73 ±0.24a	7.04 ± 0.29a
T_3	15.56 ± 0.27b	62.17 ± 1.21b	93.36 ± 1.14b	12.62 ±0.27a	6.96 ± 0.24a
T_4	15.32 ± 0.29b	61.38 ± 1.29b	93.60 ± 0.51b	11.45 ±0.25b	6.45 ±0.31b
F-value	9.48	8.14	7.31	10.51	77.08

Value means within a column followed by the same letter are not significantly different (P <0.05; Tukey's post hoc Test). T_1=Prophylactic use of insecticide, T_2=Perching + sweeping + need base insecticide application, T_3=Perching, T_4=Farmers' practice.

Table 8. Plant characteristics, yield component and yield of different treatments at Pirganj, Boro 2013-14.

Treatment	Tiller/ hill (no.) (Mean ± SE)	Leaf/ hill (no.) (Mean ± SE)	Plant ht (cm) (Mean ± SE)	Panicle/ hill (no.) (Mean ± SE)	Yield (t/ha) (Mean ± SE)
T_1	15.40 ±0.27a	79.19 ±1.56a	100.75 ±0.24a	13.89 ±0.22a	8.45 ± 0.21a
T_2	14.61 ± 0.27a	72.30 ±1.58b	100.54 ±0.25a	13.61±0.27a	8.49 ±0.23a
T_3	14.02 ± 0.28a	71.56 ± 1.60b	100.21 ±0.27a	13.15 ±0.23a	8.30 ±0.24a
T_4	13.57 ± 0.28b	71.36 ± 1.64b	99.59 ±0.23b	12.09 ±0.27b	7.40 ±0.30b
F-value	12.55	13.97	2.00	77.08	4.3

Value means within the column followed different letter are significantly different at the 5% level of Tukey's post hoc Test. T_1=Prophylactic use of insecticide, T_2=Perching+ sweeping+ need base insecticide application, T_3=Perching, T_4=Farmers practice.

(RB) were found during Boro season at Barisal region. Leaf damage by the rice hispa adult and grub found highest in Barisal region followed by LHC and GH.

Among the natural enemies spider (SPD), ladybird beetle (LBB), staphylinid beetle (STB) and carabid beetle (CDB) were found in all the treatments. Spider and STB were found lowest in T_1 where fortnightly used insecticide. Though definite trend was not found but it is clear that number of different natural enemies found lower in insecticide treated plots compared to other treatments.

Plant characteristics, yield component and yield at Barisal region. There was no significant differences were observed among the treatments T_2, T_3 and T_4 for tiller, leaf and panicle per hill and also plant height at the experimental field in Barisal. Significantly lower panicle and yield was observed at treatment T_4 (Table 9). All the farmers

Table 9. Plant characteristics, yield component and yield in different treatments during Boro 2013-14 at Barisal region.

Treatment	Tiller/ hill (no.) (Mean ± SE)	Leaf/ hill (no.) (Mean ± SE)	Plant ht (cm) (Mean ± SE)	Panicle/ hill (no.) (Mean ± SE)	Yield (t/ha) (Mean ± SE)
T_1	14.86 ± 0.16	41.41 ± 0.58	94.97 ± 0.60a	12.95 ± 0.29a	7.01 ± 0.22a
T_2	14.68 ± 0.20	40.98 ± 0.53	94.91 ± 0.48a	13.02 ± 0.24a	7.04 ± 0.29a
T_3	14.56 ± 0.19	40.39 ± 0.52	94.86 ± 1.14a	12.98 ± 0.27a	6.96 ± 0.24a
T_4	14.69 ± 0.22	40.25 ± 0.54	93.60 ± 0.51b	11.75 ± 0.25b	6.45 ± 0.31b
F-value	1.892 (ns)	4.791(ns)	21.00	18.38	77.08

ns=Not significant, Value means within a column followed by the same letter are not significantly different ($P< 0.05$; Tukey's post hoc Test). T_1=Prophylactic use of insecticide, T_2=Perchin+ sweeping+ need base insecticide application, T_3=Perching, T_4=Farmers' practice.

in all the locations avoid line sowing, perching, sweeping and used imbalanced doses fertilizer and insecticides. As a result yield reduction happened in the farmers treated plots. Moreover, no significant difference in yield was observed in other three treatments (T_1, T_2 and T_3) (Table 9).

CROP LOSS ASSESSMENT

Reaction of pro-vitamin A enriched 'Golden Rice' event GR2-R introgressed lines of BRRI dhan29
A total of 24 test entries including BRRI dhan29 were evaluated under natural infestation at the confined field trial (CFT) site of BARI, Gazipur during Boro 2013-14 season to observe the insect abundance and their damage severity under natural infestation. The insect pests were monitored in weekly and were reported fortnightly. Based on the fortnightly report, prophylactic application of insecticide (both granular and liquid) was applied at 15 days interval in the main field. Insecticides were applied during afternoon as per recommended dose (s).

Based on the weekly monitoring report, rice pest was managed using prophylactic measures at the different crop growth stages. Environmental safety guidelines were followed during data collection. The event GR2-R was severely infested (>50%) by LF followed by BR29–GR#9-GID21, BR29-GR#5-GID7, BR29-GR#4-GID6 and BR29-GR#M28-GID22. The SB infestation was observed from vegetative stage to the subsequent stages. No unknown pest was recorded. Actives barrier system (ABS) and chicken net were used to protect crops from rice

field rat and bird infestation respectively during reproductive stage.

EVALUATION OF CHEMICALS AND BOTANICALS

Evaluation of commercial insecticides against major insect pest of rice
Brown planthopper. The experiments were conducted as per procedure in a unit plot of 20 m² to evaluate the efficacy of different commercial formulations of insecticides against major insect pests of rice. One hour after spraying of test insecticides, ten 3rd-4th instar BPH nymphs were confined by mylar film cages on four randomly selected rice hills. While the granular insecticides were broadcast one day before infestation. Mortality of insects was calculated both from treated and untreated plots at 24 and 48 hours after treatment (HAT) and the results were adjusted by Abbott's formula.

Yellow stemborer. The unit plot size was 20 m². Four randomly selected rice hills per plot were separately infested with the 1st instar larvae emerging from one egg mass. Test insecticides were applied after one to two hours of infestation. The same plants were infested again with new larvae at 48 hours of spraying or hand broadcasting insecticides. Records on dead heart incidence were taken at 14 and 21 days after insecticide application.

A total of 159 commercial formulations of insecticides from 36 generic group were evaluated against brown planthopper (BPH) and 44 from 17 generic group against YSB of which 151 were found effective against BPH and 13 against YSB in different seasons during the year.

HOST PLANT RESISTANCE

Screening of breeding lines against major insect pests of rice

A total of 436 entries were screened to identify resistant sources against BPH, WBPH and GLH during 2013-14. In addition, two F_2 materials were also screened against BPH. Screening was done by seedling bulk test method. Scores were made according to SES.

Out of 307 entries, one was resistance (score 0-1) and 26 materials were moderately resistance (score 3-5) against BPH. Out of 79 entries, five materials were found moderately resistant (score 3-5) against WBPH. Out of the 52 materials none were promising against GLH. The two F_2 populations were found moderately resistant against BPH (score 3-5). Table 10 shows the results. The selected F_2 plants were handed over to Plant Breeding Division.

Screenings of IRBPHN 2013 materials against BPH

Fifty-four IRBPHN materials were screened against BPH to identify resistance source by seedling bulk test method and the scores were made according to SES. Thirteen out of 54 materials (IRBPHN 2013) were found promising against BPH. Table 11 presents the results.

Screening of rice germplasm against gall midge (GM)

Nine test entries including one susceptible (BRRI dhan49) and one resistant (BRRI dhan33) check were assigned separately in each line in a row to identify resistance sources of rice against rice gall midge. Thereby, 27 lines in a cork sheet (58- × 45-cm) were used. The design was RCB with three replications. The seedlings were allowed to grow for 13-15 days in Yoshida (1976) solution. About one hundred mated females were released in confined net with the raised seedlings and allowed them to lay eggs on the test entries. Data on infested (Onion shoots or silver shoots) and un-infested tillers on the test entries were recorded and analyzed statistically. Further reactions were made according to SES.

A total of 153 rice germplasm/varieties were screened against GM during July 2013 to June 2014. Out of 38 BRRI released Aus, T. Aman and Boro varieties , BR10 and BRRI dhan38 were found moderately resistant (MR) to GM (Table 12). Only two lines, BR7641-24-3-2-2 and BR7642-62-1-2-3 out of 20 RYT and ALART materials were found highly resistant to moderately resistant (Table 13). Among 56 OT materials, six (OT-1, OT-3, OT-4, OT-12, OT-16 and OT-29) was recorded as resistant to highly resistant (0-1% OS) against GM. Among 14 differential materials,

Table 10. Reaction of different materials tested against BPH, WBPH and GLH, Entomology Division net house, BRRI, Gazipur 2013-14.

Seed source	Entry (no.)	Target pest	Promising material	Score
Breeding line	307	BPH	BR 8182-1-1-1-1	1
			IR83140-B-28-B, IR83142-B-19-B, IR83142-B-60-B, 8696 IR68544-25-21-3-1-2/T20A (PG), 8696 (43), 8696 (46) (PG), IR78761-B-SATB1-28-3-26, BR7799-51-3-1-3, BR7987-57-1-4-3-4, BR7800-32-6-2HR1, BR7987-16-1-3-1, BR8475-35-2-1, BR8475-38-2-1	3
			8696 (42), 8696 (45), 8696 (47), BR7947-16-1-1-3-1, BR7948-2-5-1-2-1 (PG), BR 8475-35-2-1 (PG), BR 8182-22-1-3, 8339, 8337-20-2-1, BR7789-19-1-1-1, BR7987-57-1-4-2-2, BR7697-15-4-4-2-1, IR83440-4-B-11-2-1-1-AJY1-B	5
	79	WBPH	IR83140-B-11-B	3
			BR6976-2B-11-1, BR7697-15-4-4-2-2, IR73055-8-1-1-3-1, IR83440-4-B-11-2-1-1-AJY1-B	5
	50	GLH	None	-
F_2 population	2	BPH	BR10419 (BRRI dhan50/T27A), BR10421(BR3/T27A)	3-5

Susceptible check: BR3 (for all), Resistant ck: T27A, IR64 and Ptb18 for BPH, WBPH and GLH respectively. Scores were made according to SES. BPH=brown planthopper, WBPH= White-backed planthopper, GLH=green leafhopper, R=Resistant (score 0-1), MR=Moderately resistant (3-5), Susceptible 7; PG=Poor germination.

Table 11. Promising lines of IRBPHN 2013 materials and their score, Entomology Division net house, BRRI, Gazipur 2013-14.

Seed source	Entry (no.)	Target pest	Promising material	Score
IRBPHN	54	BPH	IR10A110	1
			IR05N412 , IR09N534, IR09N538 , IR10A108, IR10A114, SINNA SIVAPPU	3
			BG367-2 , T12, IR08N210 , IR09A104, IR09N496 , RP1486-842-1	5

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

Table 12. Screening of BRRI released varieties against rice gall midge.

Variety	Tiller (Av.)	OS (%)*	Remark
BR3	17.00	38.54	S
BR4	13.00	31.16	S
BR5	19.00	26.57	S
BR7	25.67	62.96	HS
BR9	22.33	52.19	HS
BR10	18.33	15.31	MS
BR11	14.00	24.70	S
BR16	30.33	72.79	HS
BR19	8.33	68.72	HS
BR22	13.00	44.03	S
BR23	17.33	52.03	HS
BR25	20.67	45.30	S
BRRI dhan28	15.00	50.66	HS
BRRI dhan29	10.33	39.54	S
BRRI dhan30	13.67	27.06	S
BRRI dhan31	10.33	31.47	S
BRRI dhan32	11.00	28.13	S
BRRI dhan33	26.33	0.01	HR
BRRI dhan34	27.67	29.32	S
BRRI dhan35	30.33	62.23	HS
BRRI dhan36	44.33	68.24	HS
BRRI dhan37	20.00	46.54	S
BRRI dhan38	24.00	9.44	MR
BRRI dhan39	11.00	39.30	S
BRRI dhan40	17.33	27.67	S
BRRI dhan41	15.67	37.02	S
BRRI dhan43	26.33	43.31	S
BRRI dhan44	12-17	44.50	S
BRRI dhan46	12.33	34.80	S
BRRI dhan49	24.00	61.22	HS
BRRI dhan50	27.67	60.53	HS
BRRI dhan51	15.33	50.05	HS
BRRI dhan52	16.00	29.52	S
BRRI dhan53	13.00	41.45	S
BRRI dhan54	21.33	35.25	S
BRRI dhan55	12.33	34.18	S
BRRI dhan56	14.00	29.17	S
BRRI dhan57	19.67	53.08	HS

*Onion shoot (OS) percentage data were transformed by Arc Sin, HR=Highly resistant, R=Resistant, MR=Moderately resistant, S=Susceptible, HS=Highly susceptible (According to SES, IRRI, 1996).

Table 13. Screening of RYT, ALART and Observation trial (OT) materials against rice gall midge for T. Aman 2013-14.

Designation/Cross	Tiller (Av.)	OS (%)*	Remark
RYT #2			
BR7641-24-3-2-2	45.67	0.01	HR
BR7642-62-1-2-3	37.67	6.06	MR
F_5 Generation Bulk-11 8692			
BR10/RD4 (OT-1)	26.33	0.01	HR
BR10/RD4 (OT-3)	33.33	4.33	R
BR10/RD4 (OT-4)	28.33	0.01	HR
Bulk-21 (Cross -8693)			
(Cross-8693) BR10/ BG400-1 (OT-12)	37.33	0.01	R
BR10/BG400-1 (OT-16)	27.33	0.01	R
BR10/BG400-1 (OT-29)	30.67	0.01	R
OB677 (differential material)	28.00	8.55	MR
Vellutha Cheera (differential material)	29.67	11.44	MR
BRRI dhan 33 (ck)	53.33	0.01	HR
BRRI dhan 49 (ck)	34.33	74.50	HS

*Onion shoot (OS) percentage data were transformed by Arc Sin, HR=Highly resistant, R=resistant, MR=moderately resistant, S=susceptible, HS=highly susceptible (According to SES, (IRRI, 1996).

OB677 and Vellutha Cheera showed moderate resistant reaction against GM population of BRRI, Gazipur.

VERTIBRATE PEST MANAGEMENT

Rice field rat management using trap barrier system (TBS)

The experiment was conducted in T. Aman 2013 season to evaluate the trap efficiency with barrier system. Rice varieties were transplanted one month earlier from the synchronous planting of that variety. Rice field with barrier system was established. The plot size was 4m × 5m for each treatment. The treatments were- 1) Rice field with

barrier system + Multiple capture live trap, 2) Rice field without barrier system + Multiple capture live trap and 3) Rice field with no trap barrier system.

The experiment was designed in RCB factorial with three replications. Data on cut and uncut tillers per hill were counted from 20 randomly selected hills diagonally in a plot. The number of rat trapped was recorded and analyzed.

Rice field rat infestation and their capture was very low (around five) in the field where trap barrier system with multiple capture traps was assigned during T. Aman 2013 season. In total, four *Bandicota bengalensis* was caught in different treatments having baits with dry fish and coconut meat. No rat infestation was observed in the control plot. Therefore, the field location and variety has to be selected carefully for transplanting the trap crop one month earlier than the synchronous planting in that area.

Plant Pathology Division

SUMMARY

BRRI dhan49 was found highly susceptible to false smut among the varieties surveyed. Drizzle raining during flowering and high doses of N fertilizer enhanced false smut incidence at Rajshahi region. Around 66.7% incidence of false smut disease was reduced by tilt 250 EC. Leaf blast incidence was high due to high humidity and comparatively low temperature in Barisal region. Again, two fungicides, Trooper (Tricyclazole) and Nativo (Trifloxystrobin + Tabuconazole) were found effective against blast disease in the farmers' field.

A total of 112 races were identified from 139 isolates of blast pathogen. Among those 25 standard reference isolates/races with good sporulation ability were selected and preserved for future use in resistance breeding programme. Both resistant and susceptible reactions were observed for Bangladeshi blast isolates against recently available cultivar having *Pi40* gene. The most amplified bands of *Pyricularia grisea* ranged from 194 to 1358 bp in length. A total of 31 fingerprint types (FPTs) were noticed among the generated band for ninety isolates of blast. Isolates from irrigated ecosystem were found in cluster A while cluster B, C and D belonged the isolates of upland rice ecosystem indicating that some degrees of host specificity related to the rice cultivars existed among the isolates based on ecosystem. A total of 12 isolates were obtained in bakanae infected rice plants collected from Selangor, Malaysia. All isolates were identified as *Fusarium proliferatum* morphologically followed by PCR with Pro1/2 primer and also confirmed by partial sequencing. Seed inoculation with 1×10^6 spores/mL was found the most suitable method compared to soil inoculation for germplasm screening against bakanae disease.

In order to develop blast resistant varieties, crosses were made between BRRI dhan29 and 3 NILs (IRBLta2-Pi, IRBLsh-B, IRBL9-W and IR65482-4-136-2-2) and F_1 populations were confirmed. Moreover, 76 BC_2F_1 seeds were obtained from the cross between BRRI dhan29 and *Pita2* gene. *Pi40* and *Pi9* genes were also introgressed separately in the backcrossed materials of BRRI dhan29 and *Pita2*. A total of 109 BC_1F_2 and 86 F_3 plants were confirmed to study the blast resistance mechanism in Bashmati370. Three multiline varieties containing *Pi9, Pita2* and *Pish* genes performed well compared to local Shadamota in tidal non-saline ecosystem. A total of 100, 91 and 103 BC1F1 seeds were confirmed respectively from the crosses between BRRI dhan28, BRRI dhan29 and a local improved variety with IRBB60 for Bacterial Blight (BB) resistance. Considering non-saline ecosystem, BRRI dhan44 was crossed with submergence tolerant BRRI dhan52 containing *Xa13* gene. Out of 2,387 F_2 plants, only three were found tolerant to complete submergence. In foreground selection for *SUB-1* QTL, markers ART5 and RM8300 were found polymorphic in parental survey. Among the 73 INGER materials, IRBB60, IRBB65, IRBB66 and IR73004-3-1-2-1 showed moderately resistant against BB. In hybrid materials, six out of eight F_2 generations were found BB resistant. Among BC_1F_1 populations, one BC_1F_1 population (BRRI15R/IRBB60) was found BB resistant. In germplasm screening, H13, H23, H25, H35, H47, H49, H136 and H138 (germplasm code) harbored three genes *pita, pita2* and *pish* against blast in their genetic background. The *pi9* gene along with *pita-2* was detected in local rice cultivar H100 and H129. These materials could be used in gene pyramiding for development of durable blast resistance. Among the selected six pure lines of Mala, one line HRP (Mala)-7-10 was found better considering agronomic traits including yield.

Out of 31, five fungicides Indofil's Baan, Trigger 75WP, Palki 75WG, Mactivo 75WG and Navita 75WG effectively controlled rice blast disease. On the other hand, four fungicides (Green DT 300 EC, Emiscore 32.5 SC, Fiscal 10 EC and Shabab 10 EC) successfully controlled rice sheath blight.

Farmers' participatory demonstrations on blast and sheath blight disease management in Barisal and Rangpur regions enhanced farmers' skill on disease identification and performance of BRRI recommended practices was better than farmers' practice. A day long specialized training on 'Rice disease management and healthy seed production' increased SAAO's knowledge (around

42%) regarding disease management issues on field oriented problems.

EPIDEMIOLOGY

Epidemiology and management of rice leaf blast and false smut (FS) diseases

Two intensive surveys were carried out at Rajshahi and Barisal to find out the factors responsible for disease outbreak of false smut and blast. Data on percent panicle and grain infection by false smut were collected for disease assessment. The disease scoring data were converted into percent disease index (PDI) by using the formula.

$$PDI = \frac{\text{Sum of scores}}{\text{No. of observation} \times \text{highest number in rating scale}} \times 100$$

Application of high doses of N fertilizer and rainfall during flowering was the major factors of FS outbreak at Rajshahi region. BRRI dhan49 was found highly susceptible to FS. Two fungicides Tilt (Propiconazole) and Folicur (Tabuconazole) were tested against false smut and around 66.7% disease incidence was reduced by tilt application. Leaf blast incidence was high due to high humidity and comparatively low temperature during study period in Barisal region Again, two fungicides, Trooper (Tricyclazole) and Nativo (Trifloxystrobin + Tabuconazole) were found effective against blast disease in the farmers' field.

PATHOGEN POPULATION BIOLOGY

Reaction of *Pi40* gene against Bangladeshi blast isolates

Pi40 gene introgressed in the background of IR line IR65482-4-136-2-2 was collected from IRRI and evaluated through pathogenicity test against Bangladeshi isolates. Results show that both virulent and avirulent genes are present in Bangladeshi blast isolates against *Pi40* gene.

Study on virulence reaction of blast isolates against differential varieties

A total of 139 blast isolates represented eight AEZs of Bangladesh were evaluated on the basis of the reaction patterns against 25 differential varieties (DVs) harboring 23 resistant genes and susceptible checks LTH and/or US2. Virulent frequencies (%) ranged from the lowest 8 with IRBL9-W (*Pi9*) to 87 with IRBLks-F5 (*Pik-s*). Higher virulent frequencies (>60%) were observed against the DVs for *Pi20, Pi12(t), Pit, Piz-t* and *Pik-s* genes while lower virulent frequencies (<20%) were recorded against the DVs for *Pi9, Pish, Pita* and *Pita-2* genes. Moderate and almost similar virulence pattern was found against *Pita=Pi4(t), Piz-5(pi-2(t)), Pib, Piz, Pi3, Pik-m, Pi5, Pia, Pik-p, Pi7(t), Pi1(t), Pii, Pik-h, Pik* and *Pi19* genes with virulence frequencies ranging from 20-60%. Except four DVs for *Pi9, Pish, Pita* and *Pita-2* genes, all other DVs were susceptible to all tested isolates. Among them Pi9, Pish showed resistance frequencies of 90% and above while *Pita* and *Pita-2* showed 82-83% against all blast isolates (Fig. 1).

Virulence frequency of blast pathogens to differential varieties (DVs) was higher for the isolates of AEZ11 (47%) followed by AEZ23 (46%) and lower for the isolates of AEZ28. Under control condition (controlled temperature and humidity) virulence frequencies of blast isolates of rainfed land against DVs was higher than the blast isolates those were collected from irrigated ecosystem (Boro season) specially for *Pii, Pi3, Pi5(t), Pik-m, Pi1, Pik-h, Pik, Pik-p,* and *Pi7(t)* genes.

Identification of pathogenic diversity and selection of standard differential blast isolates of *Pyricularia grisea* using monogenic lines

To identify variability of blast pathogen and selection of standard differential blast isolates (SDBIs), 139 blast isolates were tested against 23 resistant genes and susceptible variety LTH and/or US2. Tested 139 blast isolates were classified into 112 races based on the five pathotypic groups. A large number of races suggest that the wide genetic variability of blast races existed in the Bangladesh. Among the 112 races 25 were found suitable with high differentiating ability of 23 resistant genes (Table 1). These representative standard differential blast isolates were selected for the development of differential system in

Frequency of blast isolate
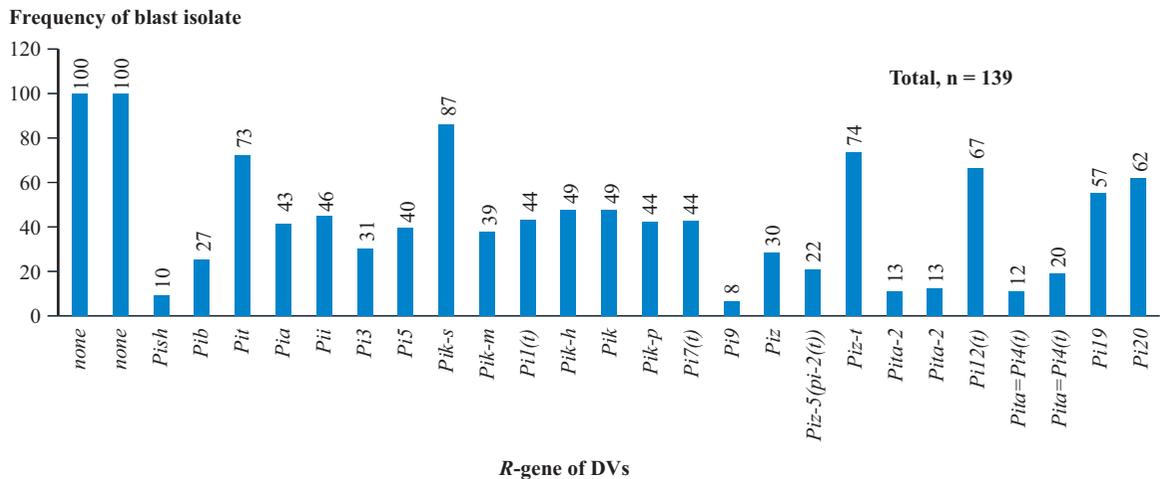
Fig. 1. Virulence frequencies of all tested blast isolates against differential varieties and susceptible check in all selected AEZs of Bangladesh.

Bangladesh. The selected standard blast isolates can cover 23 different resistant genes.

Characterization of *Pyricularia grisea* isolates based on molecular approach

A total of 100 isolates of *P. grisea* were isolated and collected from five AEZs of Bangladesh to determine the genetic diversity. DNA of each isolate was extracted following fungal DNA miniprep method. Two primers, Pot2-1 5'CGGAAGCCCTAAAGCTGTTT3' and Pot2-2 5'CCCTCATTCGTCACACGTTC 3' were used. The PCR product was run in agarose gel, stained by ethidium bromide and visualized under gel doc computer based machine. Binary outputs (0 and 1) were used in the analysis with NTSYS-pc version 2.1.

The most amplified bands ranged from 1358 bp to 194 bp in length. A total of 31 fingerprint types (FPTs) were determined (Fig. 2). Several of the FPTs were widely distributed geographically with FPT-B_1, C_1, D_1, E_1, D_2 and F_2 being dominant. Most of the isolates (25%) belong to FPT-D_1 and B_1. Especially these two types were widely distributed across the locations. The majority of isolates (82%) clustered into a single group with considering similarity coefficient of approximately 20%, except four isolates that separated individually and other 13% isolates formed cluster A. The cluster group B, C and D

belonged to rainfed ecosystem with 76 isolates showing the high genetic diversity. The results of the present study suggest that isolates from irrigated and upland rice cultivar belonged to cluster A and clusters (B, C, D) respectively, indicating the some degree of host specificity of the isolates to the cultivars.

Sample collection, isolation and morphological characterization of bakanae causing pathogen from infected plants

Bakanae infected rice plants were collected randomly from rice growing areas in Tanjung karang, Sabak bernam and Sekinchan, Selangor, Malaysia. Infected plants were washed with water to remove the soil. The samples were cut about 1 to 2 cm long from the node regions and surface sterilized with 70% ethanol, washed with sterile water and air dried on sterilized filter paper. Morphological characteristics were identified from the seven and 14-day-old cultures. Cultures on PDA plates were used to assess growth characteristics and colony pigmentation produced on the medium. Cultures grown on SNA plates from single spore conidium were used to describe the shape, size, mode of formation of macroconidia and microconidia, septation of conidia, production of chlamydospores and perithecia. A total of 12 isolates, eight from Tanjung Karang and four from Sekinchan areas

Table 1. Standard blast isolates for the development of differential system in Bangladesh.

Differential variety and susceptible control — Resistant gene harboring in the genetic background.

Column groups: **U** (IRBLsh-B, IRBLb-B, IRBLt-KS9, LTH/I, IRBLa-A); **i** (IRBLi-FS, IRBL3-CP4, IRBL5-M); **k** (IRBLks-F5, IRBLkm-Ts, IRBL1-CL, IRBLkh-k3(LT), IRBLkh-K(LT), IRBLkp-K60, IRBL7-M); **z** (IRBL9-W, IRBLz-Fu, IRBLz5-CA-1, IRBLzt-T); **ta** (IRBLta2-Pi, IRBLta2-Re, IRBL12-M, IRBLta-K1, IRBLta-CP1, IRBL19-A, IRBL20-IR24).

Isolate code	Virulent frequency (%)	ISporulation rate ($\times 10^4$)	$Pish$	Pib	Pit	–	Pia	Pii	$Pi3$	$Pi5$	$Pik\text{-}s$	$Pik\text{-}m$	$Pil(t)$	$Pik\text{-}h$	Pik	$Pik\text{-}p$	$Pi7(t)$	$Pi9$	Piz	$Piz\text{-}5(pi\text{-}2(t))$	$Piz\text{-}t$	$Pita\text{-}2$	$Pita\text{-}2$	$Pil2(t)$	$Pita{=}Pi4(t)$	$Pita{=}Pi4(t)$	$Pi19$	$Pi20$
H-1-8	92	225	R	s	s	s	s	s	s	s	s	s	s	s	s	s	s	R	s	s	s	s	s	s	s	s	s	s
H-23-108	88	210	s	R	s	s	s	s	s	s	s	s	s	s	s	s	s	R	R	s	s	s	s	s	s	s	s	s
H-1-2	58	28	R	s	R	s	s	s	s	s	s	R	s	s	s	R	R	R	s	R	s	R	R	R	R	s	s	R
H-13-74	54	15	R	s	s	s	R	s	R	s	s	s	s	s	R	R	R	R	R	R	s	R	R	s	s	s	s	R
H-19-95	62	89	R	s	s	s	s	R	R	s	s	s	s	s	s	s	R	R	s	s	s	R	R	s	R	R	s	s
H-2-23	77	155	s	s	s	s	s	s	R	s	s	s	s	s	s	s	s	R	s	s	s	R	s	s	R	R	s	s
H-2-25	77	95	R	s	s	s	s	s	s	R	s	s	s	s	s	s	s	s	s	s	s	R	s	s	R	R	s	s
H-11-61	58	55	s	s	s	s	s	s	s	R	R	s	R	s	s	s	s	R	R	R	R	R	R	s	R	R	s	s
H-9-42	69	105	R	s	s	s	s	s	s	s	s	R	s	s	s	s	s	R	s	R	s	R	R	s	R	R	s	s
H-13-71	81	190	R	s	s	s	s	s	s	s	s	s	R	s	s	s	s	R	s	s	s	R	R	s	R	R	s	s
H-1-5	69	125	R	s	s	s	s	s	s	s	s	s	s	R	s	s	s	R	R	R	s	R	R	s	R	R	s	s
H-13-80	73	70	s	R	s	s	s	s	s	s	s	s	s	s	R	s	s	R	s	s	s	R	R	s	R	R	s	s
H-2-19	46	21	R	s	R	s	R	s	s	R	R	R	s	s	s	R	R	R	s	s	s	R	R	s	R	R	R	s
H-28-112	50	12	R	R	s	s	s	s	R	R	s	s	s	s	s	s	R	R	s	s	R	R	R	R	R	R	R	s
H-11-67	96	390	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	R	s	s	s	s	s	s	s	s	s	s
H-28-117	81	165	R	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	R	s	s	R	s	s	R	R	s	s
H-9-41	77	59	R	s	s	s	s	s	s	s	s	s	s	s	s	s	s	R	s	R	s	R	R	s	R	s	s	s
H-19-82	77	144	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	R	s	s	R	R	R	s	R	R	s	s
H-1-1	92	278	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	R	R	s	s	s	s	s
H-11-60	58	50	R	R	s	s	s	s	s	s	s	s	s	s	s	s	s	R	R	R	R	R	R	R	R	R	s	s
H-19-93	77	98	R	s	s	s	s	s	s	s	s	s	s	s	s	s	s	R	s	s	s	R	R	R	R	R	s	s
H-11-64	88	160	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	R	s	s	s	s	s	s	R	R	s	s
H-28-130	85	180	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	R	s	s	s	R	R	s	s	R	s	s
H-11-50	50	50	R	R	s	s	s	s	R	R	s	s	s	s	s	s	s	R	R	R	R	R	R	s	R	R	R	s
H-1-4	69	234	s	s	s	s	s	s	s	s	s	s	s	s	R	R	s	R	s	R	s	R	s	R	R	s	s	R

were isolated from the bakanae infected rice plants. All the isolates from the two sites were identified as *F. proliferatum* based on morphological characteristics. No *Fusarium* spp., presumed to be associated with the samples collected from Sabak Bernam area. A wide range of pigments produced on PDA medium. Sporodochia and sclerotia were orange and black respectively produced from four isolates. Macroconidia were hyaline, delicate, slightly
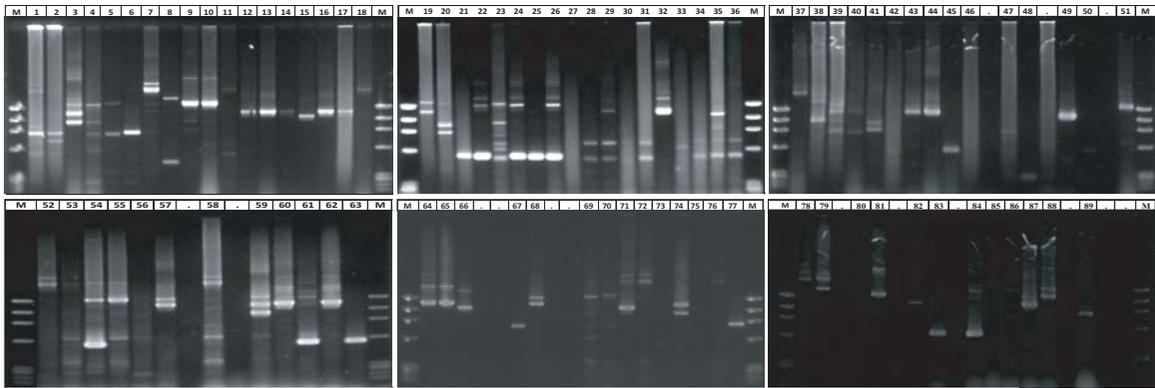
Fig. 2. Agarose gel electrophoresis of DNA from *P. grisea* amplified with primers *Pot2-1* and *Pot2-2.* [1st and last lanes of each plates: Phi X174/*Hae*III markers, the rest are blast isolates].

sickle-shaped or almost straight, 3-5 septate (Fig. 3a). Microconidia were hyaline, mostly obovoid with a distinct base 1-2 celled, and fusiform to oval (Fig. 3b). The microconidia were more or less agglutinated in chains and were found to be produced from polyphialides rather than monophialides and formed "V" shaped chains (Fig. 3c). Chlamydospores were absent.

Molecular characterization and identification of bakanae causing pathogen from Malaysian infected rice plants

The genomic DNA of 12 *Fusarium* isolates was extracted from 200 mg of ground fresh mycelia. All isolates were tested with the universal primer ITS 1/4 for amplifying and sequencing (representative isolate) the fungal rDNA-ITS region and species-specific primer pairs PRO1/2,

VERT1/2 were used to amplify the calmodulin-encoding regions. PCR product of a representative isolate was purified using the QIAquick PCR Purification Kit following the manufacturer's instructions and sequenced with primer ITS1/4 commercially using the Bioneer 3730. The gene sequence was compared with sequences of *F. proliferatum* using the BLAST network services for similarities present in the National Centre for Biotechnology Information (NCBI) database. Multiple sequence alignment was performed using Clustal W. Single bands were obtained with species-specific primers Pro1 and Pro 2 from PCR products and all isolates were identified as *F. proliferatum* and fragment size obtained was approximately 550 bp (Fig. 4). No isolate was identified as *F. verticillioides* when used with VERT 1 and VERT 2 primer pairs. The amplified
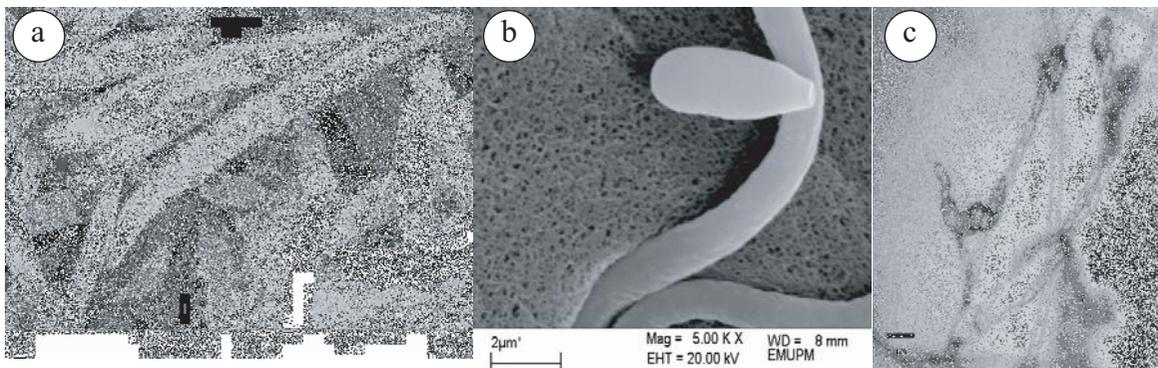
Fig. 3. SEM micrograph of three septate macroconidia of *Fusarium proliferatum* in SNA medium (a), obovoid and distinct based 1-celled microconidium (b), microconidia produced on long chain and formed a "V" shaped monophialid (c).
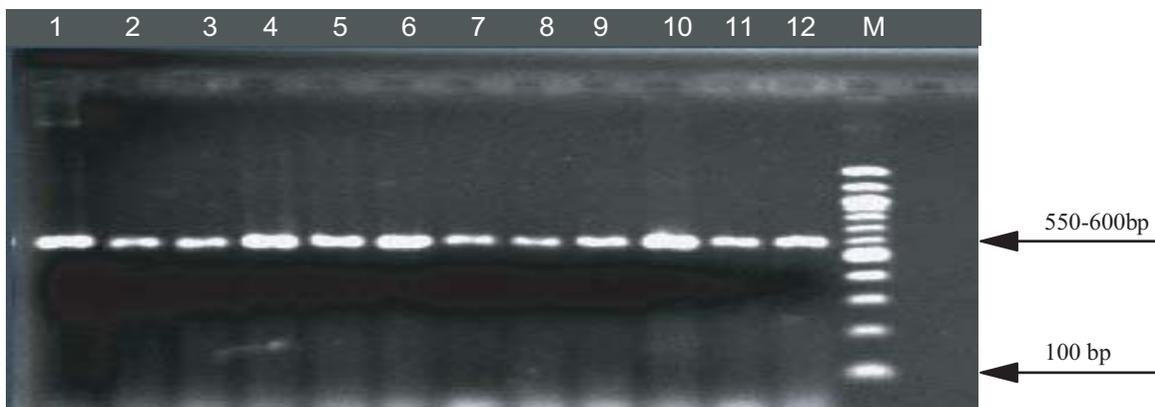
Fig. 4. PCR amplification of *Fusarium proliferatum* isolates with species specific primer pairs for *Fusarium proliferatum* PRO 1/ PRO 2 [Lane 1-12: isolated species from bakanae diseased rice plant. Lane M: DNA size marker (100 bp)].

and purified DNA fragment of *F. proliferatum* isolate (Iso-8) was sequenced in both directions using the ITS region and was deposited in the Genebank (NCBI Acc. JQ 807850). The ITS primer sequences obtained from both directions showed 99% homology with the different *F. proliferatum* isolates. Based on species specific primer and partial sequencing, all isolates of Fusarium were identified as *F. proliferatum.*

Development of mass screening method of bakanae disease
Two inoculation methods (seed and soil inoculation) were evaluated. Data on plant height increase (%) compared to control and disease severity index (DSI) was collected. A modified disease severity scale was used to calculate disease severity index (Table 2).

   Seed inoculation. Seeds of variety MR 211 were surface sterilized and soaked in sterilized distilled water overnight. The water was drained out and seeds were further soaked in spore suspension of the respective isolates (10^6 conidia/mL) for 48 h. The seeds were planted in sterilized soil in trays arranged in a completely randomized design with three replications per isolate (20 seeds/replication). Seeds for the control treatment were soaked in sterile distilled water for 72 h before sowing. Development of disease symptoms was recorded weekly after inoculation.

   Soil inoculation. Soil and spore suspensions for inoculation were prepared in the same manner

as for seed inoculation. Surface sterilized MR 211 seeds were pre-soaked in water (24 h) and sown in sterilized soil, followed by spraying with the respective spore suspension (200 mL/tray @10^6 conidia/mL) of *F. proliferatum* isolates. Evaluations were determined based on disease severity index (DSI) and other parameters described above. Re-isolation of pathogen from infected plants was carried out by random plating of inoculated tissues on PDA. Morphological characterization of *Fusarium* colonies derived from the infected tissues were compared with the identified *F. proliferatum.* Based on increase in plant height (%), DSI, seed inoculation was found to be the most suitable method for assessing bakanae disease development compared to soil inoculation in all the 12 isolates tested (Table 3).

Table 2. Disease severity scale (DSS) used for scoring disease symptoms based on scale 0 to 5.

Disease severity scale	Disease symptom
0	Healthy and symptomless plant
1	Stunted plant with yellowing leaves
2	Thin plants with narrow, pale yellow leaves
3	Abnormal elongated internodes with chlorotic or brownish leaves
4	Root formation from the upper 3rd-4th internodes and necrosis symptoms on the lower internodes
5	Fungal mass seen on the infected plants or dead plant

Table 3. Pathogenicity testing of *Fusarium proliferatum* isolates on rice seeds of MR 211 using seed and soil inoculation methods.

Isolate	% plant height elongation over control		Disease severity index (DSI) after 21 days of inoculation	
	Seed inoculation	Soil inoculation	Seed inoculation	Soil inoculation
*Iso-1	63.23a**	51.51a	2.1	2.05
Iso-2	35.76f	12.43g	1.9	1.60
Iso-3	48.48d	46.32bc	2.3	1.95
Iso-4	43.36e	26.38e	1.8	1.65
Iso-5	52.55c	26.38e	1.6	1.55
Iso-6	43.27e	37.34d	1.7	1.7
Iso-7	47.18d	10.53g	0.7	0.9
Iso-8	63.56a	54.88a	3.0	2.40
Iso-9	43.27e	39.13d	1.7	1.55
Iso-10	42.47e	19.15f	1.3	1.30
Iso-11	9.25g	3.00h	2.4	2.10
Iso-12	57.05b	43.45cd	1.9	1.65
LSD at 5%	3.644	6.598	-	-

*Iso-Isolate, **Means tagged with different letters within column are significantly different using LSD at 0.05.

DISEASE RESISTANCE AND MOLECULAR STUDIES

Development of blast screening hub for evaluating blast resistant multiline varieties of IR64 in Bangladesh

Blast screeing hub was developed to evaluate resistant multilines of IR64 at BRRI East byed farm. A susceptible variety, IR64 was grown with high doses of N fertilizer to increase the inoculum pressure of *P. grisea.* No fungicide was used during the whole growing season. Three cycles of IR64 cultivation has been completed. Around 300 neck blast infected panicles were collected from the plot of IR64.

Performance of blast resistant multiline varieties of IR49830 under tidal non-saline sub eco-system of Bangladesh

Performances of blast resistant multiline varieties of IR49830 having submergence tolerant gene *Sub1* were tested to select appropriate multiline varieties for tidal non-saline ecosystem. Sixty-day-old and tall seedlings were transplanted and three lines (IRBL9-W, IRBLta2Pi and IRBLsh-T) out of nine performed well considering both disease severity and yield (Table 4) and were selected for further trial.

Development of BC_1F_2 population for QTL mapping of blast resistance

The experiment was conducted to develop BC_1F_2 population from the cross of US2 × Bashmati370 for QTL mapping of blast resistance. US2 was used as recurrent parent and Bashmati370 as donor. The F_1 seeds were crossed again with US2 to get BC_1F_1 seeds. Finally BC_1F_1 seeds were selved to get BC_1F_2 seeds. A total of 109 BC_1F_2 plants were harvested from the cross between US2 × Bashmati370. Seeds were transferred to JIRCAS Laboratory, Japan for QTL mapping.

Pyramiding blast resistance genes into the genetic background of BRRI dhan29

BRRI dhan29 (mega variety of Boro season susceptible to blast disease) crossed with indica background monogenic lines (MLs) IRBLta2-Pi [CO], IRBLsh-B [CO] and IR65482-4-136-2-2 and Japonica background IRBL9-W to develop blast resistant variety for Bangladesh.

Table 4. Performance of blast resistant multiline varieties of IR49830 under field condition.

Designation	False smut score (0-5)	Blast score (0-5)	Yield (t/ha)
IR49830-7	3	5	3.66
IRBL9-W	0	0	3.83
IRBLz5CA	1	3	3.59
IRBL3CP4	1	5	4.11
IRBL5-M	1	3	3.85
IRBL7-M	1	5	4.23
IRBLk-Ku	1	3	3.82
IRBLta2Pi	0	0	3.24
IRBLsh-T	0	0	3.61
Sadamota (Local check)	0	5	2.82
LSD (5%)			2.47

All of the F_1 plants were confirmed considering both phenotypes and molecular markers (Table 5). Under NATP project, 76 BC_2F_1 seeds were obtained from the cross between BRRI dhan29 and *Pita2* gene. *Pi40* and *Pi9* genes were also introgressed separately in the backcrossed materials of BRRI dhan29 and *Pita2*.

Development of bacterial blight (BB) resistant variety

BRRI dhan28, BRRI dhan29 (two mega varieties for Boro season) and a local improved variety were crossed with IRBB60 and IRBB65 to develop BB resistant rice varieties. Pathogenicity result showed that some plants of BC2F1 developed from the crosses of local improved variety and IRBB60/65 were resistant to BB. For new crosses, all the F_1 plants were confirmed considering both phenotypes and molecular markers.

Development of suitable BB resistant variety

BRRI dhan44 and BRRI dhan52 (both *Sub-1* and BB resistant *xa13* donor) were crossed with IRBB21 (*Xa21* donor) to develop submergence tolerant as well as BB resistant rice variety for tidal non-saline ecosystem of Barisal region. Among 48 plants of F_1, only one plant was found tolerant to complete submergence during physiological screening. Again, out of 2387 F_2 plants, only three were found tolerant to complete submergence. In F_2 population desired heterozygous plants were also found by two markers (Fig. 5).

Pure line selection of local Mala for Barisal region

Panicles of local Mala called Mala IRRI were collected from farmers` field of Bakerganj, Barisal to increase Aus production in Barisal region through varietal improvement. Among the collected panicles, the best ten were selected for pure line selection. Panicles were collected during Aus season and head to row selection was done for purification in consecutive Boro season at West byed, BRRI HQ, Gazipur. Among the tested lines HRP (Mala)-7-10 was found best considering agronomic and yield characteristics (Table 6).

Screening of existing parental lines, F_2 populations and BC_1F_1 populations against BB resistance of hybrid materials

A total of 19 parental lines, eight F_2 populations with parents and three BC_1F_1 populations were screened against BB to identify BB resistant maintainers and restorers. In case of F_2 generations, six were found BB resistant while only one BC_1F_1 population (BRRI15R/IRBB60) was found moderately resistant to BB.

Evaluation of genotypes against major diseases

Advanced breeding lines of BRRI were screened against major diseases to know their disease reaction. Among the tested materials, none of the materials was found resistant against bacterial blight. In case of blast, twelve materials (Weed tolerant rice, BR7384-2B-5, BR6976-2B-11-1, IR78761-B-SATB2-4-25-3, IR78761-B-SATB1-28-3-24, IR78761-B-SATB1-28-3-26, IR83373-B-B-27-4, IR87707-446-B-B-B, IR82589-B-B-84-3, BR7357-11-2-4-1-1 and BR7622-5-1-1-1) were found moderately resistant while none of the materials performed well against rice sheath blight disease.

Screening INGER materials against BB and blast diseases

INGER materials of IRRI were tested against both BB and blast diseases to identify resistant source for developing durable disease resistant variety for Bangladesh. Four materials (IRBB60, IRBB65, IRBB66 and IR73004-3-1-2-1) out of 73 showed moderately resistant to BB while eight materials (IRBL5-M, IRBL7-M, IRBL9-W, IRBLsh-B, IRBL9-W (RL), IRBLsh-S, IRBLsh-T/RL, and IRBLT-K59) out of 79 showed moderately resistant to blast.

Table 5. Development of F_1 seeds between the crosses of BRRI dhan29 and blast resistant sources.

Recipient	Donor		No. of F_1 seeds harvested
	Designation	Target *R* gene	
BRRI dhan29	IRBLta2-Pi [CO]	*Pita2*	103
BRRI dhan29	IRBLsh-B [CO]	*Pish*	98
BRRI dhan29	IRBL9-W	*Pi9*	67
BRRI dhan29	IR65482-4-136-2-2	*Pi40*	88
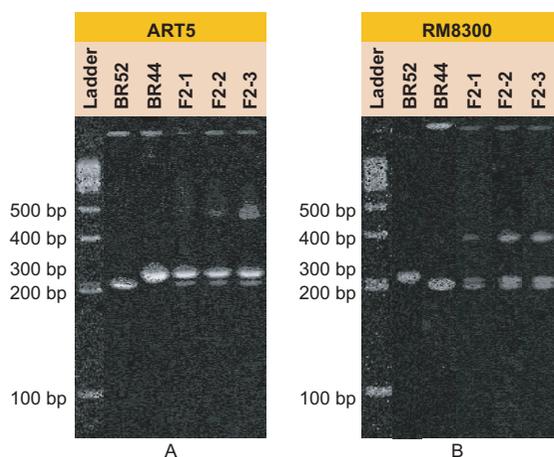
Fig. 5. Gel picture of foreground selection of F_2 progenies using polymorphic markers, ART5 and RM8300.

Table 6. Characteristic of some pure lines selected from local Mala during Boro season.

Designation	Plant ht (cm)	Panicles (no./hill)	Panicle length (cm)	Field duration (day)	Yield (t/ha)
HRP (Mala)-1-10	138	24	25	105	3.94
HRP (Mala)-1-24	140	25	26	109	3.73
HRP (Mala)-3-9	128	20	24	111	4.76
HRP (Mala)-7-1	125	23	26	115	4.37
HRP (Mala)-7-10	125	24	26	115	5.48
HRP (Mala)-M-68	135	21	27	107	3.63
Local Mala	145	15	18	123	3.55

Blast resistant major gene assessment based on reaction to standard blast isolates

To assess major blast resistant gene in land races of rice in Bangladesh, reaction patterns of 100 plant materials against standard blast isolates were compared with differential varieties (DVs). These cultivars were classified into different cultivars groups (CG) based on reaction patterns to four distinct blast isolates, H-11-64, H-1-8, H-1-1 and H-11-67. From these reactions, presence or absence of these four genes was estimated in the cultivars for each CG. All the cultivars showed various patterns of reactions to the differential blast isolates. From these reactions, presence or absence of these four genes was estimated in the cultivars for each CG. In total, ten CGs were formed (Table 7). In germplasm screening, H13, H23, H25, H35, H47, H49, H136 and H138 (germplasm code) harbored three genes *pita, pita2* and *pish* against blast in their genetic background.

Genotyping of *Pita, Pish, Pita-2* and *Pi9* genes in tested plant materials using DNA markers

To confirm phenotypic assessment of major blast resistant gene in land races of rice in Bangladesh, *Pita, Pish, Pita-2* and *Pi9* genes were surveyed in the background of rice. Gene-specific primers were used to identify the target gene in plant samples. Young leaves (about 3 cm long leaf tips) of 21-day-old rice plants were collected for DNA extraction (Modified miniscale method). SSR-PCR was performed following standard laboratory protocol. Specific primers correspond to resistant gene, *Pita, Pish, Pi9* and *Pita-2* were used for PCR. Amplified PCR products were separated on agarose gel. The gel was stained in Ethidium Bromide and visualized under gel doc machine.

The presence and absence of the Pita gene in 48 materials and control cultivars were estimated using the DNA marker *Pita440* (YL153/YL154). The *Pita* gene on chromosome 12 was scored to 24 out of 48 tested plant materials (Fig. 6). Out of 48 materials eight accessions showed the positive reactions of *Pish* genes located on chromosome 1 with tightly linked markers AOL45/AOL48 (Fig. 7). Out of 48 materials, 28
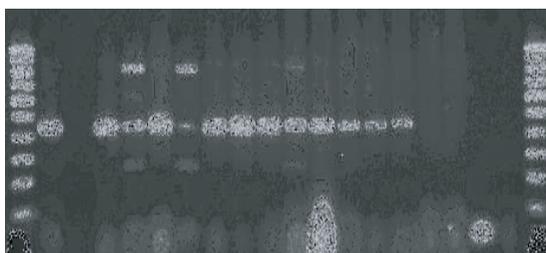
Fig. 6. Screening for *Pita* gene. The 1st and the last lanes of each gel: 100bp ladder, 2nd and 3rd lanes: (+)ve and (-)ve control; other lanes: plant samples.
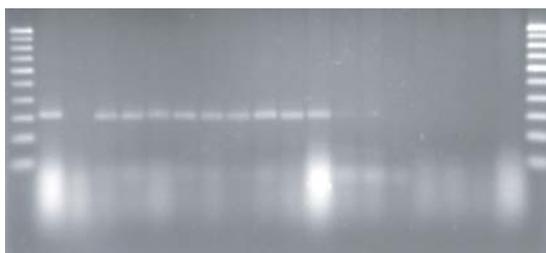
Fig. 7. Screening for *Pish* gene. The 1st and last lanes of each gel: 100bp ladder, 2nd and 3rd lanes: (+)ve and (-)ve control; other lanes: plant samples.

Table 7. Cultivar classification based on reaction pattern to four selected blast isolates.

| CG	DVs/variety	Reaction to SDBIs				Estimated gene harboring in the genetic background			
		1	2	3	4				
I	LTH,US2,H3,H9,H26,H27,H34,H41, H44,H46,H51,H53,H55, H64,H65,H66,H69,H82,H91,H93,H95, H133,H134	S	S	S	S	-	-	-	-
II	IRBLtaCP1,H12,H29,H52,H63,H78,H77,H96	R	S	S	S	Pita	-	-	-
III	IRBLshB,H8,H38,H40,H61,H68,H80,H81,H84	S	R	S	S	-	Pish	-	-
IV	IRBLta2Pi,H2,H7,H10,H24,H33,H43,H56,H60, H62,H73,H74, H85, H98, H99, H139	S	S	R	S	-	-	Pita-2	-
V	IRBL9-W	R	R	S	R	-	-	-	Pi9
VI	H4,H28,H36,H45,H50,H67,H71,H141	R	R	S	S	Pita	Pish	-	-
VII	H1,H11,H14,H19,H31,H32,H39,H48,H86,H90, H144	R	S	R	S	Pita	-	Pita-2	-
VIII	H15,H16,H18,H21,H22,H37,H42,H57, H58, H72, H79,H83,H135	S	R	R	S	-	Pish	Pita-2	-
IX	H13,H23,H25,H35,H47,H49,H136,H138	R	R	R	S	Pita	Pish	Pita-2	-
X	H100, H129	R	R	R	R	Pita	Pish	Pita-2	Pi9

S' susceptible and R' resistant reaction of host plant to blast isolates; 1= H-11-64; 2= H-1-8; 3= H-1-1; 4= H-11-67.

accessions produced bands with OSM89 marker. This indicates that *Pita-2* gene might present in those plant materials. Out of 48 germplasms including land races, wild accession and some BRRI released promising cultivars of Bangladesh, only two showed DNA fragments with primer 195R-1/195F-1 indicating the presence of *Pi9* gene.

The detection of DNA fragments in agarose gel electrophoresis for *Pi9, Pita, Pish* and *Pita-2* genes and their combinations using specific DNA markers were consistent for plant materials with the results of gene estimation based on reaction to standard blast isolates.

DISEASE MANAGEMENT

Chemical control of neck blast disease of rice, T. Aman 2013

The experiment was conducted at experimental plot of Plant Pathology Division, BRRI to determine the efficacy of new fungicides against neck blast. A highly susceptible variety BRRI dhan34 was used as a test variety and 32 fungicides were evaluated. Fungicides were sprayed twice. Among the tested fungicides, Indofil's Baan and Trigger 75WP from Tricyclazole group and Palki 75WG, Mactivo 75WG and Navita 75WG from mixed group (Tebuconazole 50% + Trifloxystrobin 25%) performed better in reducing disease incidence >80% over control.

Chemical control of sheath blight disease of rice, T. Aman 2013

The experiment was conducted at BRRI HQ Gazipur farm under artificial inoculation condition to determine the efficacy of new fungicides against sheath blight disease of rice. BR11 was used as a test variety and 20 fungicides were tested. The plants were inoculated with local *Rhizoctonia solani* isolate at PI stage. Four fungicides, Green DT 300EC, Emiscore 32.5SC, Fiscal 10EC and Shabab 10EC controlled rice sheath blight disease more than 80% compared to the diseased control.

TECHNOLOGY DISSEMINATION

Demonstration on neck blast and sheath blight disease management under field condition

A total of 16 field trials, 13 at Barisal and three at Rangpur region were conducted during T. Aman 2013 to demonstrate both neck blast and sheath blight disease management practice at farmer's field condition. Aromatic rice (Sakkorkhora, Chinigura and Kalijira) were grown for blast and Swarna and BRRI dhan52 were grown for sheath blight disease management at farmer's field condition. Whole plot was divided into two parts, one was BRRI recommended practices and the other was farmer's practices. Balanced doses of fertilizer, additional potash application and judicial application of fungicides (Tricyclazole for

blast and Hexaconazole for sheath blight) were in the package of BRRI recommended practices.

Both blast and sheath blight diseases were successfully controlled in BRRI managed plot than that of farmers plot. In case of blast, higher panicle blast incidence (35-87%) along with lower yield (1.1-2.1 t/ha) were observed in farmer's field than BRRI recommended practice (higher yield 1.8-3.0 t/ha with minimum 5-15% panicle blast incidence). In case of sheath blight, comparatively higher yield (5.7-6.2 t/ha) with minimum disease incidence (20-28%) was observed in BRRI recommended plots than farmer's plots (comparatively low yield 4.6-5.7 t/ha with higher disease incidence 50-60%).

Demonstration on neck blast disease management under field condition

A total of five demonstrations were conducted at Barisal region while two at Rangpur region during Boro 2013-14 to demonstrate blast disease management practices at the farmers field. BRRI dhan28, BRRI dhan29 and BRRI dhan47 were grown at farmer's field condition. The whole plot was divided into two parts, one part remained as BRRI recommended practices where balanced doses of fertilizer along with judicial application of fungicides (Trooper or Nativo or Zeel) were applied and the other part was treated as farmer's practices.

Blast diseases were successfully controlled in BRRI managed plot than that of the farmers plot. In case of Barisal, higher panicle blast incidence (62-88%) along with comparatively lower yield (4.4-5.7 t/ha) were observed in farmer's field than BRRI recommended practices (higher yield 5.8-6.6 t/ha with minimum 10-25% panicle blast

incidence). Similar trend of higher yield (5.8-6.2 t/ha) with minimum disease incidence (10-18%) were observed in BRRI recommended plot than that of the farmer's plot (comparatively lower yield 4.4-5.0 t/ha with higher disease incidence 27-58%) in Rangpur region.

Training on rice disease management and healthy seed production

A day long training on rice disease management and healthy seed production was conducted to train SAAO (Sub Assistant Agriculture Officer) of DAE at Mujibnagar project site (MIADP BRRI part). Four training programmes were conducted at different upazilas of project site. A total of 92 SAAOs were trained and knowledge of SAAOs on rice disease management was increased sharply (42%) through this training (Fig. 8).

Marks obtained
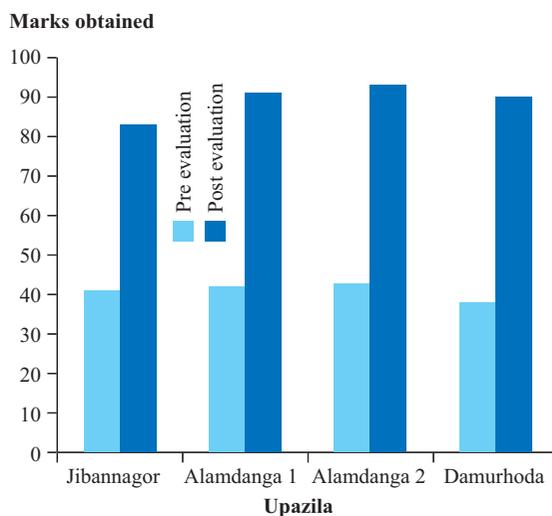
Fig. 8. Impact of training of SAAO on rice disease management and healthy seed production.

Rice Farming Systems Division

SUMMARY

Survey of existing cropping patterns was done for the year 2012-2013 in six upazilas viz, Chuadanga sadar, Alamdanga, Meherpur sadar, Mujibnagar, Khoksha and Kumarkhali. Maize-T. Aus-Fallow, Boro-Fallow-T. Aman, Wheat-Jute-T. Aman, Boro-Fallow-T. Aman, Wheat-Jute-T. Aman and Onion-Fallow-T. Aman, respectively was the most dominant cropping pattern of the upazilas.

Higher yields of wheat (2.25-3.38 t/ha), mungbean (0.77-0.89 t/ha) and rice (3.30-3.84 t/ha) were produced by permanent bed with 100 % crop residue retention over the five years period from 2009 to 2013 followed by permanent bed with 50% crop residue retention than the conventional method in a conservation agriculture trial with Wheat-Mungbean-DS Aman cropping pattern.

Tomato-Mugbean-T. Aman produced the highest water productivity (11.2 kg/mm/ha) which was followed by Wheat-Mugbean-T. Aman and Potato-T. Aus-T. Aman, Lentil- T. Aus-T. Aman, Chickpea-T. Aus-T. Aman and Boro-Fallow-T. Aman.

The highest grain yield was produced by application of one-fourth N at initiation of tillering stage (IT) + one-fourth at active tillering stage + half at PI stage in BRRI dhan29 and one-third at IT stage + two-thirds at PI stage in BRRI dahn28 in Boro season. The highest yield was produced by application of half N at IT stage + half at PI stage treatment in T. Aman.

Under late situation, double transplanting produced significantly higher grain yield than that of normal transplanting with older seedling in both T. Aman and Boro seasons.

In a long-term study with four cropping patterns, the Potato-Boro-T. Aman cropping pattern produced the highest REY and gross margin than Boro-Fallow-T. Aman, Boro-T. Aus-T. Aman and Maize-Mungbean-T. Aman in both Rangpur and Gazipur sites.

BARI panikachu-3 and monosex tilapia in pond along with vegetables (sweet gourd and bottle gourd) and papaya on the pond bank was found to be an effective combination of vegetables, fruit and fish in a mini pond system.

Double transplanted Boro in Haor area under Boro-Fallow-Fallow cropping patttern allowed to harvest BRRI dhan29 one week earlier with increased yield than normal transplanting with old seedling.

Tomato-DS Aus-T. Aman (BRRI dhan39) produced significantly the highest REY than the other cropping patterns with different T. Aman varieties.

Performance evaluation of BRRI prilled urea and BRRI USG applicators was done in Boro and T. Aman rice in BRRI experimental farm.

In a high intensity cropping pattern trial highest REY was found from Maize+Potato/Pumpkin-T. Aus-T. Aman cropping pattern. The other patterns were Maize+Potato/Pumpkin-T. Aus-T. Aman and Maize+Spinach-T. Aus-Aman cropping pattern.

Intercropping of maize with vegetables in different cropping patterns indicated that significantly the highest MEY (27.22 t/ha) was obtained from Maize+Potato-Sweet gourd-T. Aman cropping pattern followed by Maize+Spinach-Sweet gourd-T. Aman.

A trial with Rice-Sunflower cropping pattern in tidal wetland ecosystem indicated that the highest REY was recorded in HYV Rice-Sunflower cropping pattern (10.04 t ha^{-1}) which was followed by LV Rice-Sunflower (6.36 t ha^{-1}) which were about 118 % and 237 % higher than HYV Rice-Fallow and LV Rice-Fallow cropping pattern respectively.

BRRI recommended and soil test based fertilizer managements along with the farmer's practice were evaluated in Chuadanga and Meherpur sadar upazila in farmers' field in T. Aman.

Multi-location testing of BRRI dhan46-BRRI dhan29-Fallow cropping pattern in medium highland phase II was undertaken at Madhabpur upazila of Habiganj district. The recommended patterns gave 15% higher grain yield and gross margin over existing farmers' patterns. The recommended cropping pattern gave the yield of 11.72 t/ha and gross margin of Tk 2,22,680/ha.

Performance of improved rice varieties in Jhum cultivation in the eastern hilly areas was studied with BRRI dhan55, NERICA Mutant

(Kudrat) and Pidi and the results indicated that there was no significant difference in grain yield among the varieties.

Validation trial of improved cropping pattern including mustard, potato, pulses, sesame and mukhikachu in the existing double rice cropping pattern for greater Kushtia showed yield and economic advantages over the existing patterns.

A validation trial was conducted with four improved cropping patterns with the existing ones in Rangpur, Kurigram, Nilphamari and Lalmonirhat districts.

Under co-ordinated sub-project on farming systems research and development for farmers livelihood improvement 25 activities on generation, validation and delivery of farming systems technologies were carried out in Barisal and Habiganj.

FARMING SYSTEMS RESEARCH AND DEVELOPMENT FOR CROSS ECOSYSTEM

Cropping pattern survey of Chuadanga, Kushtia and Meherpur

Existing cropping patterns for 2012-13 were collected using structured questionnaire from upazila Agricultural Office of Chuadanga sadar, Alamdanga, Meherpur sadar, Mujibnagar, Kumarkhali and Khoksha upazila. Collected data were checked and validated through focus group discussion (FGD) with farmers and SAAO in three representative spots of each upazila. In Chuadanga sadar upazila, Maize-T. Aus-Fallow was the most dominant cropping pattern representing 38% of net cropped area followed by Maize-Jute-Fallow, Boro-Fallow-T. Aman and Maize-T. Aus-Early winter vegetables. In Alamdanga upazila, Boro-Fallow-T. Aman is the foremost cropping pattern covering 37% of net cropped area followed by Maize-Jute-T. Aman, Wheat-Jute-T. Aman and Boro-T. Aus-Fallow. In Meherpur Sadar upazila, Wheat-Jute-T. Aman is the most dominant cropping pattern representing 31.35% of net cropped area followed by Boro-Fallow-T. Aman, Mustard-Boro-T. Aman and Boro-Green manure-T. Aman. In Mujibnagar upazila, Boro-Fallow-T. Aman is the foremost cropping pattern covering

27% of net cropped area followed by Wheat-Jute-T. Aman, Onion-Jute-Onion, Mustard-Boro-T. Aman and Onion-Jute-T. Aman. In Khoksha upazila, Wheat-Jute-T. Aman is the most dominant cropping pattern representing 19.23% of net cropped area followed by Boro-Fallow-T. Aman, Pulse-Jute-T. Aman, Onion-Jute-T. Aman and Boro-T. Aus-T. Aman. Other major patterns were: Pulse-Seasume-T. Aman, Vegetable-Vegetable-Vegetable, Sugarcane etc. In Kumarkhali upazila Onion-Fallow-T. Aman was the foremost pattern covering nine percent of net cropped area followed by Boro-T. Aus-Fallow, Wheat-Fallow-T. Aman, Boro-T. Aus-T. Aman, Boro-Fallow-T. Aman, Boro-Fallow-Fallow.

DEVELOPMENT OF FARMING SYSTEMS TECHNOLOGIES FOR DIFFERENT ECOSYSTEMS

Crop residue and weed management of permanent raised beds in rice-wheat systems

A long term experiment was initiated in Rabi season 2007-8 at BRRI experimental farm, Gazipur with five crop establishment options viz, T_1-permanent beds with 100% crop residue retention ; T_2-permanent bed with 50% crop residue retention; T_3-permanent bed without crop residue retention; T_4-semi permanent bed (new beds with conventional tillage in every wheat season) and T_5-conventional (flat), and two weed control methods viz, (W_1) hand weeding and (W_2) herbicide + hand weeding were evaluated in RCB design with three replications in Wheat-Mungbean-DS Aman rice cropping pattern. For the treatments with herbicide, non-selective herbicide Gramoxan was used in transition period between mungbean and rice and the transition period between wheat and mungbean with one or two hand weeding. In Rabi season, wheat was sown within first to third week of November and harvested on first to second week of March. Mungbean was sown in second to third week of March after wheat harvest and harvested up to third week of May and after mungbean, DS rice (BRRI dhan33) was sown in third week of June to first week of July and harvested in first to last week of October and was followed by wheat.

Recommended management practices were followed for wheat, mungbean and rice cultivation. In Wheat-Mungbean-DS Aman pattern, significantly higher yields of wheat (2.25-3.38 t/ha), mungbean (0.77-0.89 t/ha) and rice (3.30-3.84 t/ha) were produced by permanent bed with 100% crop residue retention over the five years period from 2009 to 2013 followed by permanent bed with 50% crop residue retention than the conventional method (Figs. 1, 2 and 3). However, without crop residue on permanent and semi-permanent beds, grain yields of wheat and rice were statistically similar from 2009-13. Weeding practice did not influence yield of mungbean.

Yield (t/ha)
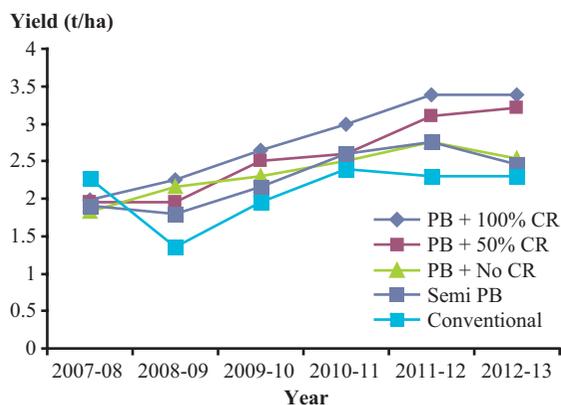
Fig. 1. Year wise wheat yield under different crop establishment options from 2007-8 to 2012-13.

Yield (t/ha)
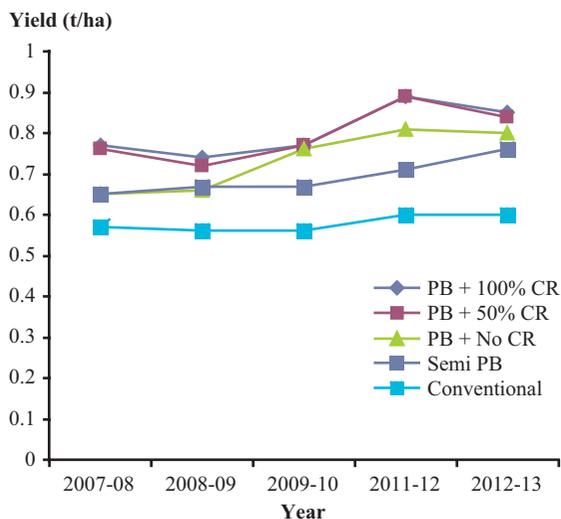
Fig. 2. Year wise mungbean yield Under Different crop establishment options from 2007-8 to 2012-13.

Yield (t/ha)
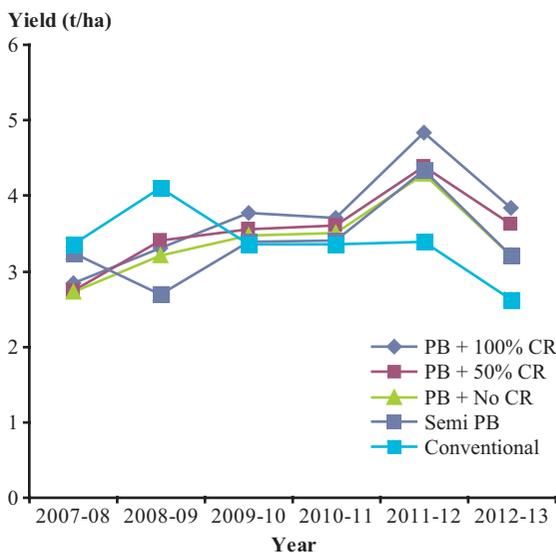
Fig. 3. Year wise rice yield under different crop establishment options from 2007-8 to 2012-13.

However, rice and wheat yield were significantly influenced by weeding practice. Herbicide (Nonselective + selective) + 1 hand weeding practices produced higher yield than herbicide (nonselective herbicide) + 2 hand weeding practices.

Evaluation of different cropping patterns for their water requirement compared to Boro-Fallow-T. Aman in medium highland ecosystem
Six cropping patterns were evaluated to find out the most water efficient profitable cropping pattern for sustainable food production. The experiment was conducted at east byde, BRRI experimental farm, Gazipur during, Kharif II-2013, Rabi 2013-14 and Kharif I-2014 season. Cropping patterns viz, Tomato (BARI hybrid tomato-5)-Mungbean (BARI mug-6)-T. Aman (BRRI dhan49), Wheat (BARI gom-26)-Mungbean (BARI mug-6)-T. Aman (BRRI dhan49), Potato (BARI alu-7)-T. Aus (BRRI dhan48)- T. Aman (BRRI dhan49), Lentil (BARI masur-7)-T. Aus (BRRI dhan48)- T. Aman (BRRI dhan49) and Chickpea (BARI chola-9)- T. Aus (BRRI dhan48)-T. Aman (BRRI dhan49) were evaluated along with the check, Boro (BRRI dhan29)-Fallow-T. Aman (BRRI dhan49) in RCB design with three replications. Recommended management practices were

followed for rice and non-rice crops. Irrigation water applied in each plot with bucket and data were recorded. Water productivity was measured with the following formula:

$$\text{Water productivity (kg/mm/ha)} = \frac{\text{Total yield of crop (kg/ha)}}{\substack{\text{Water requirement of crop in mm} \\ \text{(Rainfall + irrigation)}}}$$

Table 1 presents rice equivalent yield (REY) of different cropping patterns. Among the six patterns, Tomato-Mugbean-T. Aman appeared profitable in respect of gross margin and applied irrigation water (Fig. 4). Among the six patterns Tomato-Mugbean-T. Aman gave the highest water productivity (11.2 kg/mm/ha). The pattern Wheat-Mugbean-T. Aman and Potato-T. Aus-T. Aman gave the water productivity of 9.1 and 7.6 kg/mm/ha respectively. The pattern Lentil-T. Aus-T. Aman, Chickpea-T. Aus-T. Aman and Boro-Fallow-T. Aman showed the water productivity of 6.3, 6.2 and 5.5 kg/mm/ha (Fig. 5) respectively. All the patterns, except Tomato-Mugbean-T. Aman showed similar water productivity and the lowest water productivity was observed in Boro-Fallow-T. Aman cropping pattern (5.5 kg/mm/ha).

DEVELOPMENT OF CROPPING PATTERN TECHNOLOGIES FOR DIFFERENT ECOSYSTEMS

Effect of fertilizer management on yield of double transplanted Aman and Boro rice under T. Aman-Boro cropping systems

In this study in late situation double transplanting of Aman and Boro with fertilizer treatments were
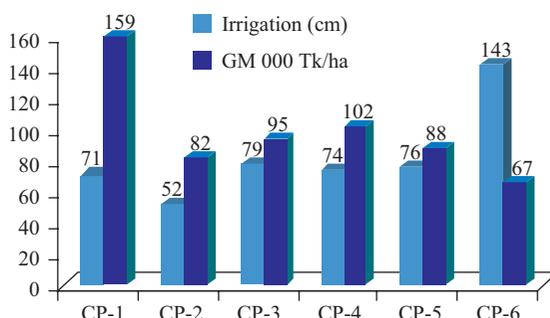
CP-1=Tomato-Mugbean-T. Aman, CP-2=Wheat-Mugbean-T. Aman, CP-3=Potato-T. Aus-T. Aman, CP-4=Lentil- T. Aus-T. Aman, CP-5=Chickpea- T. Aus-T. Aman, CP-6=Boro-Fallow-T. Aman

Fig. 4. Applied irrigation water and gross margin of different tested cropping pattern, BRRI, Gazipur 2013-14.
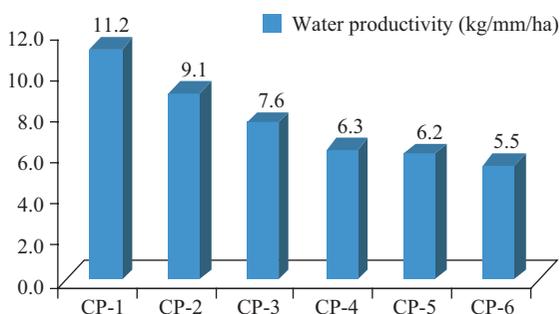
CP-1=Tomato-Mugbean-T. Aman, CP-2=Wheat-Mugbean-T. Aman, CP-3=Potato-T. Aus-T. Aman, CP-4=Lentil- T. Aus-T. Aman, CP-5=Chickpea- T. Aus-T. Aman, CP-6=Boro-Fallow-T. Aman

Fig. 5. Water productivity (kg/mm/ha) of different evaluated cropping pattern, BRRI, Gazipur 2013-14.

evaluated. The experiment was conducted during 2011-12 in Boro and T. Aman seasons at BRRI farm, Gazipur. Six planting methods and three fertilizer application methods were used. The design of the experiment was RCB with three

Table 1. Yield of tomato, wheat, potato, lentil, chickpea, mungbean, rice and REY of different cropping patterns, BRRI, Gazipur 2013-14.

Cropping pattern	Yield t ha^{-1}			
	Rabi/ Boro	Mug/ T. Aus	T. Aman	REY
Tomato-Mugbean-T. Aman (CP$_1$)	22.54	1.02	4.98	18.72
Wheat- Mugbean-T. Aman (CP$_2$)	2.44	1.09	5.14	12.83
Potato-T. Aus-T. Aman (CP$_3$)	13.20	4.17	4.84	16.77
Lentil- T. Aus-T. Aman (CP$_4$)	1.35	4.15	4.91	13.81
Chickpea- T. Aus-T. Aman (CP$_5$)	1.47	4.16	4.98	13.47
Boro-Fallow-T. Aman (CP$_6$)	6.25	-	4.87	11.12
CV (%)	-	-	-	3.9
F for treatment	-	-	-	*
LSD$_{0.05}$ for treatment	-	-	-	1.03

Price- Tomato: Tk 8/kg, wheat: Tk 30/kg, potato: Tk 10/kg, lentil: Tk 60/kg, chickpea: Tk 50/kg, mungbean: Tk 52.50/kg and rice: Tk 17/kg.

replications. In T. Aman season, treatments were: Planting methods under different time of transplanting: T_1=Normal transplanting with 60 DOS (TP: 25 Sep; Sowing: 25 Jul), T_2=Normal transplanting with 30 DOS (TP: 25 Sep; Sowing: 25 Aug), T_3=Double transplanting (No fertilizer in 1st transplanted plot; all seedling removed), T_4=Double transplanting with (1st split urea in 1st transplanted plot; all seedling removed), T_5=Double transplanting (Full fertilizer in 1st transplanted plot; 75% seedling removed) and T_6=Remaining 25% seedlings in fully fertilized 1st transplanted plot. In Boro season, T_1=Normal transplanting with 80 DOS (TP: 25 Feb; Sowing: 05 Dec), T_2=Normal transplanting with 40 DOS (TP: 25 Feb; Sowing: 15 Jan), T_3=Double transplanting (No fertilizer in 1st transplanted plot; all seedling removed), T_4=Double transplanting with (1st split urea in 1st transplanted plot; all seedling removed), T_5=Double transplanting (Full fertilizer in 1st transplanted plot; 50% seedling removed) and T_6=Remaining 25% seedlings in fully fertilized 1st transplanted plot. Nitrogen, P, K, S and Zn were applied as per recommendation. In Boro season, the grain yield of rice was significantly affected by different treatments (p 0.05). The highest grain yield was obtained from T_6 (6.12 t/ha) treatment, followed by the T_4 and T_5 treatments. The lower and statistically similar grain yields were observed from T_2 (4.12 t/ha), T_3 (4.94 t/ha) and T_1 (5.03 t/ha) treatments. The grain yield reduction under T_2, T_3 and T_1 treatments was 49, 24 and 22% respectively, as compared to the T_6. The grain yield-producing trend under different treatments was $T_6 > T_4 > T_5 > T_1 > T_3 > T_2$ (Table 2) In T. Aman season, the grain yield ranged from 2.86 to 5.95 t/ha among the treatments. The treatment effect on grain yield was significant (p 0.05). The highest grain yield was obtained by T_7 treatment (5.95 t/ha.), followed by the T_6, T_5 and T_4 treatments and minimum under T_1 (2.86 t/ha) treatments. The grain yield reduction under T_2 and T_1 treatments was 70 and 108% respectively, as compared to the T_7 treatment. The grain yield-producing order under different treatments was $T_7 > T_6 > T_5 > T_4 > T_2 > T_1$ which were shown in Table 3.

Nitrogen management options in Boro and T. Aman rice under Boro-Fallow-T. Aman cropping system

This study was undertaken to determine appropriate timing of split application of N for making accurate N fertilizer recommendations for rice. The experiment was conducted during Boro 2013-14 and T. Aman 2014 at the experimental farm of BRRI, Gazipur. There were five treatments: i) One-third of N was applied at initiation of tillering (IT) + one-third at active tillering stage (AT) + one-third at panicle initiation (PI) (N_1); ii) Half of N was applied at IT stage + another half was at PI stage (N_2); iii) One-third at IT stage + two-thirds at PI stage (N_3); iv) One-fourth at IT stage + one-fourth at AT stage + half at PI stage (N_4) and (v) N-control (N_5) were evaluated in Boro season. In T. Aman season there were six treatments: i) One third of N was applied at IT stage + one third at AT stage + one-third at PI stage (N_1); ii) One-half at IT stage + another-half at PI stage (N_2); iii) One third at IT stage + two-third at PI stage (N_3); (iv) One-fourth at IT stage + one-fourth at AT stage+ half at PI stage (N_4); v) Half at IT stage + another half at AT stage (N_5); and vi) N-control (N_6). BRRI dhan28 and BRRI dhan29 were used in Boro season and BRRI dhan49 was in T. Aman season. In Boro season,

Table 2. Grain yield of DT Boro Rice in Boro-Fallow-T. Aman cropping pattern, BRRI, Gazipur 2012-13.

Treatment	Grain yield (t/ha)
T_1=Normal transplanting with 80 DOS (TP: 25 Feb; Sowing: 5 Dec)	5.03
T_2=Normal transplanting with 60 DOS (TP: 25 Feb; Sowing: 25 Dec)	4.12
T_3=Normal transplanting with 40 DOS (TP: 25 Feb; Sowing: 15 Jan)	4.94
T_4=Double transplanting with removed seedling (100%) and no fertilizer in 1st transplanted plot	5.35
T_5=Double transplanting with removed seedling (100%) and 1st split urea in 1st transplanted plot	5.22
T_6=Remaining 25% seedling in fully fertilized 1st transplanted plot	6.12
CV (%)	11.5
$LSD_{0.05\%}$ for treatment	1.07

Table 3. Grain yield of DT Aman Rice in Boro-Fallow-T. Aman cropping pattern, BRRI, Gazipur 2013.

Treatment	Grain yield (t/ha)
T_1=Normal transplanting with 60 DOS (TP: 25 Sep; Sowing: 25 Jul)	2.86
T_2=Normal transplanting with 45 DOS (TP: 25 Sep.; Sowing: 10 Aug)	3.50
T_3=Normal transplanting with 30 DOS (TP: 25 Sep.; Sowing: 25 Aug)	-
T_4=Double transplanting with removed seedling (100%) and no fertilizer in 1st transplanted plot	4.40
T_5=Double transplanting with removed seedling (100%) and 1st split urea in 1st transplanted plot	4.72
T_6=Double transplanting with removed seedling (75%) and full fertilizer in 1st transplanted plot	5.25
T_7=Remaining 25% seedling in fully fertilized 1st transplanted plot	5.95
CV (%)	9.5
$LSD_{0.05}$ for treatment	0.64

each treatment received 119 kg N/ha and 136 kg N/ha as urea for BRRI dhan28 and BRRI dhan29 respectively. In T. Aman season, each treatment received 70 kg N/ha as urea. phosphorus, K, S and Zn were applied as triple super phosphate, muriate of potash, gypsum and zinc sulphate respectively, during final land preparation as per recommended rate.

Grain and straw yields were significantly affected by N application timing (N) and variety (V) in Boro season. But the interaction effects of N and V were insignificant. Significantly higher grain yield was produced under N_4, N_1, N_2 and N_3 treatments compared to N_5 treatment in BRRI dhan29. The grain yield producing order was N_4>N_1>N_2>N_3>N_5 in BRRI dhan29. In BRRI dahn28, the highest grain yield was obtained with the N_3 treatment, followed by the N_4, N_2 and N_1 treatments and minimum under the N_5 treatment (Table 4). Grain yield under the N treatments was in the order of N_3>N_4>N_2>N_1>N_5. BRRI dhan29 achieved significantly higher grain yield and straw yield compared to BRRI dhan28, irrespective of different N treatments. Nitrogen treatment significantly affected the straw yield production. Agronomic use efficiency (AUE) was not significantly affected by N application timing. Apparently the higher AUE in BRRI dhan29 was in N_4 treatment (17.85 kg/kg) followed by N_1 and N_2 treatments (16.14 and 15.50 kg/kg respectively). But in BRRI dhan28, the N_4 treatment also gave the higher AUE (14.21 kg/kg) followed by N_3 and N_2 treatments (14.13 and 13.88 kg/kg respectively). In T. Aman season, timing of N application treatments had significant effect ($p<0.01$) on grain yield. Significantly higher grain yield was observed in N_4 treatment followed by N_3, N_2 and N_1 treatments. The lowest grain yield was produced in N_6 treatment. Grain yield under the N treatments was in the order of N_4> N_3> N_2> N_1> N_5> N_6 (Table 5).

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

A study was designed to determine the long-term implications of Potato-Boro-T. Aman, Maize-Mungbean-T. Aman and Boro-T. Aus-T. Aman

Table 4. Grain yield, straw yield and agronomic use efficiency (AUE) of Boro rice in Boro-Fallow-T. Aman cropping pattern, BRRI, Gazipur 2013-14.

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		AUE (kg/kg)	
	BRRI dhan28	BRRI dhan29	BRRI dhan28	BRRI dhan29	BRRI dhan28	BRRI dhan29
N_1	5.33	6.90	5.84	7.69	9.92	16.14
N_2	5.80	6.82	6.33	7.42	13.88	15.50
N_3	6.04	6.67	6.65	6.90	14.13	14.46
N_4	5.84	7.13	6.23	7.66	14.21	17.85
N_5	4.15	4.71	5.22	6.19	-	-
F value for V	** (0.45)		** (0.41)		ns	
F value for N	** (0.72)		** (0.65)		ns	
F value for V×N	ns		ns		ns	
CV (%)	10.0		8.1		24.9	

**, ns=significant at the 0.01 probability level and not significant respectively.

Table 5. Grain yield of T. Aman rice in Boro-Fallow-T. Aman cropping pattern, BRRI, Gazipur 2014.

Treatment	Grain yield (t/ha)
N_1	5.13
N_2	5.33
N_3	5.47
N_4	5.50
N_5	4.60
N_6	3.99
F value for N	** (0.49)
CV (%)	5.4

**Significant at the 0.01 probability level.

cropping patterns on the system productivity, economics and soil fertility. The experiment was conducted during 2011-12 at the experimental farms, BRRI HQ, Gazipur and BRRI RS, Rangpur. 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. Recommended management practices were followed. Table 6 presents the yield, REY and economic performance.

Evaluation of double transplanting at low lying area (*Haor* area) under Boro-Fallow-Fallow cropping pattern

This study was undertaken to evaluate the performance of double transplanted rice in haor areas to escape flash flood at ripening stage of Boro by reducing life span using double transplanting. The study was conducted at BRRI RS, Habiganj during Boro 2013-14 seasons. The design of the experiment was RCB with three replications. The treatments: T_1-Normal transplanting (45-day-old seedling) with 20- × 20-cm spacing; T_2-Normal transplanting (45-day-old seedling) with 20- × 10-cm spacing; T_3-Double transplanting (first transplanting of 45-day-old seedlings and 2nd transplanting with tillers of 30-day-old crop of 1st planting from T_2 Plot); T_4-Delayed transplanting (75-day-old seedlings) were evaluated. BRRI dhan29 was grown in this experiment. Normal transplanting produced significantly higher grain yield than the DT and delayed transplanting (Table 7). Significantly highest grain yield was obtained from normal planting (T_1=8.90 t/ha and T_2=8.80 t/ha) and lowest grain yield was observed from delayed transplanting of 75-day-old seedlings (7.59 t/ha). DT gave significantly higher grain yield (8.32 t/ha) than the delayed planting. Crop duration of delay planting was higher than the normal and DT. In DT the duration was one week shorter than delayed transplanting and four days longer than normal transplanting which may provide an opportunity to escape crop from early flash flood from delayed transplanting in *haor* area.

Evaluation of rice-based cropping pattern in partially irrigated ecosystem

This investigation was undertaken to evaluate the performance of some recently released BRRI

Table 6. Yield of rice, potato and mungbean and REY under different cropping patterns, BRRI, Gazipur and Rangpur 2012-13.

Cropping pattern	Grain/Tuber yield (t/ha)				REY (t/ha)
	Maize/Potato	Boro	T. Aus/Mug	T. Aman	
		Rangpur			
Boro-Fallow-T. Aman	-	7.6	-	3.2	11.03
Boro-T. Aus-T. Aman	-	5.9	2.5	3.3	11.36
Maize-Mungbean*-T. Aman	6.4	-	*	3.2	7.06
Potato-Boro-T. Aman	25.3	4.76	-	3.0	17.83
CV (%)					8.90
Lsd (0.05)					**1.80**
		Gazipur			
Boro-Fallow-T. Aman	-	6.43	-	5	11.56
Boro-T. Aus-T. Aman	-	4.13	4.3	5.2	13.61
Maize-Mungbean-T. Aman	5.3	-	0.63	5.2	10.42
Potato-Boro-T. Aman	13.1	3.1	-	5.3	13.65
CV (%)					4.70
Lsd (0.05)					**1.16**

In case of REY, means followed by common letter(s) are not different at the 5% level of significance. Price: Potato- Tk 8/kg, Rice- Tk 20/kg, Maize- Tk 12/kg, Mungbean- Tk 65/kg. *Establishment was not possible due to high soil moisture.

Table 7. Yield and yield contributing characters of Boro at BRRI RS, Habiganj 2013-14.

Treatment	Panicle (no./m^2)	Filled grain (no./pan)	1000-grain wt (g)	Yield (t/ha)	Duration (day)
T$_1$: NT (45-day-old seedling) with 20- × 20-cm spacing	366.33	121.83	21.09	8.90a	161
T$_2$: NT (45-day-old seedling) with 20- × 10-cm spacing	351.00	116.90	20.78	8.80a	162
T$_3$: DT (45 days SB + 30 days 1st TP)	350.33	117.90	21.64	8.32b	165
T$_4$: NT (75-day-old seedling)	315.67	109.87	21.69	7.59c	173

In a column, means followed by different letters differ significantly at the 5% by DMRT.

varieties in Vegetable-Mungbean-DS Aman cropping system. The experiment was conducted at east byde, BRRI experimental farm, Gazipur during 2013-14. Five cropping patterns viz, Tomato (BARI hybrid tomato5)-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)-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.

The REY among the tested patterns yielded from 27.36 to 30.46 t ha^{-1} and apparently the higher REY was observed in CP$_4$ followed by CP$_5$ and CP$_1$.The lower REY was produced under CP$_2$ (Table 8). Higher gross return, gross margin and benefit cost ratio (BCR) were obtained from CP$_4$ (Tomato-Mungbean-BRRI dhan39) followed by CP$_5$ (Tomato-Mungbean-BRRI dhan33) and CP$_1$ (Tomato-Mungbean-BRRI dhan57). The total variable cost (TVC) was similar in the tested cropping patterns due to similar monetary involvement (Table 9).

Evaluation of BRRI prilled urea applicator in Boro and T. Aman rice in Boro-Fallow-T. Aman cropping system

This study was designed to find out the amount of saved urea using applicator and determine N use efficiency of different applied methods of N application and compare the yield and yield contributing characters under varying methods of N application. The experiment was conducted in Boro and T. Aman seasons of 2013-14, at the experimental farm, BRRI, Gazipur. There were five treatments: (i) Hand broadcasting of prilled urea as per BRRI recommendation (T$_1$), (ii) USG application by applicator (2.7 g/4 hills) (T$_2$), (iii) Prilled urea application by applicator (70% of the recommended urea in broadcasting) (T$_3$), (iv) Hand broadcasting of prilled urea as per T$_3$ dose (T$_4$) and (v) N-control (T$_5$). BRRI dhan28 and BRRI dhan44 were grown in Boro and T. Aman season respectively. Treatment showed significant effect on grain yield and the highest grain yield was obtained from T$_3$ followed by T$_1$ treatment. The lowest yield was observed in T$_5$ treatment. In straw yield, a similar trend was observed and the highest straw yield was found in T$_3$ followed by T$_1$ treatment. Harvest index did not differ significantly. Agronomic use efficiency (AUE) differed significantly (p<0.01) among the treatments.

Table 8. Yield of tomato, mungbean and rice and REY of different cropping patterns, BRRI, Gazipur 2013-14.

Cropping pattern	Yield t ha^{-1}			REY (t ha^{-1})
	Tomato	Mungbean	DS Aman	
BARI hybrid tomato-5-BARI mug-6-BRRI dhan57 (CP$_1$)	37.84	1.57	3.8	30.06
BARI hybrid tomato-5-BARI mug-6-BRRI dhan56 (CP$_2$)	33.08	1.69	3.37	27.36
BARI hybrid tomato-5-BARI mug-6-BRRI dhan62 (CP$_3$)	33.48	1.82	3.74	28.40
BARI hybrid tomato-5-BARI mug-6-BRRI dhan39 (CP$_4$)	36.82	1.76	4.14	30.46
BARI hybrid tomato-5-BARI mug-6-BRRI dhan33 (CP$_5$)	38.41	1.58	3.81	30.43
CV(%)	-	-	19.8	15.9
F-values	-	-	ns	ns

ns=not significant, Price: Tomato- Tk 10/kg, Mungbean- Tk 60/kg and Rice- Tk 18/kg.

Table 9. Economic performance of different cropping patterns, BRRI, Gazipur 2013-14.

Cropping pattern	TVC ('000 Tk/ha)	Gross return ('000 Tk/ha)	Gross margin ('000 Tk/ha)	BCR
BARI hybrid tomato-5-BARI mug-6-BRRI dhan57 (CP$_1$)	541.08	156.09	384.99	3.47
BARI hybrid tomato-5-BARI mug-6-BRRI dhan56 (CP$_2$)	492.48	156.09	336.39	3.16
BARI hybrid tomato-5-BARI mug-6-BRRI dhan62 (CP$_3$)	511.20	156.09	355.11	3.27
BARI hybrid tomato-5-BARI mug-6-BRRI dhan39 (CP$_4$)	548.28	156.09	392.19	3.51
BARI hybrid tomato-5-BARI mug-6-BRRI dhan33 (CP$_5$)	547.74	156.09	391.85	3.50

The AUE was the highest (44 kg/kg) in T_3 followed by T_1 (30 kg/kg) (Table 10). In T. Aman season, rice grain yield was significantly affected by different N management treatments. The significantly higher grain yield was obtained from T_1 treatment followed by T_3 and T_2 treatments. The lowest yield was observed in T_5 treatment. The grain yield producing order under different treatments was $T_1> T_3> T_2> T_4> T_5$ (Table 11).

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

This study was undertaken to assess the suitability of growing different short duration Rabi vegetables with hybrid maize in Maize-Sweet gourd-T. Aman cropping system. The study was conducted at farmer's field of Chuadanga sadar, during November 2013 to November 2014. Three cropping patterns viz, Maize+Spinach-Sweet gourd-T. Aman, Maize+Potato-Sweet gourd-T. Aman and Maize+Carrot-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. 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 (27.22 t/ha) was obtained from CP$_3$ followed by CP$_2$. High yield of potato and spinach compared to carrot contributed significant difference among the tested patterns. Significantly lower MEY were obtained from sole maize plot (Table 12).

From the economic analysis, the highest gross margin was obtained from CP$_3$ (Tk 137000/ha) followed by CP$_2$. CP$_3$ and CP$_2$ that gave about 56 and 41% higher gross margin (GM) than the check pattern. The lowest gross margin (Tk 86,000/ha) was obtained from the pattern CP$_1$ which was 2% lower than the check pattern (Table 13).

Development of Rice-Sunflower cropping pattern for rainfed coastal saline area

This experiment was undertaken with a view to evaluate the T. Aman-Sunflower cropping pattern against the existing single T. Aman rice cropping pattern in rainfed medium coastal saline area. The field experiment on dibbling dates, (a) zero tilled dibbled in moist soil on 14 January, (b) dibbled in tilled soil at field capacity on 22 February, (c) dibbled in tilled soil at field capacity on 29 February, (d) dibbled in tilled soil at field capacity on 5 March was arranged in a randomized

Table 10. Grain yield and yield contributing characters of BRRI dhan28 under different N application method, Boro 2013-14.

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index	AUE (kg/kg)	Panicle (no./m^2)	Filled grain (no./panicle)	1000-grain wt (g)	Sterility (%)
T_1	6.86	7.77	0.47	30	302	92	22.99	17
T_2	4.26	4.70	0.48	12	225	86	23.22	18
T_3	6.96	8.17	0.46	44	317	89	23.35	17
T_4	5.18	6.27	0.45	23	288	113	23.09	12
T_5	3.22	4.13	0.43	-	199	74	24.07	14
F-values	**	**	ns	**	*	ns	ns	ns
LSD$_{0.05}$	1.41	1.49	0.07	5.99	75.5	27.6	0.85	6.5
CV (%)	14.1	12.8	8.8	11.0	15.1	16.1	1.9	22.0

Note: USG was not effective due to long time storage. *, **, ns=significant at the 0.05 and 0.01 probability levels and not significant respectively.

Table 11. Grain yield of BRRI dhan44 under different N application methods, T. Aman 2014.

Treatment	Grain yield (t/ha)
T_1	5.66
T_2	5.53
T_3	5.60
T_4	4.59
T_5	4.16
F value for N	** (0.33)
CV (%)	3.4

**significant at the 0.01 probability level.

complete bock design with four replications in 2012. The study on cropping sequence including sunflower after T. Aman harvest was conducted during July 2012 to May 2013 at farmers' field of Ponchu, Dumuria, Khulna. Twelve representative adjacent farmer's fields were selected where T. Aman rice-Fallow cropping pattern has been in practice over the period of three decades. The study area belongs to agro-ecological zone 13 where dry season crops could not grow due to soil salinity (6-8 dS m^{-1}) and lack of fresh irrigation water. The high yielding rice variety, BR23 and the popular local variety, Jotaibalam were grown in each of six farmers' fields. After harvesting of T. Aman rice each field was divided into two subplots where the hybrid sunflower variety, Hysun33 was grown in a part keeping the other fallow. Thus the combination of cropping of LV T. Aman-Fallow, LV T. Aman-Sunflower, HYV T. Aman-Fallow and HYV T. Aman-Sunflower were assigned in a RCB design with six dispersed replications.

Grain yield of HYV and LV T. Aman rice varied significantly (Table 14). Irrespective of cropping sequence, grain yield of HYV was higher (4.61 and 4.65 t ha^{-1}) compared to LV rice (1.89 and 2.09 t ha^{-1}). The yield differences of HYV and LV rice under cropping sequences were not significant which indicated the similar fertility of the soils of the study fields. Straw yield of rice followed the similar trend of grain yield. High yielding variety and LV rice produced 4.81 and 4.84 t ha^{-1} and 2.37 and 2.62 t ha^{-1} respectively. The HYV rice required higher fertilizer, pesticide, labour cost which accounted higher total variable cost (Tk 40,001 and 41,437 ha^{-1} compared to LV rice (Tk 25,545 and 25,959 ha^{-1}). The higher investment in HYV gave higher gross return (Tk 76,304 and 77,062 ha^{-1}) due to their higher yield. Gross margin was recorded higher in HYV (Tk 34,866 and 37,061 ha^{-1}) than that of LV rice (Tk 14,267 and 16,815 ha^{-1}). The benefit cost ratio was recorded 1.94 and 2.00 in HYV whereas it was 1.55 to 1.66 in LV rice.

Seed yield of succeeding sunflower was similar irrespective of HYV and LV of T. Aman rice (Table 15). Sunflower yielded 1.95 and 2.02 t ha^{-1} after LV and HYV rice, respectively. The TVC and GR were more or less similar in those sunflowers (Table 15). The BCR was recorded 2.65 and 2.73 in those cases, respectively.

Table 12. Yield and maize equivalent yield (MEY) of different cropping patterns, Chuadanga 2013-14.

Treatment	Yield (t/ha)				MEY (t/ha)
	Maize	Carrot/Potato/Spinach	Sweet gourd	T. Aman	
Maize+Carrot-Sweet gourd-T. Aman (CP_1)	8.56	1.06	18.06	4.46	20.23
Maize+Spinach-Sweet gourd-T. Aman (CP_2)	7.98	11.65	18.22	3.62	22.51
Maize+Potato-Sweet gourd-T. Aman (CP_3)	7.80	15.98	18.13	3.77	27.22
Sole Maize-Sweet gourd-T. Aman (CP_4)	9.01	-	18.27	3.94	19.44
CV (%)	-	-	-	-	4.8
F for treatment	-	-	-	-	**
$LSD_{0.05}$ for treatment	-	-	-	-	2.16

Table 13. Economic performance of different cropping patterns, Chuadanga 2013-14.

Cropping pattern	TVC (000 Tk/ha)	GR (000 Tk/ha)	GM (000 Tk/ha)	GM (%) over FP
Maize+Carrot-Sweet gourd-T. Aman (CP_1)	203	289	86	(-) 2
Maize+Spinach-Sweet gourd-T. Aman (CP_2)	197	321	124	(+) 41
Maize+Potato-Sweet gourd-T. Aman (CP_3)	241	378	137	(+) 56
Sole Maize-Sweet gourd-T. Aman (CP_4)*	190	278	88	-

*Farmer's practice.

Table 14. Grain and straw yield and economic return of T. Aman rice under different cropping sequence, Khulna 2012-13.

Cropping sequence	Grain yield (t ha⁻¹)	Straw yield (t ha⁻¹)	TVC (Tk ha⁻¹)	GR (Tk ha⁻¹)	GM (Tk ha⁻¹)	BCR
LV rice-Sunflower	2.09	2.62	25545	42360	16815	1.66
HYV rice-Sunflower	4.65	4.84	40001	77062	37061	2.00
LV rice-Fallow	1.89	2.37	25959	40226	14267	1.55
HYV rice-Fallow	4.61	4.81	41437	76304	34866	1.94
LSD $_{0.05}$	0.29	0.34	-	-	-	-
CV (%)	7.2	7.7	-	-	-	-

Table 15. Seed yield and economic return of sunflower under rice sunflower cropping sequence, Khulna 2012-13.

Cropping sequence	Grain yield (t ha⁻¹)	TVC (Tk ha⁻¹)	GR (Tk ha⁻¹)	GM (Tk ha⁻¹)	BCR
LV rice-Sunflower	1.95	33307	87758	54452	2.65
HYV rice-Sunflower	2.02	33343	90887	57544	2.73
LSD $_{0.05}$	ns	-	-	-	-
CV (%)	7.3	-	-	-	-

ns=not significant.

The REY varied significantly among the cropping sequence combinations (Table 16). The highest REY was recorded in HYV T. Aman-Sunflower (10.04 t ha⁻¹) significantly followed by LV rice-Sunflower (6.36 t ha⁻¹) which were about 118 and 237% higher than HYV rice-Fallow and LV rice-Fallow respectively. Results indicated that the inclusion of sunflower after T. Aman rice increased the cropping intensity and thus increased productivity. The highest TVC was recorded higher in HYV rice-Sunflower (Tk 7,33,344 ha⁻¹) followed by LV rice-Sunflower (Tk 58,852 ha⁻¹). Inclusion of sunflower increased the TVC which also earned higher gross return.

Evaluation of fertilizer management options in major crops in Kushtia region

Farmers in Bangladesh especially Chuadanga, Meherpur, Kushtia and Jhenaidaha districts usually apply several folds higher amount of different fertilizers compared to BRRI recommended rates. Therefore, the present study was undertaken to demonstrate the impact of using recommended fertilizer dose on yield of T. Aman rice. Each farmer's field was divided into three parts to imply the treatments viz, BRRI recommended fertilizer dose, soil test based fertilizer dose and farmer's usual fertilizer dose. On average, farmers apply 113, 171, 56 and 254% higher urea, TSP, MoP and gypsum respectively compared to BRRI recommended dose and farmer's average urea, TSP, MoP, gypsum and zinc sulphate dose was 101, 965, 62, 247 and 138% higher than that of soil test based fertilizer dose respectively.

Tables 17 and 18 present the effect of different fertilizer management options on yield and yield contributing characters. In Chuadanga and Meherpur sadar, there was no significant difference among the treatments in case of different yield contributing characters. In Chuadanga sadar, BRRI recommended fertilizer management and farmer's practice gave similar grain yield. Whereas soil test based fertilizer treatment resulted significantly lower grain yield compared to other treatments. In Meherpur, BRRI recommended fertilizer management and farmer's practice gave significantly higher grain yield than that of soil test based fertilizer treatment.

Table 16. Rice equivalent yield and economic return of different cropping sequences, Khulna 2012-13.

Cropping sequence	REY (t ha⁻¹)	TVC (Tk ha⁻¹)	GR (Tk ha⁻¹)	GM (Tk ha⁻¹)	BCR
LV rice-Sunflower	6.36	58852	130118	71266	2.21
HYV rice-Sunflower	10.04	733344	167948	94605	2.33
LV rice-Fallow	1.89	25959	40226	14267	1.55
HYV rice-Fallow	4.61	41437	76304	34866	1.94
LSD $_{0.05}$	0.42	-	-	-	-
CV (%)	6.1	-	-	-	-

Table 17. Grain yield and yield contributing characters of T. Aman rice under different fertilizer management options, Chuadanga sadar 2014.

Treatment	Tiller (no./m^2)	Panicle (no./m^2)	Panicle length (cm)	Grain/ panicle	Unfilled grain/ panicle	1000-grain wt (g)	Grain yield (t/ha)
Soil test based	234	232	23.22	113	12	30.36	4.05
BRRI recommended	222	220	23.28	111	11	30.11	4.48
Farmer's practice	239	235	23.27	114	12	29.76	4.38
CV (%)	10.1	10.4	7.5	25.4	63.7	2.2	5.8
F for treatment	NS	NS	NS	NS	NS	NS	**
LSD$_{0.05}$ for treatment	-	-	-	-	-	-	0.24

Table 18. Grain yield and yield contributing characters of T. Aman rice under different fertilizer management options, Meherpur sadar 2014.

Treatment	Plant ht (cm)	Tiller (no./m^2)	Panicle (no./m^2)	Panicle length (cm)	Grain/ panicle	Unfilled grain/ panicle	1000-grain wt (g)	Grain yield (t/ha)
Soil test based	108	152	148	20.83	114	30	30.05	4.33
BRRI recommended	113	174	170	21.83	138	21	30.73	4.75
Farmer's practice	115	162	159	21.50	138	30	30.31	4.75
CV (%)	3.1	12.3	12.8	5.8	12.2	42.7	3.4	4.0
F for treatment	NS	NS	NS	NS	NS	NS	NS	*
LSD$_{0.05}$ for treatment	4.49	25.79	26.17	1.6	20.31	14.9	1.33	0.24

FARMING SYSTEMS TECHNOLOGY TRANSFER

Multi-location testing of BRRI dhan46-BRRI dhan29-Fallow cropping pattern in different locations

Multi-location trial of BRRI dhan46-BRRI dhan29-Fallow cropping pattern in medium highland phase II was undertaken at Madhabpur upazila of Habiganj district. Block demonstration was done at five bigha land of five farmers. BRRI recommended management practices adopted in T. Aman and Boro seasons. The recommended patterns gave 15% higher grain yield and gross margin over existing farmers' patterns. The recommended cropping pattern gave the yield of 11.72 t/ha and gross margin of Tk 222,680/ha (Tables 19 and 20). It was because of higher yield advantage between recommended and farmers' practice in both T. Aman and Boro seasons of newly released variety BRRI dhan46 which allowed to accommodate BRRI dhan29 in the pattern instead of BRRI dhan28.

Performance of improved rice varieties in jhum cultivation

A study was undertaken to observe the performance of BRRI dhan55 and NERICA Mutant (Kudrat) along with the local check Pidi to indentify the suitable rice variety for increasing system productivity under jhum at Banderban sadar, Banderban. The seeds of the varieties were sown in June in hill slope with four replications. Other crop management practices were followed as per farmers' choice. Table 21 presents the plant height, yield components and the grain yield. The plant height was found higher in the existing rice, Pidi compared to the HYVs. Plant height was similar in BRRI dhan55 and NERICA Mutant (Kudrat). Similar number of panicles was recorded in all the tested rice varieties. Kudrat and Pidi produced similar filled grain/panicle which was higher than BRRI dhan55. The 1000 grain weight (TGW) was found higher in Kudrat compared to other two varieties. Although there was significant differences in filled grain/panicle

Table 19. Grain yield of T. Aman-Boro-Fallow cropping pattern in Habiganj 2013-14.

Management	Cropping pattern	Grain yield of T. Aman (t/ha)	Grain yield of Boro (t/ha)	Total grain yield (t/ha)	Yield increased than FP
Recommended management	BRRI dhan46-BRRI dhan29-Fallow	4.80	6.92	11.72	15.12
Farmers' practice	BR22-BRRI dhan28-Fallow	4.30	5.88	10.18	

Table 20. Gross return of T. Aman-Boro-Fallow cropping pattern in Habiganj 2013-14.

Management	Cropping pattern	Gross return of T. Aman (Tk/ha)	Gross return of Boro (Tk/ha)	Total gross return (Tk/ha)	Return increased (%)
Recommended management	BRRI dhan46-BRRI dhan29-Fallow	91,200	131,480	222,680	15.12
Farmers' practice	BR22-BRRI dhan28-Fallow	81,700	111,720	193,420	

Price of paddy Tk 18/kg, and Straw Tk 1/kg.

Table 21. Plant height, yield component and grain yield of rice varieties under jhum cultivation, 2014.

Variety	Plant ht (cm)	Panicle (no./m^2)	Filled grain/panicle	TGW (g)	Grain yield (t/ha)
BRRI dhan55	89	177	83.33	26.38	3.86
NERICA Mutant (Kudrat)	86	174	92.02	26.72	4.23
Pidi	133	163	93.13	29.77	4.47
LSD$_{0.05}$	4	ns	5.83	2.51	ns
CV (%)	1.5	3.9	2.9	4.0	7.5

and TGW, There was no significant difference in grain yield among the varieties. However, Pidi gave 0.5 t/ha higher grain yield than BRRI dhan55.

Validation of improved cropping systems for greater Kushtia

Improved cropping patterns were validated to increase the system productivity through introduction of improved and intensified cropping pattern in farmer's fields of different ecosystems of greater Kushtia district. 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 variety BRRI dhan57. After harvesting of BRRI dhan57 a short duration mustard variety BARI sahrisha-14 was sown in the same land. In all blocks of Chuadanga proposed improved pattern resulted significantly higher rice equivalent yield (REY) compared to the farmers' practice. In Kutubpur Union Chuadanga sadar and Jehala union, Alamdanga Mustard-Boro-T. Aman cropping pattern was tested over the existing Boro-Fallow-T. Aman. The REY of the improved pattern was 13.17 and 12.67 in the two locations respectively while the REY of existing cropping pattern were 10.68 and 10.76. Similar results were also found in Subitpur, Meherpur, Komorpur Meherpur, Nagdaha, Alamdanga and Meherpur Sadar, Meherpur. Similarly other improved cropping patterns like Potato-Boro-T. Aman, Maize-Mungbean-T.

Aman, Wheat-Mungbean-T. Aman, Lentil-Jute-T. Aman, Maize-Til-T. Aman, Lentil-Til-T. Aman, Wheat-Til-T. Aman and Potato-Mukhikachu-T. Aman against the existing cropping patterns of Boro-Fallow-T. Aman, Boro-Fallow-T. Aman, Maize-Fallow- T. Aman, Wheat-Jute-T. Aman, Wheat-Jute-T. Aman, Lentil-Jute-T. Aman, wheat –Jute-T. Aman and Boro-Mukhikachu-Fallow.

Validation of improved cropping patterns for northern region

Improved three cropped cropping patterns with newly released varieties were validated against the existing three cropped cropping patterns in the farmer' field of Rangpur, Kurigram, Nilphamari and Lalmonirhat district. The improved cropping patterns were- i) Potato (Diamant/Aesterix/ Cardinal)-Boro (BRRI dhan28)-T. Aman (BRRI dhan49), ii) Potato (Diamant/Aesterix/Cardinal)-Boro (BRRI dhan55)-T. Aman (BRRI dhan49), iii) Potato (Diamant/Aesterix/Cardinal)-Maize (BARI hybrid bhutta-5)-T. Aman (BRRI dhan57) and iv) Wheat (BARI gom-26)-Mungbean (BARI mug-6)-T. Aman (BRRI dhan57). Technological advantages were measured with these improved cropping patterns.

FARMERS' LIVELIHOOD IMPROVEMENT

A coordinated sub-project on farming systems research and development for farmers' livelihood improvement BRRI component was undertaken by

BARC to address non-saline tide prone area of Barisal and non-*haor* area of Sylhet region. The project sites were in Chakhar union of Banaripara upazila under Barisal district and Jagatpur village under sadar upazila of Habiganj district. The project was aimed to improve the production, income, employment and nutrition etc and ultimately to enhance livelihood status of the target farms towards poverty alleviation. The objectives were to :

- Develop location-specific system-based technologies,
- Modify/fine tune on-station technologies generated by NARS institutes at different Agro-ecological zones (AEZs),
- Integrate component technologies (crops, livestock, fisheries, agro-forestry and homestead, etc) for improving farm practices and establish linkage with different stakeholders and
- Improve family income and livelihoods.

Results are very briefly presented as follows:

Introduction of improved cropping pattern by replacing local rice variety Sadamota and Bhojon with modern T. Aman and Boro varieties increased 11-299% gross margin compared to existing pattern.

Introduction of improved patterns with new crops viz, BARI Mung-5, BARI Mung-6 and BARI *Sarisha*-14 that increased the gross margin 543-1241% compared to existing pattern.

Fish + vegetables production in *Sorjan* system appeared as profitable with the increased gross margin of Tk 2,25,428-9,40,557 per ha in Barisal region.

Introduction of high value fish species viz, *Magur*, *Shing* and *Koi* in *Sorjan* system appeared as potential and profitable technology.

Introduction of fish in single or double rice system with modern rice varieties appeared as profitable with increased REY of 16.12-19.86 t/ha in single rice system and 14.84-18.33 t/ha in double rice system in Barisal area.

Carp poly-culture technique with low-cost management practices appeared promising with the gross margin of Tk 1,15,366-2,27,240 per ha in Barisal area.

Vaccination for cattle and poultry significantly reduced the mortality rate in both sites.

Visual health improvement of cattle and goat was observed along with 11% higher milk production of cattle by de-worming.

Duck and chicken rearing is remunerative to the farmers along with additional monthly income of Tk 840 from six ducks and Tk 461 from 10 chickens respectively.

Vegetables intercropping with Banana that fetched the gross margin of Tk 2,41,935 per ha in Habiganj area.

Higher (33.5%) gross margin was found in BRRI dhan48 than BRRI dhan28 in Aus season in Habiganj area.

Aromatic rice viz BRRI dhan34 in T. Aman season and BRRI dhan50 in Boro season appeared potential variety with the gross margin of Tk 37,500 and 53,500 per ha respectively.

Agricultural Economics Division

SUMMARY

BRRI dhan28 and BRRI dhan29 were the most popular varieties in Boro season covering 65% of the area, whereas BR11 and BRRI dhan49 were the mostly adopted varieties (20%) in T. Aman season. In Aus season, area coverage of BRRI dhan28 was the highest (19%) followed by BRRI dhan48 (7%). BRRI dhan29 was the top yielder in Boro (5.75 t/ha) season followed by BRRI dhan58 (5.50 t/ha). In T. Aman season, BRRI dhan49 ranked top in terms of per unit yield (4.79 t/ha) followed by BRRI dhan46 (4.73 t/ha). In Aus season, BRRI dhan29 also produced higher yield (5.02 t/ha) followed by both BR16 and BRRI dahn48 (4.40 t/ha). Hybrids rice are being adopted as replacement of other MVs in both Boro and Aus seasons due to higher yield performance.

Rice farmers used more seeds than the recommended rate irrespective of cropping season. Although, they used higher dose of urea, they applied comparatively lower amount of MoP fertilizer, 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. MV T. Aman growers received higher net return due to lower costs of production and better market price.

Although, mango cultivation required huge cost initially, received higher net return than the other crops which is the main reason of shifting their crop land to mango orchard in Barind region.

Variety selection was not quite accurate in Khulna district as long duration and coarse grain varieties were demonstrated under SPDP and the farmers were not interested to preserve seed as TLS and foundation seeds were available.

Value chain analysis indicates that the miller captured the highest net margin (45%) followed by the retailer (15%) and wholesaler (13%). On the other hand, miller and wholesaler shared the highest marketing cost (52% and 15%) among the actors of the rice supply chain. The rice market structure should be guided to transitional value chain of less intermediaries' actor-involvement and their roles should be valued as per their contribution in value addition.

Bangladesh is severely vulnerable to the impacts of climate change due to its geographic location; flat and low-lying topography; dense population; high poverty; reliance of livelihoods on climate sensitive agriculture. Under this situation the production of Aman and Boro, is increasing and thereby boosting up the aggregate production of rice. The increasing trend in production eventually augmented the volume of rice stock and consequently declining the imports quantum.

Analysis indicates that ARIMA (3, 1, 1), ARIMA (4, 1, 2), ARIMA (2, 2, ma(9)) and ARIMA (2, 1, 4) were the best fitted model for short run forecasting of Aus, Aman, Boro rice and wheat production respectively. On the basis of the fitted models, production of Aus, Aman, Boro and wheat would be 2330, 14235, 18809 and 1698 thousand tons respectively by the year 2022-23. On the other hand, best ARIMA models for area of Aus, Aman, Boro and wheat were (2, 1, 2), ARIMA (3, 1, 1), ARIMA (2, 1, 2) and ARIMA (3, 1, 2) would be 557, 5628, 5698 and 515 thousand ha respectively by 2022-23.

Irrigation cost is increasing continuously due to higher fuel, electricity and labour costs. The projected irrigation cost would be 20 and 19% higher by 2024 for STW and DTW respectively. Irrigation cost could be minimized by improving on farm water management practices. So, policies should be taken to promote water management practices and training.

FARM LEVEL EVALUATION OF MODERN RICE CULTIVATION IN BANGLADESH

Agricultural Economics Division of BRRI has been conducting survey to monitor the farm level adoption status and yield performance of different rice varieties in Aus, T. Aman and Boro seasons with the following objectives:

● Determine the region-wise adoption rate of different MVs in Boro, Aus and T. Aman seasons; and
● Estimate the yield of different modern and local rice varieties.

A total of 4,034 sample farmers were selected through multistage stratified random sampling

technique and interviewed under Aus, T. Aman and Boro seasons. Indeed, pooled data were used in this study to cover most of the districts of Bangladesh from 2009-10 to 2013-14.

Adoption of modern rice varieties

In Boro season, BRRI dhan28 and BRRI dhan29 were dominant rice varieties covering 65% of the total area (Table 1). There were other promising hybrid and modern varieties, which covered about 13 and 4% of the Boro area respectively. The overall adoption rate of BRRI varieties was about 77%. Nevertheless, the coverage of modern varieties in Boro season was about 98% (Table 1). BBS study also reveals that coverage of MV Boro was about 99% in 2012-13 season.

BR11 and BRRI dhan49 appeared as the prominent rice varieties covering 20% areas in T. Aman season. The adoption rate of BRRI varieties was 50% in T. Aman season whereas the coverage of Indian varieties was about 21%. The overall coverage of modern varieties was 79% in this season (Table 2). The adoption rate of modern Aus varieties was about 86% of which BRRI varieties

was about 66%. BRRI dhan28 ranked the top position (19%) in terms of area coverage followed by BRRI dhan48 (7%). The Indian and other MVs covered about 15% area (Table 3).

Yield of modern rice varieties

In Boro season, BRRI dhan29 was the top yielder (5.75 t/ha) followed by BRRI dhan58 (5.50 t/ha), (Table 4). Average yield of BRRI varieties was 5.12 t/ha. The yield of hybrid rice was 5.97 t/ha. Among the BRRI varieties in T. Aman season, BRRI dhan49 was the top yielder (4.79 t/ha) followed by BRRI dhan52 (4.74 t/ha). Overall yield of modern varieties was 4.38 t/ha and the average yield of BRRI varieties was 4.25 t/ha (Table 5). In Aus season, BRRI dhan29 provided the highest yield (5.02 t/ha) followed by BR16 and BRRI dhan48 (4.40 t/ha each) jointly (Table 6).

Trend changes in adoption and yield level

The overall MV Aus adoption increased from 26% in 1990-91 to 86% in 2013-14. The adoption of modern varieties in T. Aman season increased from 34% in 1990-91 to 79% in 2013-14 (Table 7).

Table 1. Adoption (%) of different Boro rice varieties by agricultural regions of Bangladesh, 2013-14.

Variety	Region										
	Barisal	Chittagong	Comilla	Dhaka	Jessore	Mymensingh	Rajshahi	Rangamati	Rangpur	Sylhet	Av. (%)
BR14				15.33		5.75					4.47
BR16		13.51									0.91
BR26					6.50						1.00
BRRI dhan28	18.82	48.65	37.02	42.86	46.51	47.13	45.09	38.46	26.67	18.50	41.00
BRRI dhan29	20.00	31.34	40.98	18.00	16.49	23.84	16.76		40.33	34.74	24.00
BRRI dhan36								7.69			0.37
BRRI dhan47	12.94										2.01
BRRI dhan50				3.10			1.70				2.37
BRRI dhan52								3.85			0.18
BRRI dhan58									10.00		0.55
All BRRI varieties	51.76	93.50	78.00	76.19	72.60	76.72	63.55	50.00	77.00	53.24	76.86
All hybrid	19.88	5.00	13.25	21.43	13.00	19.54	12.32	43.03	14.00	43.26	12.50
Bhozan	9.41										1.20
Swarnamusuri			7.50								0.89
Kotarabari									3.83		0.73
All Indian varieties	14.11		7.50		12.20		2.49		7.50		4.19
Jira							18.09				2.89
76	1.18										0.18
Bina dhan8	5.88						1.05				0.91
Kalo IRRI	1.18										0.18
All other MVs	8.24						19.14	3.12			4.16
All MVs	93.99	98.50	98.75	97.62	97.80	96.26	97.50	96.15	98.50	96.50	97.61
All LVs	6.01	1.50	1.25	2.38	2.20	3.74	2.50	3.85	1.50	3.50	2.39
Grand total	100	100	100	100	100	100	100	100	100	100	100

Table 2. Adoption (%) of different MV T. Aman rice varieties by agricultural regions of Bangladesh, 2013-14.

Variety	Region										
	Barisal	Chittagong	Comilla	Dhaka	Jessore	Mymensingh	Rajshahi	Rangamati	Rangpur	Sylhet	Av. (%)
BR10								3.7		2.4	0.40
BR11	8.17	18.64	1.25	8.70		15.10	6.34	20.23	16.67	18.61	10.00
BR22	3.39	1.69	27.5	4.35						17.0	5.30
BR23	14.6			4.36							1.30
BRRI dhan28						1.64		11.11			0.70
BRRI dhan32		13.56	5.00		8.70	7.80					3.10
BRRI dhan33			2.50		8.70			5.12	8.21		2.10
BRRI dhan34				6.15	13.00	3.40	2.11				2.10
BRRI dhan39					4.32		10.56	3.70			3.10
BRRI dhan40	5.85				4.38						2.10
BRRI dhan41	3.77	3.39			4.35						1.30
BRRI dhan44	5.25										0.90
BRRI dhan46	3.39	1.69	2.50				1.70			9.80	1.10
BRRI dhan48							1.50				0.20
BRRI dhan49		23.73	11.25	34.78	18.23	14.80	13.38		16.68	12.0	10.00
BRRI dhan50								7.41			0.50
BRRI dhan51		3.39		4.35							0.50
BRRI dhan52	5.07		11.25	8.70		6.28	3.52			5.12	4.20
BRRI dhan56							3.52				0.90
BRRI dhan62			2.50								0.40
All BRRI varieties	49.49	66.09	63.75	71.39	61.69	49.02	42.63	51.27	41.56	64.93	50.20
All hybrid								14.11			0.50
Swarna		3.40		2.51	21.7	3.75	45.06		43.89	10.00	19.00
Other Indian varieties								6.70			1.50
All Indian varieties		3.40		2.51	21.7	3.75	45.06	6.70	43.89	10.00	20.50
Bina dhan7		2.39	7.5	4.35		11.5	2.41		5.11	5.14	2.30
Hori dhan						1.64		5.13			0.70
Pajam	2.20	11.49	1.25			4.28	2.75				4.70
All other MVs	2.20	13.88	8.75	4.35		17.4	5.16	5.13	5.11	5.14	8.30
All MVs	51.69	83.73	72.5	78.25	83.39	70.17	92.85	77.21	90.56	80.07	79.00
All LVs	48.31	13.28	27.5	21.75	16.61	29.83	7.15	22.79	9.44	19.93	21.00
Grand total	100	100	100	100	100	100	100	100	100	100	100

Table 3. Adoption (%) of different MV Aus rice varieties by agricultural regions of Bangladesh, 2013-14.

Variety	Region										
	Barisal	Chittagong	Comilla	Dhaka	Jessore	Mymensingh	Rajshahi	Rangamati	Rangpur	Sylhet	Av. (%)
BR1						5.21				2.12	2.58
BR2	20.30			18.37		2.30					4.54
BR3	2.12			3.12						6.53	2.41
BR14	5.01	7.59				3.12			1.54	10.82	5.87
BR16		8.88									0.24
BR21						4.12	10.21	7.76			0.65
BR26		13.90	12.12	3.13	16.20	18.20					3.28
BRRI dhan27	28.20							1.60			3.54
BRRI dhan28		8.54	23.04	9.95	28.3	20.40	40.43	5.32	35.50	27.26	19.15
BRRI dhan29					10.7				12.2	14.13	4.82
BRRI dhan33					8.34			6.65			1.45
BRRI dhan40										1.08	0.24
BRRI dhan42		19.01									1.13
BRRI dhan43			1.13								2.17
BRRI dhan47						8.93					1.2
BRRI dhan48		15.42		6.87					3.54		7.19
BRRI dhan50										2.15	0.48
Other BRRI varities	2.87		20.61	7.21		11.08	12.55	17.37	8.10	12.99	10.40

Table 3. Continued.

Variety	Region										
	Barisal	Chittagong	Comilla	Dhaka	Jessore	Mymensingh	Rajshahi	Rangamati	Rangpur	Sylhet	Av. (%)
All BRRI varieties	58.5	57.92	72.32	41.78	70.40	73.36	50.64	38.70	60.88	78.09	65.76
All hybrid		18.07	4.12		4.65		11.5	10.21	16.70		4.89
All Indian varieties	1.1			18.68	6.25		31.78	5.3	10.30	1.08	6.95
Basa IRRI		5.89									5.89
BAU63	6.28										0.24
China				9.21				14.65		5.38	3.61
IR50			10.35			1.20					0.48
Pajam						10.12				6.45	3.13
Minikit					3.12						0.18
All other MVs	6.28	5.89	10.35	9.21	3.12	11.32			14.65	11.83	8.45
All MVs	65.88	81.88	86.79	69.67	81.33	84.68	94.08	68.86	87.88	91.00	86.05
All LVs	34.12	18.12	13.21	30.33	18.7	15.32	5.92	31.14	12.12	9.00	13.95
Grand total	100	100	100	100	100	100	98.14	100	100	100	100

Table 4. Yield (t/ha) of different Boro rice varieties by agricultural regions of Bangladesh, 2013-14.

Variety	Region										
	Barisal	Chittagong	Comilla	Dhaka	Jessore	Mymensingh	Rajshahi	Rangamati	Rangpur	Sylhet	Av. (%)
BR14				5.45		4.57					5.01
BR16		3.89									3.89
BR26					4.66						4.66
BRRI dhan28	5.49	5.22	4.50	5.50	5.56	4.93	4.15	5.10	5.90	4.98	5.13
BRRI dhan29	6.21	5.79	5.50	6.00	5.75	5.68	5.25		5.50	6.12	5.75
BRRI dhan36								5.50			5.50
BRRI dhan50					4.01		3.15				3.58
BRRI dhan52								5.01			5.01
BRRI dhan58									5.50		5.50
All BRRI varieties	5.50	4.97	4.77	5.48	5.00	5.06	4.08	5.21	5.63	5.55	5.12
All hybrid	5.98	6.10	6.00	6.02	6.05	6.00	5.70	6.10	5.88	6.02	5.97
Nayanmoni						3.98					3.98
Parija									4.50		4.50
All Indian varieties	4.91		3.70		4.14				4.50		4.53
Bina dhan8	4.92					4.94					4.93
Kalo IRRI	5.49										5.49
All other MVs	5.09						3.85		5.50		4.81
All MVs	5.11	5.32	4.60	5.02	4.62	5.21	5.12	5.3	5.30	5.21	5.19
All LVs	2.50	2.35	2.90	2.13	2.00	2.56	2.45	3.00	2.87	2.64	2.50
Average yield	5.15	5.13	4.50	5.12	4.47	5.27	4.98	5.00	5.10	5.19	5.08

Table 5. Yield (t/ha) of different MV T. Aman rice varieties by agricultural regions of Bangladesh, 2013-14.

Variety	Region										
	Barisal	Chittagong	Comilla	Dhaka	Jessore	Mymensingh	Rajshahi	Rangamati	Rangpur	Sylhet	Av. (%)
BR10								4.57		4.02	4.29
BR11	4.15	4.05		5.29			3.90	4.75	4.90	4.26	4.36
BR22	4.49	4.94	4.00	4.82						4.38	3.95
BR23	4.61			5.39							4.70
BRRI dhan28						4.56		4.68			4.62
BRRI dhan32		5.08	5.00		4.32	3.89					4.74
BRRI dhan33			4.00		3.36				4.00		3.75
BRRI dhan34				2.91	2.73		2.29				2.50
BRRI dhan39					4.14		4.21	4.04			4.15

Table 5. Continued.

Variety	Region										
	Barisal	Chittagong	Comilla	Dhaka	Jessore	Mymensingh	Rajshahi	Rangamati	Rangpur	Sylhet	Av. (%)
BRRI dhan40	3.83				4.01						3.91
BRRI dhan41	4.77	3.89			3.95						4.49
BRRI dhan44	4.45										4.45
BRRI dhan46	4.74	4.49	5.00				4.94			4.69	4.73
BRRI dhan48							4.73				4.73
BRRI dhan49		4.79	5.00	4.97	4.87	4.34	4.61		4.80	4.88	4.79
BRRI dhan50								3.54			3.54
BRRI dhan51		3.41		4.94							3.92
BRRI dhan52	4.73		5.00	5.09		4.32	4.65				4.74
BRRI dhan56							4.73				4.73
BRRI dhan62			4.00								4.00
All BRRI varieties	4.02	4.12	4.00	4.14	4.19	4.24	4.12	4.21	4.1	4.15	4.25
All hybrid								5.15			5.15
Swarna	2.14	4.69		4.28			3.83		4.30	4.14	4.32
Other Indian varieties	2.45			4.34							3.39
All Indian varieties	2.34	4.69		4.18			4.25	3.71	4.6	4.18	4.27
Bina dhan7			3.00	3.29		2.71	3.95				3.14
Hori dhan						3.46		4.61			4.32
Pajam		4.15	3.00			3.50	4.07				4.03
Sadamota	3.62										3.62
All other MVs	3.62	4.15	3.00	3.29		2.94	4.05	4.61			3.75
All MVs	4.50	4.44	4.00	4.62	4.27	3.72	4.32	4.63	4.20	4.37	4.38
All LVs	1.94	2.75	2.87	2.24	2.47	2.63	2.51	2.57	2.49	2.5	2.53
Average yield	4.01	4.12	4.00	4.12	4.27	3.12	4.3	4.32	4.00	4.21	3.95

Table 6. Yield (t/ha) of different Aus rice varieties by agricultural regions of Bangladesh, 2013-14.

Variety	Region										
	Barisal	Chittagong	Comilla	Dhaka	Jessore	Mymensingh	Rajshahi	Rangamati	Rangpur	Sylhet	Av. (%)
BR1						2.97				2.22	2.87
BR2			3.54			3.45					3.48
BR3			3.04							3.99	3.51
BR14	4.36					3.47				4.12	3.96
BR16		4.40									4.40
BR21						3.25	3.65	3.45			3.35
BR26		3.86	3.23	3.12	3.3	2.99					3.75
BRRI dhan27	4.19							3.89			4.04
BRRI dhan28		4.32	4.01	4.51	4.01	4.14	4.12		3.99	3.75	4.11
BRRI dhan29				5.24					4.81	5.01	5.02
BRRI dhan33					3.50			3.48			3.49
BRRI dhan48			4.38	4.41							4.40
BRRI dhan50										2.97	2.97
Other BRRI varieties	3.52		3.66	3.55		3.94	3.72	3.70	3.73	3.45	3.64
All BRRI varieties	3.35	3.87	4.12	3.76	3.57	3.56	3.98	3.95	3.99	3.34	3.78
All hybrid								4.54	4.69		4.61
All Indian varieties				3.81			3.80	3.81		3.29	3.65
Basa IRRI		3.82									3.82
BAU63	2.31										2.31
China				3.46				3.46		3.3	3.07

Table 6. Continued.

Variety	Region										
	Barisal	Chittagong	Comilla	Dhaka	Jessore	Mymensingh	Rajshahi	Rangamati	Rangpur	Sylhet	Av. (%)
IR50			3.29			2.97					3.13
Pajam						2.52				2.31	2.42
All other MVs	3.31	3.82	3.29	3.46		2.57		3.46		2.3	3.40
All MVs	3.33	3.55	4.09	3.22	3.57	2.85	2.80	3.90	4.11	3.22	3.70
All LVs	2.91	2.44	2.53	2.25	2.45	2.42	2.45	2.64	2.45	2.57	2.49
Average yield	3.45	3.48	4.09	3.59	3.57	3.06	3.24	3.9	4.11	3.32	3.58

Table 7. Changes (%) in the adoption and yield level of modern rice varieties over the years.

Item	Period		Difference
	1990-91*	2013-14	
	Aus		
Adoption (%)	25.57	86.05	60.48
Yield (kg/ha)	1770	3700	1930 (109.04)
	T. Aman		
Adoption (%)	34.00	79.00	45.00
Yield (kg/ha)	3290	4380	1090 (33.13)
	Boro		
Adoption (%)	88.93	97.61	8.68
Yield (kg/ha)	4410	5190	780 (17.69)

Figures in parentheses indicate the percent. *National average.

In the same period, the adoption rate of MV Boro increased from 89 to 98%. In the same period, increase of yield was much higher in Aus season (109%) compared to T. Aman (33%) and Boro (18%).

ESTIMATION OF COSTS-RETURN OF MV RICE CULTIVATION AT FARM LEVEL

Adoption or non-adoption of a technology largely depends on its economic viability and profitability to the farmers. Costs-return analysis is an economic tool which evaluates the profitability of modern rice cultivation at the farm level. Hence, a macro level study was undertaken to get indication about the profit/loss of modern rice cultivation with the following objectives:
- Determine the level of inputs used in MV Aus, MV T. Aman and MV Boro rice cultivation;
- Estimate the costs of MV rice cultivation in different seasons; and
- Evaluate the profitability of MV Aus, MV T. Aman and MV Boro rice cultivation at the farm level.

Multistage random sampling technique was adopted to select the respondents. The study used a sample size of 120 rice growers from each of Aus, T. Aman and Boro season. Data were collected through face to face interview method with structured questionnaire.

Level of inputs used. Majority of the rice farming activities like pulling of seedlings and transplanting, weeding, harvesting and post harvest operations (carrying, threshing, cleaning and winnowing, etc) were done on contractual basis. The highest number of human labour (92 man-days/ha) was used for MV T. Aman followed by MV Aus (87 man-days/ha) and MV Boro (70 man-days/ha) rice cultivation (Table 8). The seed rates for MV Aus, MV T. Aman and MV Boro rice were 36, 38 and 39 kg/ha, indicating farmers still using a bit higher amount of seed than the recommended rate (25 to 30 kg/ha). Farmers applied comparatively lower amount of TSP and MoP fertilizer in MV Aus and MV T. Aman seasons.

Cultivation cost. Per hectare human labour costs were Tk 34,737, 36,201 and 39,504 for MV Aus, MV T. Aman and MV Boro rice cultivation

Table 8. Per hectare inputs used for MV rice cultivation in different seasons of Bangladesh, 2013-14.

Input item	Season		
	Aus	Aman	Boro
Human labour (man-days/ha):	87	92	70
Family labour	41	40	33
Hired labour	46	52	37
Seed (kg/ha)	36	38	39
Fertilizer (kg/ha):			
Urea	150	187	250
TSP	50	70	95
MoP	58	51	72
DAP	-	20	6
Gypsum	7	15	45
$ZnSO_4$	-	0.68	1

respectively (Table 9). Fertilizer costs for MV Aus, T. Aman and Boro, were Tk 5,569, 6,888 and Tk 8,706/ha respectively (Table 9).

Profitability. The yield received by the rice farmers from MV Aus, MV T. Aman and MV Boro crops were 3,850, 4,380 and 5,310 kg/ha respectively (Table10). However, MV Boro

Table 9. Per hectare costs (in taka) of MV rice cultivation in different seasons of Bangladesh, 2013-14.

Cost item	Season		
	Aus	Aman	Boro
Seedbed preparation (Tk/ha)	1,830	2,120	2,432
Seed (Tk/ha)	1,641	1,439	1,697
Human labour (Tk/ha):	34,737	36,201	39,504
	(45.42)	(47.56)	(39.39)
Family labour	12,710	12,320	9,900
Hired labour	14,260	16,016	11,100
Contract	7,767	7,865	18,504
Land prep. cost (Tk/ha)	9,682	7,327	8,032
Fertilizer (Tk/ha):	5,569	6,888	8,706
	(7.28)	(9.05)	(8.68)
Urea	3,090	3,530	4,375
TSP	1,312	1,740	189
MP	1,103	523	2,565
DAP		863	1,116
Gypsum	64	138	315
ZnSO$_4$		94	146
Cow-dung (Tk/ha)			1,074
Irrigation (Tk/ha)	1,504	667	14,133
	(1.97)	(0.87)	(14.09)
Herbicide (Tk/ha)	141	400	296
Pesticides (Tk/ha)	1,393	2,096	2,397
Variable cost (Tk/ha)	56,497	57,139	78,271
	(73.87)	(75.07)	(78.05)
Interest on operating capital @ 10% for five months	1,178	1,186.58	1,656
Land rent (Tk/ha)	18,808	17,784	20,354
	(24.59)	(23.37)	(20.23)
Total cost (Tk/ha)	76,483	76,109	1,00,281

Note: Figure in the parentheses indicate percent of total.

Table 10. Comparative costs and return of MV rice cultivation in different seasons of Bangladesh, 2013-14.

Item	Season		
	Aus	Aman	Boro
Yield (kg/ha)	3,850	4,380	5,310
Paddy price (Tk/kg)	16.71	18.72	17.5
Return from paddy (Tk/ha)	64,334	81,994	92,925
Return from Straw (Tk/ha)	3,910	9,168	8,500
Gross return (Tk/ha)	68,244	91,161	1,01,425
Variable cost (Tk/ha)	56,497	57,139	78,271
Total cost (Tk/ha)	76,483	76,109	1,00,281
Gross margin (Tk/ha)	11,746	34,029	23,154
Net return (Tk/ha)	-8,240	15,052	1,144
Unit cost of production (Tk/kg)	19.87	17.38	18.89
BCR (Undiscounted)	0.89	1.20	1.01

growers received higher gross return (Tk 1,01,425 /ha) than MV T. Aman (Tk 91,161/ha) and MV Aus (Tk 68244/ha) season due to higher yield and better market price (Table 10).

CROP LAND SHIFTS INTO MANGO ORCHARD: CAUSES AND IMPACTS

Barind ecosystem is characterized by drought, extreme temperature, erratic rainfall and drawdown of groundwater, etc depleting the label of groundwater and soil nutrients. Under such a condition, Boro-the main irrigated crop of this region is being exhausted facing multidimensional problems and farmers are shifting their crop land into fruit cultivation which is economically profitable compared to other field crops. Thus, an investigation was made to find out the factors responsible for land transformation into mango orchard in Barind area to:

● Estimate the relative profitability of mango production;
● Identify the factors responsible for crop land shifts into mango orchard;
● Explore the problems of cultivating mango at farm level; and
● Suggest future policy guidelines for transformation of land in Barind area.

Mainly descriptive statistics were used to process the data. Benefit-cost analysis (BCA) was used to examine the profitability of mango cultivation; whereas net present value (NPV) and internal rate of return (IRR) were employed to evaluate the returns to investment on mango orchard.

Cost and return of mango cultivation

Mango farmers usually start getting yield from the 2nd year of cultivation. They obtained on average 238 kg/ha yield in 1st quarter (year 1-3) and then production increased sharply and reached 2,245 kg/ha in 5th quarter. The highest gross return of mango was found in the 5th quarter (year 13-15), which was Tk 1,06,638/ha. In the 1st quarter (year 1-3) farmers gained negative gross return. The BCR (undiscounted) of 1st, 2nd, 3rd, 4th and 5th quarters were 0.30, 2.07, 3.23, 4.37 and 5.33

respectively, which indicates that increasing life span of mango orchard increases profitability (Table 11).

Returns to investment in mango cultivation

Discounted benefit cost ratio (BCR) was 1.44 at 15% discount rate which is greater than unity and highly accepted (considering 15 years life span). The estimated net present value (NPV) of the project was Tk 99,588 per hectare, which indicates that mango cultivation was profitable in Rajshahi area. The internal rate of return (IRR) was 28%. It is highly acceptable because it is much higher than the opportunity cost of capital (Table 12).

Impact of mango cultivation on farm income

Mango cultivation has created tremendous impact on farm income. About 92% respondent farmers mentioned positive impacts to some extent on household income, food intake and livelihoods improvement due to shifting of crop land into mango orchards. More than 83% farmers obtained increased income and about 67% achieved improved livelihoods. The amount of food intake was also increased to some extent for some of the responded households (48%). But farmer also reported that in the long run mango cultivation may decrease both rice and non-rice land (65%) and thus lead to decreased food grain/pulses/oil seed/vegetable production (55%), which may be a threat to the food security in the area (Table 13).

Table 13. Impact of mango cultivation on farm income, livelihood and food security.

Item	% farmers responded
Positive impact	92
Negative impact	8
Types of positive impact	
Increase in household income	83
Increase in livelihoods	67
Increase in food production	48
Less water requirement	90
Types of negative impact	
Decrease food grain/pulses/oil seed/ vegetable production	50
Decrease non-rice land	65

VALUE CHAIN ANALYSIS AND SHARE OF DIFFERENT ACTORS IN RICE MARKETING CHANNEL IN A SELECTED AREA

Value chain analysis of rice encompasses all economic activities including production, transformation, handling, transport, marketing, and distribution necessary to create, sell, and deliver to the ultimate users. Rice value chain analysis might pave the way to improve the performance of different actors in the rice marketing system. Effective value chain generates profits by increasing producer's share on consumer's price and reduces the middlemen's margin. So, the present study was undertaken with the following objectives;

● Mapping and critically analyze the value chain of rice: examining different actors and their activities; and

Table 11. Cost and return (Tk/ha) analysis for mango cultivation.

Item	Life span of mango orchard (year)				
	1st quarter (1-3)	2nd quarter (4-6)	3rd quarter (7-9)	4th quarter (10-12)	5th quarter (13-15)
Yield (kg/ha)	238	1,221	1,618	1,912	2,245
Sale price (Tk/kg)	47.5	47.5	47.5	47.5	47.5
Total return (Tk/ha)	11,305	57,998	76,855	90,820	1,06,638
Total cost (Tk/ha)	37,683	28,018	23,794	20,783	20,007
Gross return (Tk/ha)	-26,378	29,980	53,061	70,037	86,631
BCR	0.30	2.07	3.23	4.37	5.33

Table 12. Estimation of NPW, BCR and IRR of mango cultivation in Rajshahi area.

Discount rate	Discounted total benefit	Discounted total cost	Net present value (NPV)	Benefit cost ratio (BCR)
15	327141.40	227553.90	99587.50	1.44
20	243396.80	200224.90	43171.90	1.22
25	187082.00	180369.30	6712.70	1.04
30	147877.70	165438.10	-17560.40	0.89
IRR (%)				28.09

● Measure the value addition computing marketing cost and margins of value chain actors.

Value addition

To estimate the value addition, contribution of input suppliers, paddy producer, and processor as well as rice marketers along with the rice value chain was examined. Total value added by different actors was 3,825 Tk/quintal. The contribution of producer, miller and input suppliers was 40, 23 and 13% respectively. Rice *Aratdar* and petty paddy traders contributed less in value addition process as well (Table 14).

Table 14. Value addition by rice value chain actors.

Value chain actor	Value addition (Tk/quintal)	%
Input supplier's contribution	482.29	12.61
Producer	1530.71	40.02
Faria	98.91	2.59
Bepari	92.06	2.41
Aratdar	73.67	1.93
Rice miller	873.73	22.84
Aratdar (rice)/Commission agent	31.34	0.82
Aratdar cum wholesaler	203.72	5.33
Wholesaler	252.21	6.59
Retailer	186.41	4.87
Total	**3825.05**	**100**

IMPACT OF CLIMATE CHANGE ON RICE PRODUCTION

Bangladesh is strongly recognized as the most vulnerable country to climate change because of its geographic location, flat and low-lying topography, dense population, high poverty, reliance of livelihoods on climate sensitive sectors and inefficient institutional and poor infrastructure. The diverse climatic phenomena like cyclone, drought, changing rainfall patterns and temperature cause significant losses in food grain production in every year. Increasing population growth and environmental degradation are going to exacerbate climate change affects on agriculture in Bangladesh (Ahsan *et al*., 2011). Under such a condition, it is imperative to evaluate the supply and demand situation of rice, which is really important for future concern of national policy of the country.

Elasticity of yield and harvested area

Elasticity of yield indicated that increased solar radiation in April enhanced yield of modern and local Aus (0.234 and 0.627) respectively, while increased temperature in May (-1.38 and -2.55) had strong negative impact on yield of both the varieties. In case of modern Aman, heavy rainfall (-0.083) in August and high solar radiation (0.447 and -0.505) in October decreased the yield detrimentally. Excessive rainfall in July (-0.087) and high temperature in September (-0.197) decreased the yield of local Aman. Elasticity of modern Boro rice signified that yield largely increased with the augmented solar radiation (0.474) in November and temperature in February (0.329). Higher solar radiation in November and temperature in February increased the yield of modern Boro rice (Table 15).

The elasticity of lagged year's farm price (0.178) had significant influence on harvested area of modern Aus. Two year lagged rainfall for December (-0.024) and one year lagged for January (-0.037) had negative influence while one year lagged rainfall in February (0.051) had positive influence on harvested area of modern Aus. It suggested that heavy rainfall in December and January decreased the area planted in modern Aus cultivation while increase rainfall in January (0.011) and February (0.012) encouraged the farmer to increase the planted area of modern Aus rice. In case of modern Aman and Boro had similar trend but the strong elasticity of one year lagged temperature in September (2.421) increased the area harvested in modern Aman season (Table 16).

Supply and demand for rice

Figures 1 and 2 portrayed the simulation results of total rice production and per capita demand of rice. The production of all three rice seasons is in increasing trend and eventually will boost up the total rice production in Bangladesh under different climate scenarios. Although, trend in Aus season is negative and shifting to modern Boro rice and non-rice crops (Maize and Tobacco), the modern varieties increase the production. Per capita rice consumption will slightly increase up to 2015 as poor people under poverty line still intake less amount of calorie per day and after that period

Table 15. Elasticity of yield in three different rice growing seasons in respect to climate variables and trend.

Variety	Trend	Jan	Feb	April	May	June	July	Aug	Sep	Oct	Nov
				Aus							
Modern	0.151			0.234(Sr)	-1.38(Tmp)	-0.046(Rf)					
Local	0.379			0.059 (Rf)	-2.55(Tmp)						
				0.627(Sr)	0.396(Sr)						
				Aman							
Modern	0.115							-0.083(Rf)	0.178(Sr)	-0.447(Sr)	
Local	0.055						-0.087(Rf)		-0.197(Tmp)	-0.505(Sr)	
									0.190 (Sr)		
				Boro							
Modern	0.274		0.329(Tmp)								0.474(Sr)
Local	0.260	0.042(Rf)									

Note: Tmp=temperature, Rf=rainfall, and Sr=solar radiation.

Table 16. Elasticity of harvested area of three different rice growing seasons with respect to lag price and area, climate variables and trend.

Variety	Trend	lag area	Lag price	Jan	Feb	Mar	May	July	Aug	Sep	Nov	Dec
						Aus						
Modern	-	0.608	0.178	$-0.037Rf_{(t-1)}$	$0.051Rf_{(t-1)}$							$-0.024Rf_{(t-2)}$
Local	-0.344	0.218	0.154	$0.011Rf_{(t-1)}$	$0.012Rf_{(t-1)}$						$0.014Rf_{(t-2)}$	
						Aman						
Modern	0.212	0.788	0.221					$0.080Rf_{(t-1)}$		$2.421Tmp_{(t-1)}$		
Local	-0.173	0.583	0.124				$0.097Rf_{(t-1)}$					
						Boro						
Modern	0.254	0.741	0.141							$0.080Rf_{(t-2)}$	$0.028Rf_{(t-2)}$	
Local	-0.28493	0.488	0.029			$0.0226Rf_{(t-1)}$			$-0.107Rf_{(t-2)}$	$-0.103Rf_{(t-2)}$		

Note: Tmp = Temperature, Rf = Rainfall, and t= Time lag.

Production (million ton)
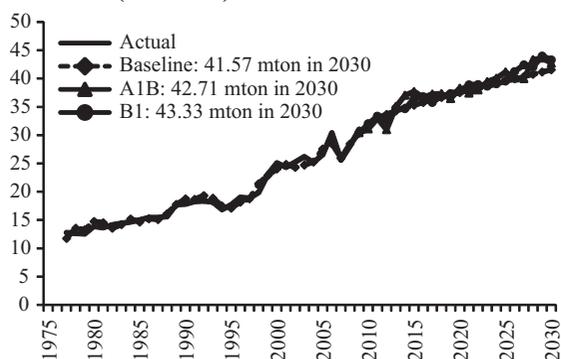
Fig. 1. Simulated result of overall rice production in Bangladesh.

Consumption (kg)
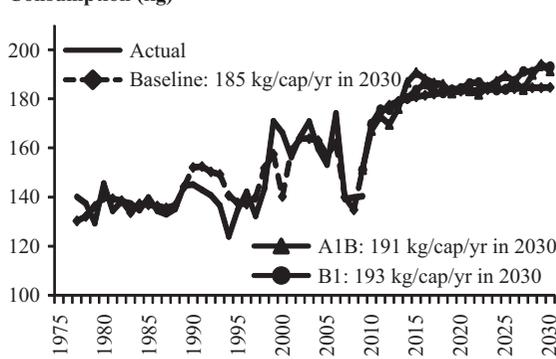
Fig. 2. Simulated result of per capita rice consumption in Bangladesh.

negative income elasticity and food diversification will make rice consumption constant.

FORECASTING OF FOOD GRAINS AREA AND PRODUCTION

Although, production of food grain increased over the last few decades but it is needed to increase food grain production to feed the growing population. So, an attempt was taken to predict food grain areas and production by 2024 by using autoregressive integrated moving average (ARIMA) models.

Forecasted food grains areas. It is indicated that Aus area would decrease by 46% in 2022-23

due to some area would shifted to Boro and Tobacco. Aman area would almost remain similar throughout the period but Boro and Wheat area would be increased by 18% each (Table 17).

Forecasted food grains production. Forecasted value of Aus and Boro revealed that the production of these two crops would decrease by 3% and 2% respectively in 2022-23. On the other hand, Aman and wheat production will increase by 13 and 30% in the same period respectively (Table 18).

Table 17. Forecasted Aus, Aman, Boro and wheat area ('000' ha).

Year	Aus, ARIMA (2, 1, 2)	Aman, ARIMA (3, 1, 1)	Boro, ARIMA (2, 1, 2)	Wheat, ARIMA (3, 1,2)
2013-14	1055	5635	4822	436
2014-15	932 (-13)	5609 (-0.46)	5011 (4)	444 (2)
2015-16	883 (-16)	5613 (-0.39)	5056 (5)	453 (4)
2016-17	884 (-16)	5624 (-0.20)	5115 (6)	466 (7)
2017-18	815 (-23)	5626 (-0.16)	5281 (10)	478 (10)
2018-19	744 (-29)	5618 (-0.30)	5347 (11)	488 (12)
2019-20	719 (-32)	5627 (-0.14)	5407 (12)	495 (14)
2020-21	676 (-36)	5627 (-0.14)	5554 (15)	501 (15)
2021-22	610 (-42)	5629 (-0.11)	5634 (17)	508 (17)
2022-23	566 (-46)	5628 (-0.12)	5699 (18)	516 (18)

Note: Figures in the parentheses represent percentage.

Table 18. Forecasted Aus, Aman, Boro and wheat production ('000' ton).

Year	Aus, ARIMA (3, 1, 1)	Aman, ARIMA (4, 1, 2)	Boro, ARIMA (2, 2, 9)	Wheat, ARIMA (2, 1,4)
2013-14	2411	12591	19210	1306
2014-15	2299 (-5)	12369 (-2)	19193 (-0.1)	1385 (6)
2015-16	2310 (-4)	12422 (-1)	19518 (2)	1418 (9)
2016-17	2416 (0.2)	12584 (-0.1)	20264 (6)	1511 (16)
2017-18	2283 (-1)	12907 (3)	19929 (4)	1586 (21)
2018-19	2396 (-0.6)	13358 (6)	19588 (2)	1619 (24)
2019-20	2355 (-2)	13765 (9)	19812 (3)	1627 (25)
2020-21	2331 (-3)	14056 (12)	19444 (1)	1639 (26)
2021-22	2404 (-0.3)	14215 (13)	18977 (-1)	1664 (27)
2022-23	2330 (-3)	14236 (13)	18810 (-2)	1698 (30)

Note: Figures in the parentheses represent percentage.

Agricultural Statistics Division

SUMMARY

In the reporting period BR11, BRRI dhan49, BRRI dhan51 and BRRI dhan52 were found as the most stable in T. Aman season while BR3, BR4 and BRRI dhan23 appeared to be below average stable among the non-aromatic rice. In case of aromatic rice BR5, BRRI dhan34, BRRI dhan37 and BRRI dhan38 also appeared to be average stable varieties.

BRRI dhan28 and BRRI dhan29 were the only most stable variety and BR1, BR2, BR6, BR7, BR8, BR18, BR19, BR26, BRRI dhan27, BRRI dhan35, BRRI dhan55 and BRRI dhan58 appeared to be below average stable in Boro season. In case of fine rice BRRI dhan50 also appeared to be average stable in Boro season.

BR11, BR22, BRRI dhan32, BRRI hybrid dhan4 and BRRI dhan28, BRRI dhan29, BRRI dhan50, BRRI hybrid dhan3 and BR9, BR16, BRRI dhan48 were found to be more preferable and cultivable varieties due to higher yield in T. Aman, Boro and Aus seasons respectively among the producers and producer cum consumers. Pure consumers were found to prefer rice varieties on the basis of taste, slenderness and availability of the varieties. Although, BRRI variety contributes about 90% of total production, it does not reflect in field label as the BRRI varieties are sold in different brand names. As for example, BRRI dhan28 sells as Nizersail and BRRI dhan29 as Jhingasail and Miniket etc.

Three mathematical models have been developed for consumers and producers and producers-cum-consumers preference to rice varieties by using four locations/districts farmers' data of Bangladesh in terms of rice deficit and rice surplus area. These three models are used to determine factors affecting producers' decision on varieties for rice cultivation and can provide an indication of the factors affecting consumers' preference to rice varieties.

A model have been developed for forecast the rice production in Bangladesh using ARIMA model. Projections have been made for the Aus, Aman and Boro rice production on the basis of their actual performance during 1971-72 to 2013-14. Forecast of Aus rice production showed a decreasing trend but Aman and Boro rice production showed increasing trend.

In total, 4,620 soil samples and 1,540 water samples from 1,540 locations has been collected and all soil samples have been processed and digested and all 1,540 water samples analysed for As, and 839 samples for Fe, Mn, P and 4,345 soil samples analysed for As. We also used 183 water samples and 552 soil samples in Faridpur and Rajbari for water and soil interpolation map, collected by BSMRAU. Almost all the surveyed upazilas' data entry has been completed by this time. From the maps and graphs it can be concluded that, the As level is high (>200 ppb) in Chandpur, Munshiganj, a part of Shariyatpur, Gopalganj and Satkhira districts for water and also high (15 ppm) in Satkhira, Gopalganj, Shariyatpur, Rajbari and Madaripur district for soil, where As level shows high in recently installed well (1995-2012) and maximum As level was observed in shallow well (<200 feet).

Minimum temperature has had prominent effect on Boro rice production during germination, subsequent growth and finally rice production. In last decade (2002-2012) minimum temperature trend of December-January more or less followed the trend of Boro rice production, which indicates that the effect of minimum temperature is prominent. Among the 23 rice regions, the production of Patuakhali, Barisal, and Noakhali regions were low may be due to the salinity effect is prominent there (as coastal area), while in Comilla, Sylhet, Kishoreganj, Bogra, Dinajpur, Rajshahi and Rangpur it was high.

In Aman season, BRRI dhan51, BRRI dhan52 are suitable for north-eastern and south-eastern region, BR23, BRRI dhan40, BRRI dhan41, BRRI dhan53, BRRI dhan54 are suitable for south-western region. BRRI dhan33, BRRI dhan39 are suitable for north-western region of Bangladesh. Further research is needed to determine the effect of soil quality and texture, groundwater quality and position and technology development in those regions.

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 120

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 etc. The static website of BRRI is converted into dynamic website (web portal-both Bengali and English) which was developed by skilled manpower of ICT cell. Also, ICT cell of Agricultural Statistics Division will provide e-Tender related support services to BRRI listed bidders such as e-Tender online registration training, e-Tender online bidding training and e-Tender ICT support etc.

STABILITY ANALYSIS OF BRRI VARIETIES

The newly developed stability model takes into account the performance of the genotypes across the geographical locations differing in land, soil and other biotic and abiotic factors and over the years characterizing fluctuation of weather variable, floods and drought etc.

Experiments are being conducted in the T. Aman and Boro seasons with BRRI released rice varieties since T. Aman 2012-13 and Boro 2013 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 Boro season those are Rajshahi, Rangpur, Comilla, Habiganj, Barisal, Bhanga, Satkhira, Kushtia and Sonagazi.

Twenty-seven varieties in T. Aman and 25 varieties in Boro season were analysed. The design used is RCB with three replications and the effective plot size (harvest area) is $5 \times 2 \text{ m}^2$ leaving the boarder. Recommended crop management practices were followed. The newly developed stability model was used to analyse the data.

The value of G_i (stability index of the ith genotypes) ranges from -1 to +3 ie, $-1 \le G_i \le 3$. The higher the value of G_i the more is the stability of the genotype across the environments. Stability of a variety is characterized as follows:

Value of G_i	Nature of stability
≤ 0	Unstable
$0 \le G_i \le 1$	Below average stability
$1 \le G_i \le 2$	Average stability
$2 \le G_i \le 3$	Stable

Tables 1 and 2 present the results. Among the non-aromatic T. Aman varieties, BR11, BRRI dhan49, BRRI dhan51 and BRRI dhan52 were found stable and their stability ranks were 4, 2, 1 and 3 respectively, while BR3, BR4 and BRRI dhan23 appeared to be below average stable. BR10, BR22, BRRI dhan25, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan33, BRRI dhan39, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan53, BRRI dhan54 and BRRI dhan56 were found to have average stability amoung non-aromatic T. Aman varieties. Among the aromatic T. Aman rice BR5, BRRI dhan34, BRRI dhan37 and BRRI dhan38 appeared to be average stable.

In Boro season, the only stable variety was BRRI dhan28 and BRRI dhan29 in each year. BR3, BR9, BR12, BR14, BR15, BR16, BR17, BRRI dhan36, BRRI dhan45, BRRI dhan47 and BRRI dhan50 appeared to have average stability. All other Boro varieties appeared to have average stability.

DEVELOPMENT AND VALIDATION OF PRODUCER, CONSUMER AND PRODUCER CUM CONSUMER PREFERENCE MODEL TO RICE VARIETIES

This study is an attempt to evaluate the factors affecting producers, consumers and producer-cum-consumers preference for rice varieties, because no systematic study has been conducted in identifying the factors that could influence or affect the preference to rice variety.

For this study four locations/districts ie 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 farmers were selected from producer, consumer and producer cum consumer from each location and the selected farmers were

Table 1. Stability parameters of new model for grain yield in T. Aman season.

Variety	Stability parameter			Stability index (G_i)	Stability rank (R_i)
	2002-13			2002-13	2002-13
	S_i	D_i	P_i	G_i	R_i
Non-aromatic rice					
BR3	8.86	25.14	4	0.81	12
BR4	8.42	28.69	10	0.99	11
BR10	8.15	31.42	13	1.13	5
BR11	8.56	30.51	12	2.06	1
BR22	7.64	30.09	12	1.13	5
BRRI dhan23	8.20	28.01	9	0.99	11
BRRI dhan25	7.76	27.88	8	1.03	10
BRRI dhan30	8.40	29.78	11	1.04	9
BRRI dhan31	8.38	29.37	11	1.03	10
BRRI dhan32	8.11	31.52	13	1.14	4
BRRI dhan33	8.59	23.69	3	1.77	2
BRRI dhan39	7.80	25.23	5	1.91	2
BRRI dhan40	8.09	30.61	12	1.11	7
BRRI dhan41	8.03	29.94	11	1.08	8
BRRI dhan44	8.44	28.54	10	1.99	2
BRRI dhan46	8.73	27.32	9	1.91	2
BRRI dhan49	7.84	31.14	15	2.16	1
BRRI dhan51	6.61	30.36	13	2.28	1
BRRI dhan52	8.24	31.46	15	2.13	1
BRRI dhan53	7.85	23.42	6	1.83	2
BRRI dhan54	8.10	26.26	10	1.92	2
BRRI dhan56	8.42	16.95	3	1.50	3
BRRI dhan57	-	-	-	-	-
Aromatic rice					
BR5	8.18	20.61	2	1.08	8(4)
BRRI dhan34	8.74	20.41	2	1.12	6(3)
BRRI dhan37	8.22	22.89	2	1.77	2(1)
BRRI dhan38	8.46	22.80	2	1.74	2(2)

Table 2. Stability parameters of new model for grain yield in Boro season.

Variety	Stability parameter			Stability index (G_i)	Stability rank (R_i)
	2002-14			2002-14	2002-14
	S_i	D_i	P_i	G_i	R_i
Non-aromatic rice					
BR1	8.40	0.22	21	0.33	13
BR2	7.48	-4.81	18	0.18	14
BR3	9.44	4.75	23	1.56	3
BR6	9.05	-6.55	18	0.05	15
BR7	4.06	0.80	21	0.70	10
BR8	2.66	-0.29	21	0.99	8
BR9	3.30	13.23	28	1.59	3
BR12	7.89	-2.43	20	1.25	5
BR14	4.48	11.41	27	1.27	5
BR15	2.97	10.05	26	1.49	4
BR16	7.50	10.10	26	1.96	2
BR17	2.83	8.66	25	1.46	4
BR18	22.20	0.57	21	0.15	14
BR19	6.31	3.18	23	0.61	11
BR26	5.65	4.65	23	0.75	10
BRRI dhan27	5.57	3.88	23	0.71	10
BRRI dhan28	2.83	9.68	26	2.51	1

Table 2. Continued.

Variety	Stability parameter			Stability index (G_i)	Stability rank (R_i)
	2002-14			2002-14	2002-14
	S_i	D_i	P_i	G_i	R_i
BRRI dhan29	5.75	20.73	32	2.70	1
BRRI dhan35	7.59	3.51	23	0.56	12
BRRI dhan36	5.29	8.65	25	1.02	7
BRRI dhan45	9.11	-1.94	20	1.22	6
BRRI dhan47	18.48	-8.48	17	1.17	6
BRRI dhan55	19.34	-20.48	11	0.62	11
BRRI dhan58	28.39	-24.67	9	0.82	9
Aromatic rice					
BRRI dhan50	13.58	-8.88	15	1.13	6 (1)

categorized into three groups such as producers, pure consumers (consume rice from market) and producer-cum-consumer.

The pure consumers were selected from the urban areas of Panchagarh, Lalmonirhat, Kurigram and Thakurgaon districts. Information was collected on the choice of varieties for production and consumption using a pre-designed questionnaire.

On the basis of newly developed three models for producers preference, consumers preference and producer-cum-consumer preference for rice varieties were used to achieve the objectives. From the validation of models, producer, consumer and producer cum consumer preferred rice varieties for their higher yield at Panchagarh, Lalmonirhat, Kurigram and Thakurgaon. On the other hand, the pure consumers preferred varieties based on their tastes.

BR11, BR22 and BRRI dhan32, BRRI hybrid dhan4 for T. Aman, BRRI dhan28, BRRI dhan29, BRRI dhan50 and BRRI hybrid dhan3 for Boro and BR9, BR16 and BRRI dhan48 for Aus were found to be more preferable and cultivable varieties due to higher yield among the producers and producer cum consumers. Pure consumers were found to prefer rice varieties on the basis of taste, slenderness and availability of the varieties (Table 3).

Although, BRRI variety contributes about 90% of total production, it does not reflect in field label because of BRRI variety sell in different brand name, as for example BRRI dhan28 sells as Nizersail and BRRI dhan29 as Jhingasail and Miniket etc.

Table 3. Reasons for liking varieties by the pure consumers in Panchagarh, Lalmonirhat, Kurigram and Thakurgaon.

Reason	Panchagarh	Lalmonirhat	Kurigram	Thakurgaon
Tasty	29(58)	24(48)	28(56)	25(50)
Fine rice	11(22)	12(24)	10(20)	8(16)
Fine rice+ tasty	7(14)	9(18)	4(8)	11(22)
Fine rice+ sticky	3(6)	5(10)	8(16)	6(12)non-sticky
Total	50	50	50	50

Figures within parenthesis indicates percent.

Three mathematical models have been developed for consumer and producer preference to rice varieties in four locations/districts in terms of rice deficit and rice surplus area. These three models uses to determine factors affecting producers' decision on varieties for rice cultivation and can provide an indication of the factors affecting consumers preference to rice varieties.

APPLICATION OF BOX-JENKINS METHOD FOR FORECASTING OF AUS, AMAN AND BORO RICE PRODUCTION

Due to population increase in Bangladesh, its accurate forecast is important for efficient planning of rice production and forecasting of rice production is a formidable challenge. In view of globalization, it is important to study the rice production trend by employing sound statistical modelling techniques that will be beneficial to the planners in formulating suitable policies to face the challenges ahead. The objective of this study was to forecast the Aus, Aman and Boro rice

production in Bangladesh by using the Box-Jenkins method. In this work we are interested to construct Autoregressive Integrated Moving Average (ARIMA) model for yearly time series data of Aus, Aman and Boro rice production in Bangladesh for the periods of 1971-1972 to 2013-2014, which are taken from the 'Year Book of Agricultural Statistics' is published by Bangladesh Bureau of Statistics (BBS). In this study the methodology first refers to use of ARIMA model as propounded by Box and Jenkins for forecasting of requirement and production of Aus, Aman and Boro rice. The Box and Jenkins methodology refers to the set of procedures for identifying, fitting, and checking models with time series data.

Model identification. Correlogram (plotting of autocorrelation and partial autocorrelation against their lag values) are being constructed for Aus, Aman and Boro rice production data to check the stationarity of the series and to have an idea about the tentative estimation model. If the autocorrelation function (ACF) and partial autocorrelation function (PACF) of the series die off rapidly that implies the stationarity of the series but if they decay gradually meaning in non-stationarity. All the constructed correlogram depicted that the series are no longer stationary at level since they are decaying gradually over lag. Now, to get the stationary series which is the foremost condition for univariate ARIMA model, the series set out under the differentiation process and found all the series stationary at first difference. Furthermore, the gradual decaying spikes for the autocorrelation functions of all three data sets indicating the series are by and large consisting of moving average term.

Model estimation and verification. Different models for production of Aus, Aman and Boro rice were fitted using different significant values of p and q. ARIMA(1,1,4), ARIMA(0,1,5) and ARIMA(1,1,4) model were selected as the best model for production of Aus, Aman and Boro rice respectively based on the minimum values of Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), Akaike Information Criterion (AIC), Normalized Bayesian Information Criterion (BIC), Hannan-Quinn information criterion (H-Q IC) and highest

R^2 and Adjusted R^2 value. The entire coefficient of estimated model is significant at the 5% level of significance. The R^2 of the estimated models is 0.60, 0.57 and 0.37 that implies about 60, 57 and 37% variation of the Aus, Aman and Boro production can be explained by the estimated coefficients and the rest are unexplained, may be due to other factors that are not encountered in this model. Test of autocorrelation was done by Durbin-Watson (D-W) test. The value of D-W statistics suggested that the estimated coefficients are free from autocorrelation problem. The minimum values of RMSE, MAE, MAPE, AIC, BIC, H-Q criterion are also confirmed.

Empirical models

Aus rice production $\quad \hat{Y}_t = -30.89 - 0.587\, Y_{t-1} - 0.63e_{t-1}$
$$-0.52e_{t-3} - 0.55e_{t-5} - 0.89e_{t-6}$$

Aman rice production $\hat{Y}_t = 163.28 + 0.657e_{t-1} + 0.35e_{t-5}$
$$- 0.46e_{t-6} + 0.61e_{t-7} - 0.64e_{t-9}$$

Boro rice production $\quad \hat{Y}_t = 506.84 + 0.37\, Y_{t-1} + 0.44e_{t-1}$
$$- 0.40e_{t-3} + 0.40e_{t-4} + 0.57e_{t-6}$$

The time series models those are tested and found satisfactory in all stages of model fitting process being used for estimation of the time series coefficient. These models will be used for forecast purpose, which is the ultimate goal of univariate time series analysis. Moreover, the residual analysis of the estimated models confirmed the stability to forecast and other relevant diagnosis of the fitted models.

Residual analysis. The residual correlogram is a good measure to have the idea about the adequacy of the fitted model (Figs. 1, 2 and 3). The constructed correlogram by using the residuals from the fitted models indicate that all the series are free from autocorrelation problem since all the spikes are laying by the limit of permissible lines.

Normality test of residuals. Normality of the residuals is a vital issue since it is expected that the produced residuals from the model used for estimation process would be dispersed consistently. By assuming the hypothesis that the series under study are normally distributed being tested and found that all the models produced normal residuals implying the adequacy of the models.
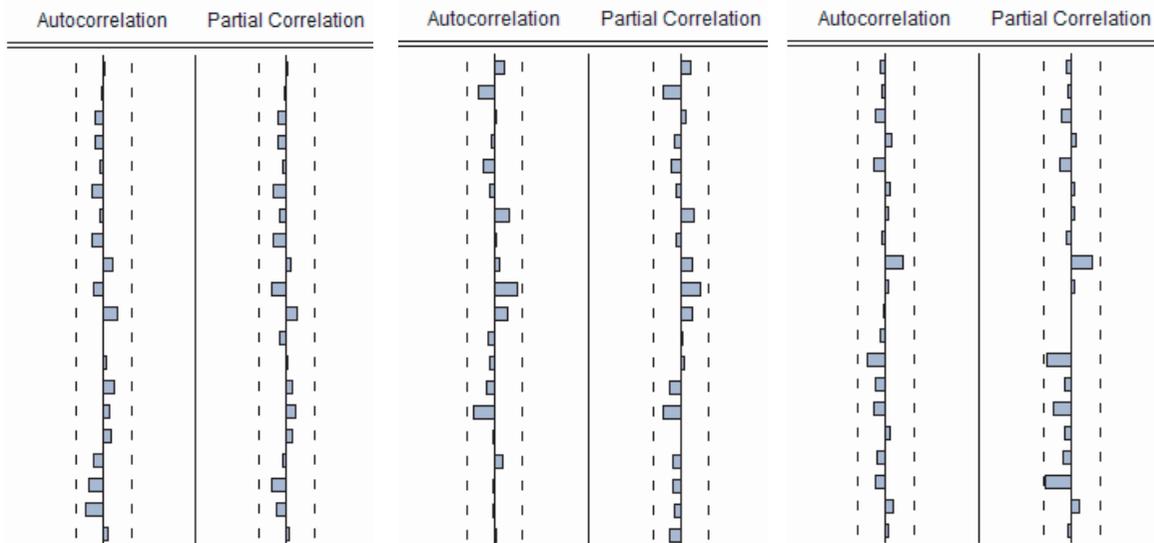
Fig 1. Correlogram for the residuals of Aus.

Fig 2. Correlogram for the residuals of Aman.

Fig 3. Correlogram for the residuals of Boro.

Forecasting

Projections have been made for the Aus, Aman and Boro rice production on the basis of their actual performance during 1971-72 to 2013-14 and Table 4 shows these projections. Since the time series model building is an iterative process, until and unless the forecast value found by maintaining the proper statistical rigor it is iterated from the identification process. The same things followed here and used the models those strictly for having better forecast. Forecast of Aus rice production showed a decreasing trend but Aman and Boro rice production showed an increasing trend.

In this study, we have introduced model and forecasted the production of rice in Bangladesh using ARIMA method. Increase in government funding to agriculture, selection of high yielding varieties, increasing agricultural linkage between farmers and research institutes are important factors needed to increase the production of rice. Also, total cropped area can be increased in future, if land reclamation and conservation measures are adopted.

MAINTENANCE OF RICE AND RICE RELATED VARIABLE DATABASE

The purpose of this activity is maintaining up-to-date information on rice and related crops and inputs and also providing rice and related

Table 4. Forecast value of production (000' metric ton) of Aus, Aman and Boro rice in Bangladesh.

Year	ARIMA (1,1,4)			ARIMA (0,1,5)			ARIMA (1,1,4)		
	LCL	Forecast	UCL	LCL	Forecast	UCL	LCL	Forecast	UCL
2015	1773.642	2059.642	2345.642	13210.16	13303.73	13397.30	19055.49	19216.29	19377.1
2016	1742.742	2028.742	2314.742	13373.44	13467.01	13560.58	19562.33	19723.14	19883.94
2017	1711.842	1997.842	2283.842	13536.73	13630.30	13723.87	20069.18	20229.98	20390.79
2018	1680.943	1966.943	2252.943	13700.01	13793.58	13887.15	20576.02	20736.83	20897.63
2019	1650.043	1936.043	2222.043	13863.29	13956.86	14050.43	21082.87	21243.67	21404.48
2020	1619.144	1905.144	2191.144	14026.57	14120.14	14213.71	21589.71	21750.52	21911.32
2021	1588.244	1874.244	2160.244	14189.85	14283.42	14376.99	22096.56	22257.36	22418.17
2022	1557.344	1843.344	2129.344	14353.13	14446.70	14540.27	22603.4	22764.21	22925.01
2023	1526.445	1812.445	2098.445	14516.41	14609.98	14703.55	23110.25	23271.05	23431.86
2024	1495.545	1781.545	2067.545	14679.69	14773.26	14866.83	23617.09	23777.90	23938.70

information to other research divisions and interested persons.

Secondary data on rice and other important crops are collected periodically from Bangladesh Bureau of Statistics (BBS), Agricultural Marketing Directorate (AMD), Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB), Bangladesh Agriculture Development Corporation (BADC) and other sources periodically and recorded.

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. Besides to make this database, we will use SQL Server 2005 express edition/2008/2010/2012 version. We will also use Oracle 9i/10g/11i version.

PROTOCOL FOR SOIL AND WATER SAMPLING

Arsenic contamination of the irrigation Water-Soil-Crop system, especially of the rice systems is a matter of great concern. In this study, arsenic contaminated ground water and soil, maps have been produced by spatial to improve knowledge of the geographical distribution of contamination of soil and irrigation water with arsenic, in order to target arsenic management strategies to the most contaminated areas. Spatial Analysis Tool of ArcGIS-10.1 versions were used for Geographic Information System (GIS) analysis and constructing the maps. Where exponential model (water interpolation) and spherical model (soil interpolation) were used in kriging determined through semi-variance analysis by GS+, Geo-statistics for environmental science software.

Sample has been collected from 4- × 4-km grid in Rice-Rice situation (medium high land), from the command area of STW/DTW of the selected Mouza. Single water and three soil samples have been collected diagonally from the command area and all sample points have been geo-referenced using global positioning system (GPS).

Figure 4 shows water arsenic (As) level interpolation map. From the map it can be
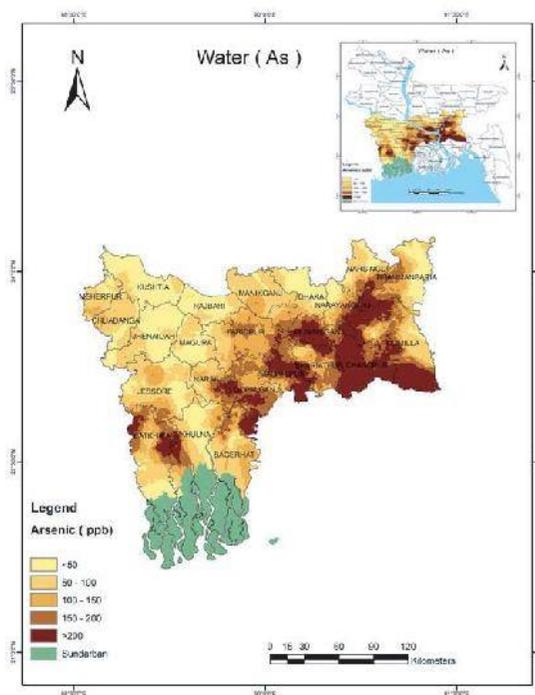
Fig. 4. Water Arsenic interpolation map.

described that very high level (>200 ppb) of As areas are Chandpur, Munshiganj, Madaripur and some parts of Goplaganj, Satkhira, Comilla and Brahamanbaria districts and then 150-200 ppb are mainly Shatkhira, Gopalganj, Shariyatpur, Comilla and some parts of Faridpur. Hundred-150 ppb areas are mainly Faridpur, Narayanganj and parts of Bagherhat, Khulna, 50-100 ppb in Meherpur, Chuadanga, Jessore, Narail, Manikganj, Narshingdi, Bagherhat and low <50 ppb dominant areas are in Kushtia, Khulna, Jhenaidah, Magura, Rajbari and Dhaka.

As level of all collected soil samples still do not not obtained from laboratory. So soil and water interpolation map are not of same extend. Figure 5, shows very high >20 ppm in Chandpur, Madaripur and some parts of Dhaka, Manikganj, Shatkhira, Narshingdi. Fifteen-20 ppm in Faridpur and some parts of Shariyatpur, Narail, Gopalganj 10-15 ppm in some parts of Magura, Rajbari, Faridpur, Shatkhira Narayanganj, Shariyatpur, Munshiganj and some parts of Comilla, Narshingdi. Five-10 ppm dominant in Kushtia, Meherpur, Chuadanga, Jhenaidah, Jessore,
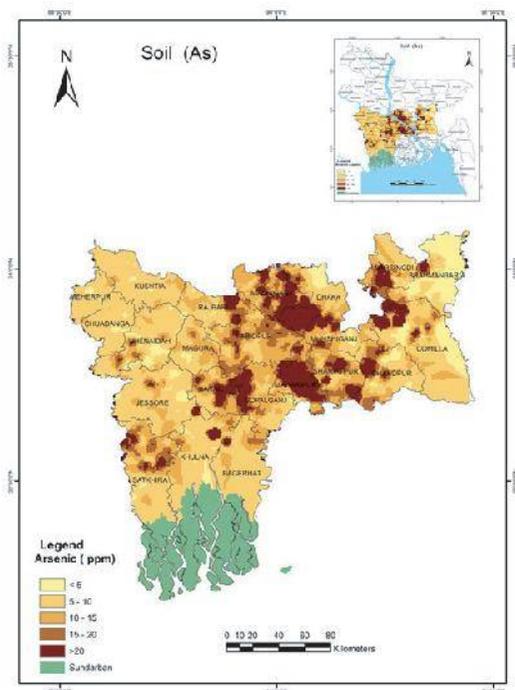
Fig. 5. Soil Arsenic interpolation map.

Khulna, Bagherhat, Dhaka and Comilla. Very low <5 ppm was in some pocket areas of Jhenaidah, Dhaka, Brahamanbaria and Comilla. It is noticeable that soil Arsenic distribution are more or less same in some areas. But in some areas intensity is more than that of water Arsenic concentration.

In total 4,620 soil samples and 1,540 water samples from 1,540 locations (Table 5) has been collected and all soil samples has been processed and digested and all 1,540 water samples analysed

Table 5. Sampling summary.

District	No. of points	District	No. of points
Kushtia	69	Chandpur	66
Meherpur	32	B. Baria	100
Chuadanga	46	Comilla	81
Jhenaidah	130	Dhaka	73
Jessore	115	Manikganj	74
Satkhira	116	Munshiganj	49
Gopalganj	76	Khulna	76
Madaripur	74	Bagherhat	61
Narail	56	Narshingdi	76
Magura	65	Narayanganj	43
Shariatpur	62		
Total			1540

for As, and 839 samples for Fe, Mn, P and 4,345 soil samples analysed for As. We also used 183 water samples and 552 soil samples in Faridpur and Rajbari for water and soil interpolation map, collected by BSMRAU. Almost all surveyed upazilas data entry has been completed by this time. From the maps and graphs it can be concluded that, the As level is high (>200 ppb) in Chandpur, Munshiganj, parts of Shariyatpur, Gopalganj and Satkhira districts for water and also high (15 ppm) in Satkhira, Gopalganj, Shariyatpur, Rajbari and Madaripur district for soil, where As level was high in recently installed well (1995-2012) and maximum As level observed in shallow well (<200 feet).

EFFECT OF MINIMUM TEMPERATURE ON BORO RICE

Boro rice ie irrigated rice is a potential area for increasing rice yield, which currently accounts for about 50% of total rice production in the country (BRRI, 2006). Boro rice is one of the major cereal food grains in Bangladesh, which is transplanted in winter season (December to February) and very susceptible to minimum temperature. The study was conducted to understand the impact of climate on Boro rice production and identify the vulnerable rice growing area in Bangladesh for changing climatic condition and adaptation process and to policy recommendation of different areas for rice production under diverse climatic condition. Rice production data are plotted in a figure using ArcGIS-10.1 software for different regions of last decade. Then we collected and calculated the data of minimum and maximum temperature for the Boro season from BMD (Bangladesh Meteorological Department) and plotted in graph for December-January and March-May differently in figures and graphs. We also plotted temperature data against the Boro rice production.

In December-January the average minimum temperature of the country was about 8.1°C and 14.4°C in March-May over the last 10 years. In December-January, minimum temperature was very low (<6°C) during 2003 and 2007 in some

region (Fig. 6) and maximum temperature little bit crossed 14°C only. But in March-May, the minimum temperature varies from 10 to 20°C where maximum temperature was high as 18 to 24°C (Fig. 7). In Figure 8, it has been shown that the minimum temperature trend of December-January more or less followed the trend of Boro rice yield. It also shows that at the extreme low temperature condition in December-January the yield reduced in 2002-03 and 2006-07. In Figure 9, the trend of minimum temperature increased while the yield of that times also increased during 2007-08 and 2008-09. Figure 10 shows rice production

of 23 rice regions, where the production of Patuakhali, Barisal, and Noakhali regions are low (not considered Bandarban, Khagrachhari, Rangamati region as these are hilly areas). Rice production in Comilla, Sylhet, Kishoreganj, Bogra, Dinajpur, Rajshahi, and Rangpur is high. Minimum temperature graph of December-January (Fig. 11) and March-May (Fig. 12) shows that low temperature in Sylhet, Mymensingh, Jessore, Kushtia, Dinajpur, and Rajshahi are helpful to increase Boro rice production.

The production is fluctuated in different years. Minimum temperature keeps prominent effect on
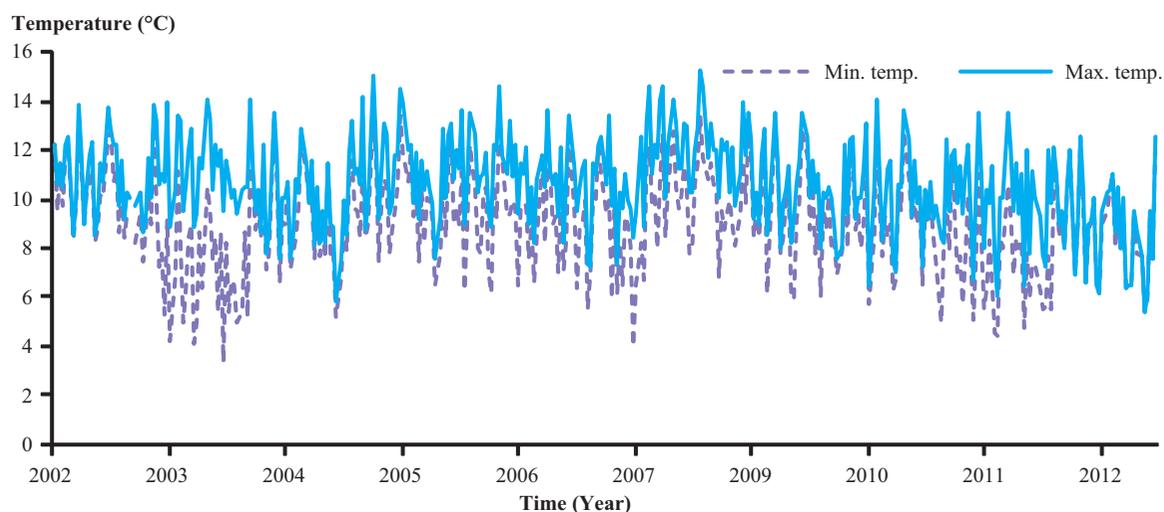
Temperature (°C)

Fig. 6. Maximum and minimum temperature in December-January from 2002-12.
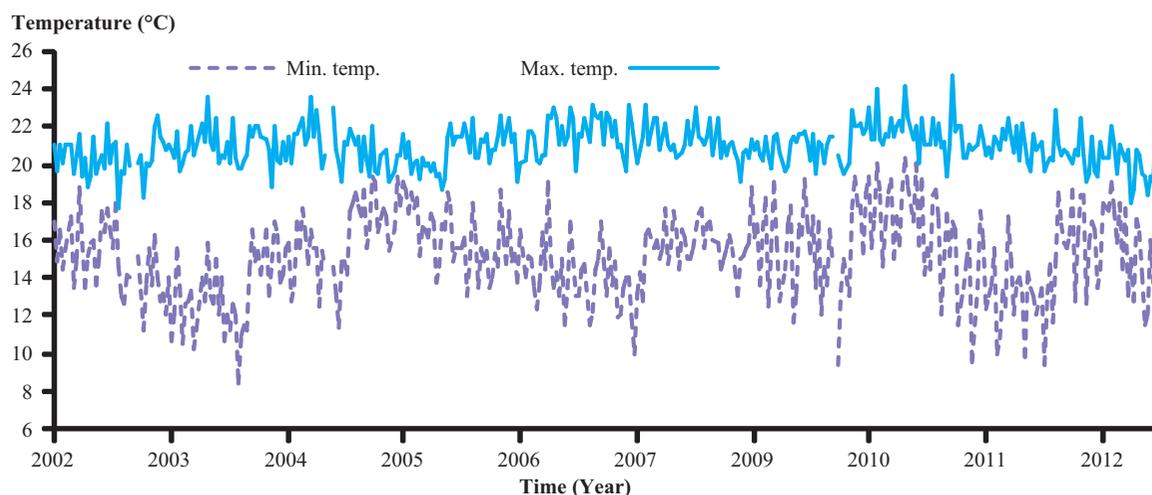
Temperature (°C)

Fig. 7. Maximum and minimum temperature in March-May from 2002-12.

Yield (M. t/ha) **Min. temp. (°C)**
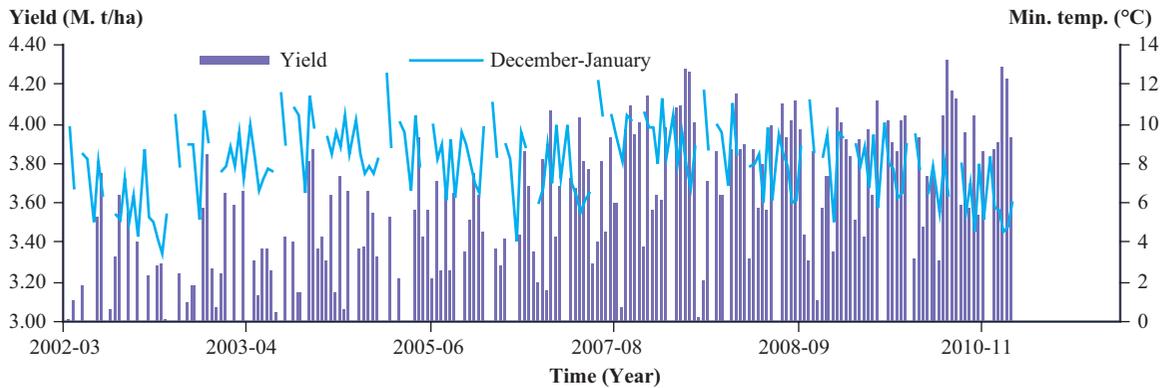
Fig. 8. Boro rice production and minimum temperature in Dec-Jan.

Yield (M. t/ha) **Min. temp. (°C)**
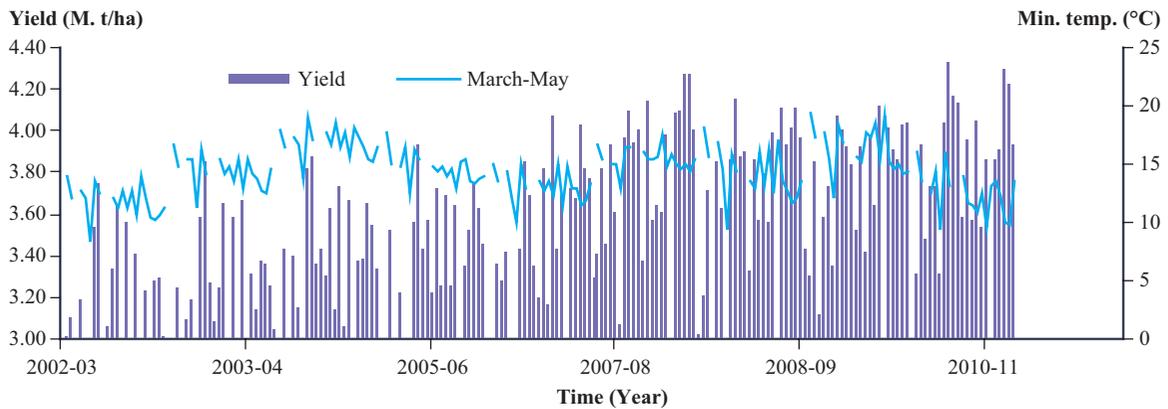
Fig. 9. Boro rice production and minimum temperature in March-May.
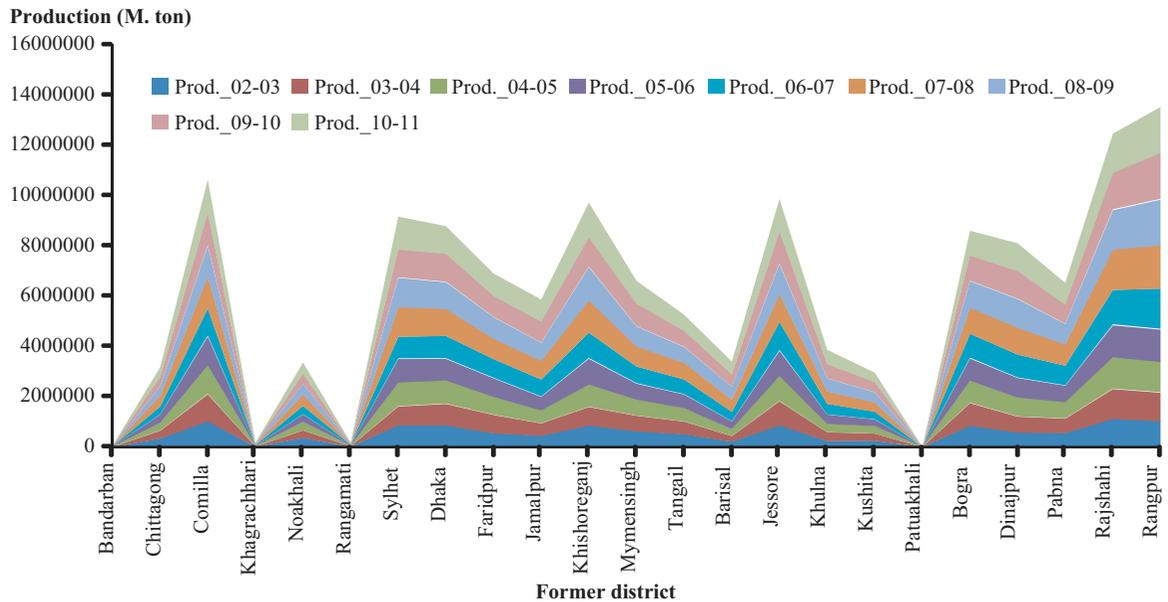
Production (M. ton)

Fig. 10. Boro rice production for 23 regions from 2002-03 to 2010-11 seasons.

Min. temp. (°C) (Dec-Jan)
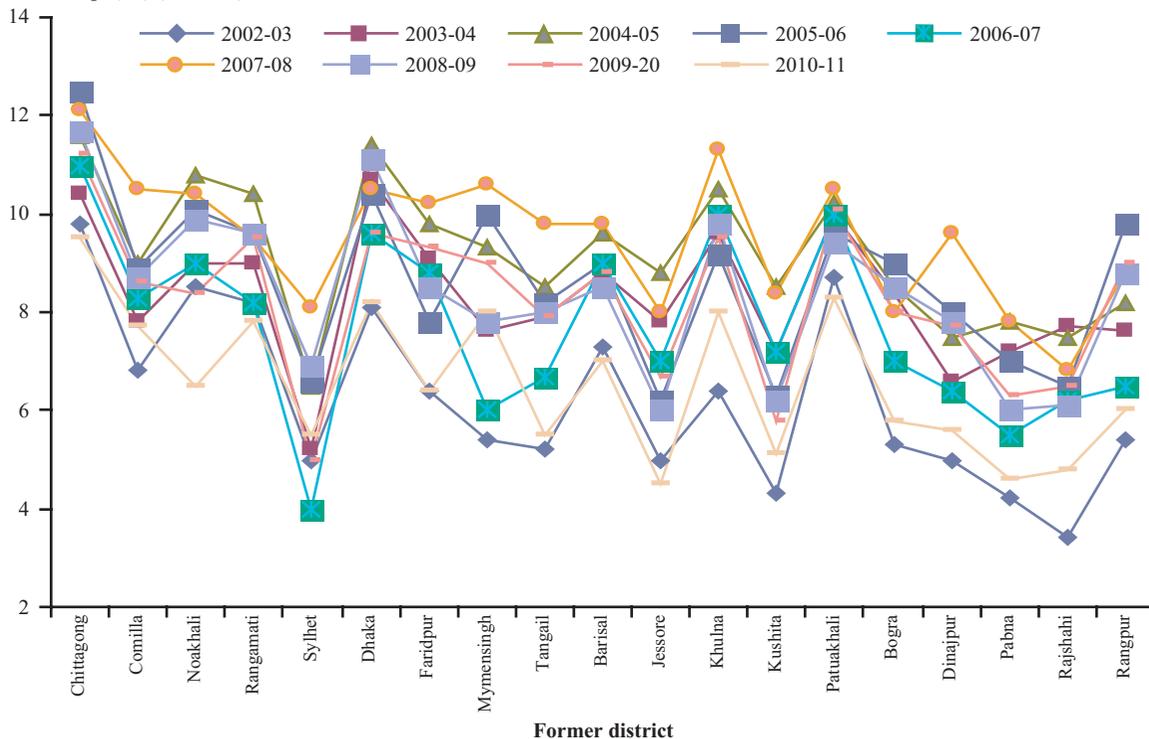
Fig. 11. Minimum temperature of December-January for different rice regions for the last decade.

Min. temp. (°C) (Mar-May)
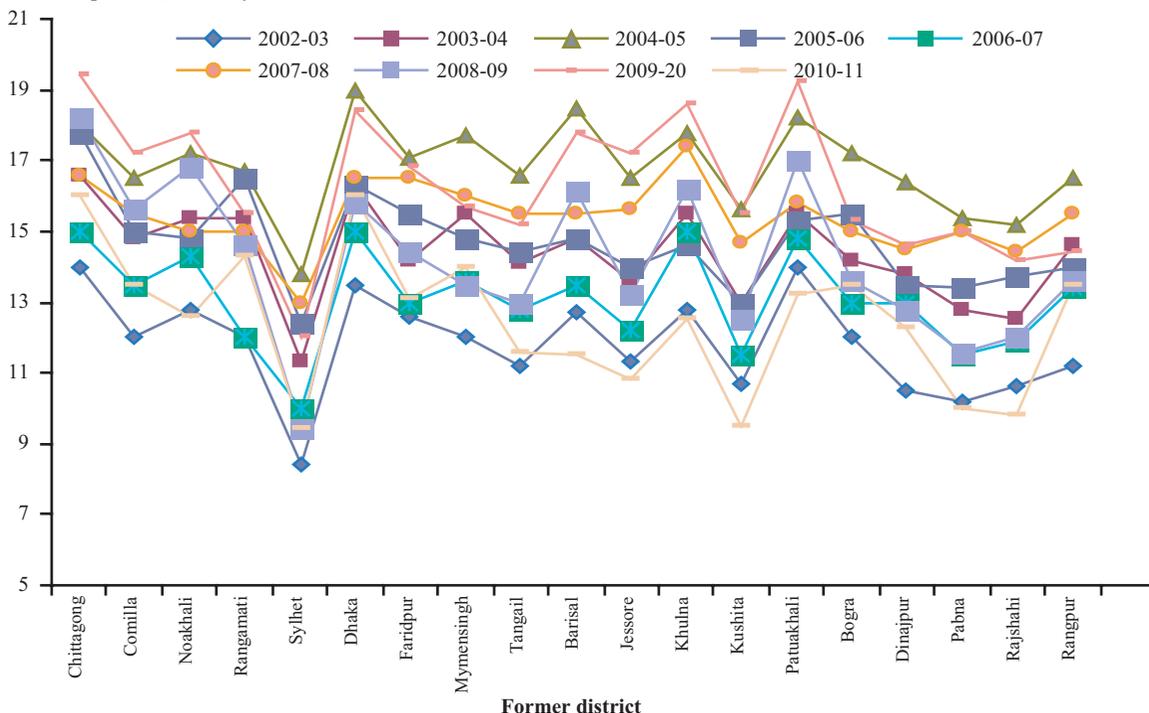
Fig. 12. Minimum temperature of March-May for different rice regions for the last decade.

Boro rice production. During germination and subsequent growth minimum temperature condition is important for plant. In December-January, minimum temperature was less than 6°C at 2003 and 2007 in some region and maximum temperature remained near to 12-14°C. In March-May, the minimum temperature varied from 10 to 20°C where maximum temperature was high as 18 to 24°C. Minimum temperature trend of December-January months more or less followed the trend of Boro rice production which indicates that the effect of minimum temperature is prominent. In December-January the minimum temperature as well as yield was reduced in 2002-03 and 2006-07. In March-May the maximum temperature (day temperature) remains below 24°C always. Among 23 rice regions, the production of Patuakhali, Barisal, and Noakhali regions are low as the salinity effect is prominent there (as coastal area) while in Comilla, Sylhet, Kishoreganj, Bogra Dinajpur, Rajshahi, and Rangpur it is high because of minimum temperature did not reach below critical temperature (<10°C) in March-May. So salinity effect is more effective over minimum temperature for Boro rice. Recently it is found that the temperature falls behind 4°C in northern region of Bangladesh which indicates that preparation is needed for facing cold temperature condition and its effect on Boro season.

To overcome low temperature stress on Boro rice and to get more production cold tolerant variety like BBRI dhan36, BRRI dhan55 can be adapted. Hence, in Sylhet, Jessore, Kushtia, Mymensingh and Rajshahi areas, where minimum temperature is low, such type of varieties can be applied to get high rice production.

RAINFALL AND TEMPERATURE EFFECTS ON AMAN RICE

The study was conducted for the effect of climate variables (rainfall, maximum temperature) on Aman rice production and mapping in Bangladesh. We used time series data for the last decade (2003-2012) for rainfall and maximum temperature from BMD (Bangladesh Meteorological Department) and BBS (Bangladesh Bureau of Statistics) respectively.

From the study we found that in north-eastern and south-eastern regions of Bangladesh Aman production is proportional to rainfall and inversely proportional to average maximum temperature (Fig. 13) which indicates, the rainfall and temperature effect of rice production prominently. So, other parameters are less prominently effect rice production in this region. In south-western region the Aman production decreased though rainfall and temperature do not show significant change. This scenario indicates rice production in this region is less dependent on rainfall and average maximum temperature. The other factors are more prominent in this region. We know that most of the area of the region is situated under tidal effect which may be the cause of production decrease. North-western region Aman production increased though rainfall decreased so significantly and average maximum temperature was high in this region. It implies that other factors such as modern technology, new varieties, irrigation systems etc led to the good production in this region. So it may be a good example of how to combat against climatic factors and further study is needed for clarification of other factors.

Maximum accurate data are required to make the research most effective and more data are needed to create interpolation map for rainfall and temperature. BRRI dhan51, BRRI dhan52 are
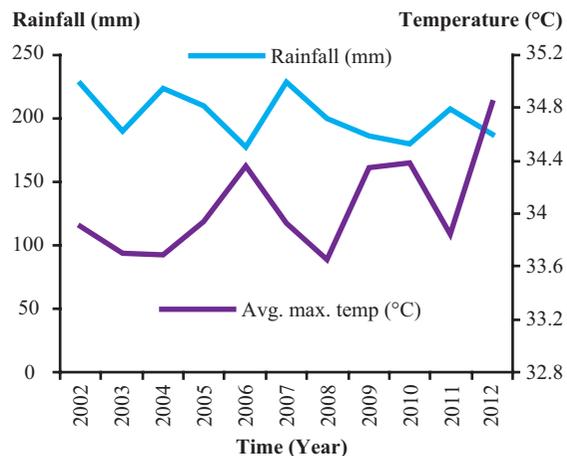
Fig. 13. Average rainfall and maximum temperature map of Bangladesh (2002-12).

suitable for north-eastern and south-eastern region, BR23, BRRI dhan40, BRRI dhan41, BRRI dhan53, BRRI dhan54 are suitable for south-western region and BRRI dhan33, BRRI dhan39 are suitable for the north-west. In south-west region, there also need further research for the salinity and tidal effect on the rice production. Further research required to find the prominent factor in the north-west region where rainfall and temperature have minimum effect in the region according to the findings of the research. There also need future research for the effect of soil quality and texture, ground water quality and position as well as technology development in those regions.

OTHER ACTIVITIES

Web portal management

The main objective of this activity is to make BRRI web portal using both English and Bengali language, complete the construction of blank pages and modify the design of the portal and manage and maintain it through regular updating of the information and documents.

BRRI website www.brri.gov.bd is being updated regularly with the latest information as a routine work. The static website of BRRI is converted into dynamic website (Web portal) which is made by our manpower of ICT cell, Agricultural Statistics Division as per requirement of the Ministry of Agriculture (MoA) and Access to Information (A2i) under Prime Minister's office (PMO). At present, BRRI website is hosted to Mango tech server. We have included rice database and weather database and maps at the BRRI dynamic website and updated it regularly. To make it more informative and updated, we developed individual web page including picture of head quarters and all regional stations of BRRI.

Management of brri network and internet connectivity

The main purpose of this activity is to manage and maintain ICT network and internet connectivity of BRRI, manage and maintain BRRI local area network (LAN) and initiate e-Governance.

We have increased our digital data network (DDN) bandwidth connectivity from 8 Mbps to 12 Mbps. Now our internet speed is faster than the previous one. We have already given internet connection in 300 computers. But we want to increase more internet connection. So, we have started to increase our bandwidth connectivity as per requirement of BRRI scientists and officers. Hopefully, within short time all the BRRI scientists and officers will get more speed for internet access with smooth communication and they will be benefited to pass information internally as well as globally.

Management information system (MIS)

The objectives of this work is to manage and maintain BRRI MIS, get BACKUP of MIS (nine modules) every day and input data of seven modules out of nine modules helped by NATP phase1.

Data entry of the seven modules has been already started in MIS Software. It is a continuous process. ICT cell of Agricultural Statistics Division provides MIS Software related support services such as create user, permission and access MIS modules, installation etc.

Video conference system

The objectives of this work are to develop 'Video conference system of BRRI' for administration, divisional heads and regional station heads of BRRI, develop 'Video conference system of BRRI' for research and administration works and developing the video conference system so that it can be implemented in local area network (LAN).

Video conference system which allows two or more locations to interact via two-way video and audio transmission simultaneously. It has also been called visual collaboration and is a type of groupware. Video conferencing technology provides a video link between two or more people, which allows them to see and hear each other at the same time. It works like two-way TV. It digitally reproduces image using IP (Internet protocols) technology, a standard set of rules to enable data transfer and LAN connection. Already we have created Skype account for all divisional heads and regional station heads.

Digital signature system

The objective of this programme is to develop 'Digital signature system of BRRI' for all divisional heads, regional station heads and section head of BRRI, develop 'Digital Signature System of BRRI' for research and administration works, develop unique system for the sender and develop proper integrity, accountability and confidentiality.

BRRI has already implemented digital signature certificate processing by controller of certifying authority (CCA) under information and communication technology (ICT) division of the government. Also, ICT cell of Agricultural Statistics Division distributed 53 digital signature certificate of scientists and officers of BRRI. It has arranged a workshop by ICT cell for distributing digital signature certificate for scientists and officers of BRRI, where officials of CCA have staged.

Personal data sheet (PDS) database

The objectives of this work are to develop 'personal data sheet (PDS)' database for all scientists, officers and staffs of BRRI, develop personal data sheet (PDS) database using user name and password and get BACKUP of personal data sheet (PDS) database regularly.

The PDS software is developed under BARC. We have created PDS database for all scientists, officers and staffs as per requirement of the Ministry of Agriculture (MoA). PDS database is updated regularly with latest information.

Web mail and group mail

The objectives of this work is to develop 'web mail' for all scientists and officers of BRRI for research and administration works and to develop 'group mail' for all scientists of BRRI for research and administration works.

We have created individual e-mail ID into BRRI domain for all scientists and all class one officers as per requirement of the MoA. We have created group mail for all scientists as per requirement of BRRI scientists. BRRI web mail and group mail hosting into Bangladesh Computer Council (BCC) server.

Facebook group (BRRI networks)

The main purpose of this work are to create a Facebook group for BRRI to promote all activities, where only official interactions, various problems and their solutions can be posted and create a big forum for all kinds of scientists, officers and staff of BRRI. One can post anything out of good work of rice and rice related activity of this forum.

BRRI introduced Facebook as per instruction from MoA. To build a linkage among all scientists, officers and staff where BRRI Networks play an important role. Already 93 members have joined this group. It will increase more gradually. The network is regularly updated by ICT cell and to protect from all types of unwanted post, photo and other spam, there is a moderator. So it is always safe and secured.

BRRI heritage

The objectives of this work are to develop 'Heritage' for all retired scientists, officers, staff and labourers of BRRI, develop heritage for research and administrative works, create and stimulate awareness amongst the present employees of BRRI about retired scientists and officer's good works so that they can follow their instruction and communicate effectively. So it may stay for long time and the employees of BRRI will remember them.

We have created heritage for all retired scientists, officers, staffs and labourers of BRRI as per requirement of the BRRI authority. We have created individual webpage including picture of all scientists, officers, staffs and all labourers of BRRI. Heritage is updated regularly.

Support services

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 120 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.

Farm Management Division

SUMMARY

This experiment was conducted at the West Byde of BRRI HQ farm, Gazipur during Boro 2013-14 season to determine the relative profitability of different sources of N and weed control methods in relation to labour use for rice cultivation. The treatments were different sources of N (PU=applies 3 equal splits; and USG=Applies at 15 DAT + PU at 45 DAT) and weed control methods (W_1=herbicide Refit + Hand weeding at 45 DAT; W_2=herbicide super clean + hand weeding at 45 DAT; and W_3=hand weeding at 15, 30 and 45 DAT). The treatments were arranged in a randomized complete block design with three replications. BRRI dhan29 was used as test materials. All the parameters were significantly affected by the interaction effect of N-fertilizers and weed control methods except 1000-grain weight, grain and straw yield. In PU applied plots, hand weeding produced the highest number of tiller m^{-2} and grain panicle^{-1} but super clean gave the highest number panicle^{-1}. Weeding method had no significant effect on grain yield. All the parameters were higher in USG applied plots than PU applied plots. Application of super clean instead of refit earned Tk 4,451 ha^{-1} additional profit but application of super clean instead of hand weeding gave Tk 12,831 ha^{-1} more profit. Application of refit instead of hand weeding earned more profit of Tk 8,750 ha^{-1} and application of USG instead of PU earned more profit of Tk 4,292 ha^{-1}.

An experiment was conducted during Aus 2013, T. Aman 2013 and Boro 2013-14 seasons at the west byde of BRRI farm, Gazipur to determine the cost and return of HYV rice cultivation in present situation. The rice varieties BR26, BRRI dhan41 and BRRI dhan29 were used in Aus, Aman and Boro seasons respectively. Total labour requirement was 264, 267 and 270 md ha^{-1} in Aus, Aman and Boro season respectively. The total variable cost, gross return and gross margin was highest in Boro season followed by Aman and the lowest in Aus season but the cost of production of per kg of rice was the highest in Aus season (Tk 23.28) followed by Aman (Tk 16.48) and Boro season (Tk 16.34). The BCR was 1.29, 1.71 and 1.72 in Aus, Aman and Boro seasons respectively.

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 335 to 350. The wage rate day^{-1}during the peak periods of the year Tk 470 to 480 in May, Tk 285 to 340 in July-August and Tk 330 to 420 in December-January were existed.

The wage rate varied between Tk 200-300, 200-300, 200-300, 250-300, 250-300, 300-400, 300-400 and 350-400 at Habiganj, Rangpur, Rajshahi, Barisal, Sonagazi, Comilla, Satkhira and Khulna respectively.

This division produced about 16,967 kg rice of which 795, 2,665 and 13,507 kg of seed, non-seed and mixed rice respectively. This rice was deposited to BRRI general store. This division also produced 9,247 kg breeder seed and 381 kg TLS in collaboration with the GRS Division.

BRRI had 561 labourers of which 540 regular, 21 irregular. In BRRI HQ, the number of labourer was 360 of which 354 were regular and six were irregular. The institute has 274 ha of land of which 163 ha was cultivable. Total labour used in different divisions was 1,70,358 man days of which 55.19, 38.30 and 6.51% were used for research, support service and holidays respectively. A total of Tk 4,41,93,007 was paid as labour wages of which Tk 2,48,37,532 and Tk 1,72,53,924 and Tk 21,01,551 were paid to the labourers for research work, support service works and leaves respectively.

About 68.43 ha of land was used by different divisions in different season of which 4.89 ha in Aus, 32.06 ha in Aman and 31.48 ha in Boro season.

This division manages the BRRI flower garden to maintain the aesthetic view of the campus by creating visible flower garden during summer and winter season.

RESEARCH ACTIVITIES

Sources of N and weed control methods in respect to labour

An experiment was conducted in the west byde of

BRRI HQ, Gazipur farm during Boro 2012-13 season in a randomized complete block (RCB) design with three replications to determine the relative profitability of different sources of N and weed control method in relation to labour use for rice cultivation. BRRI dhan29 was used for experimental purpose. The treatments were different sources of N (PU=applies in three equal splits; and USG= Applies at 15 DAT + PU at 45 DAT) and weed control methods (W_1=herbicide Refit+ Hand weeding at 45 DAT; W_2=herbicide super clean + hand weeding at 45 DAT; and W_3=hand weeding at 15, 30 and 45 DAT). The unit plot size was 10- × 10-m. The collected data were analyzed by following a standard statistical procedure and the mean differences were adjusted by LSD method.

Interaction effect. Tiller m^{-2}, panicle m^{-2} and grain panicle^{-1} was significantly affected by the interaction effect of N-fertilizers and weed control methods (Table 1).

Tiller number. In PU applied plots; hand weeding produced the highest number tiller m^{-2}, followed by super clean and the lowest in refit applied plot. In USG applied plots, weeding method had no significant effect on number of tiller m^{-2}. Regardless of weed control method, USG applied plots gave the highest number of tiller $^{-2}$ than PU applied plots with no significant difference between USG applied plot and PU applied plots except PU × refit + HW plots.

Panicle number. Irrespective of N-fertilizers, weed control method had no significant effect on panicle number m^{-2}. Irrespective of weed control method, USG applied plots produced the highest number of panicle than PU applied plots.

Grain number. In PU applied plot, hand weeding produced the highest number of grain panicle^{-1} followed by that of super clean and the lowest in refit applied plot with no significant difference between super clean and hand weeding plots. In USG applied plots, refit and super clean applied plot gave the higher number of grain panicle^{-1} and the lowest in hand weeding plot. Irrespective of weeding method except hand weeding USG produced the highest number grain panicle^{-1} than PU applied plots.

Grain yield. It was observed that USG applied plot produced the highest grain yield than PU applied plot. It was observed that, USG applied plots produced the highest number of tiller m^{-2}, panicle m^{-2} and grain panicle^{-1} but 1000 grain weight, grain yield and straw yield were not significantly affected nitrogenous fertilizers (Table 2). None of the parameters were significantly affected by nitrogenous fertilizers.

Total labour requirement

Hand weeding required the highest number of labour followed by Refit and lowest in Super clean applied plot. USG applied plots required higher (7%) number of labour than PU applied plots (Table 3).

Partial budgeting. Table 4 presents the cost and return for calculation of partial budgeting (Tables 5 and 6). Application of super clean instead of refit gave Tk 4,451 ha^{-1} additional profit but application of super clean instead of hand weeding gave Tk 12,831 ha^{-1} additional profit. However, application of refit instead of hand weeding the additional profit was Tk 8,750 ha^{-1} and application of USG instead of PU earned the

Table 1. Yield and yield components of rice as affected by the interaction effect of method of weed control and application of N-fertilizer, Boro 2013-14.

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})
PU × Refit+HW	320bB	280aB	121bB	24.38	7.6	8.6
PU × Super Clean+HW	328aB	281aB	125aB	24.72	7.4	8.9
PU × Hand weeding	333aB	279aB	127aA	25.56	7.5	8.5
USG × Refit+HW	336aA	288aA	130aA	25.18	7.8	8.7
USG × Super Clean+HW	339aA	289aA	129aA	23.95	8.0	8.6
USG × Hand weeding	339aA	290aA	125bA	24.16	7.9	8.8
LSD at 5% level	5.1	7.6	*2.3*	ns	ns	ns

In a column, different small letters indicate the differences among methods under same N-fertilizers and different capital letters indicate the difference among N-fertilizers under same methods, ns=Not significant.

Table 2. Yield and yield components of rice as affected by the effect of method of weed control and application of N-fertilizer, Boro 2013-14.

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})
			N-fertilizer			
PU	327	280	124	24.89	7.5	8.7
USG	338	289	128	24.43	7.9	8.7
LSD at 5% level	4.6	5.3	1.6	ns	ns	ns
			Weed control method			
Refit	328	284	125	24.78	7.7	8.6
Super Clean	333	285	127	24.34	7.7	8.7
Hand weeding	336	285	126	24.86	7.7	8.6
LSD at 5% level	ns	ns	ns	ns	ns	ns

In a column, different small letters indicate the differences among treatments, ns=Not significant.

Table 3. Labour requirement as affected by method of weed control and application of N-fertilizer, Boro 2013-14.

Treatment	Refit + HW	Super Clean + HW	Hand weeding	Mean
PU=Application of prilled urea (PU) as per recommended rate of N and applied 3 equal splits	233	215	269	239
USG=Application of USG as per recommended rate of N	246	235	285	255
Mean	240	225	277	

Table 4. Cost and return of weed control method and N-fertilizer use for rice cultivation.

Treatment combination	Total variable cost (Tk ha^{-1})	Gross return (Tk ha^{-1})	Gross margin (Tk ha^{-1})
PU × Refit	64155	196371	132216
PU × Super Clean	59165	192864	133699
PU × Hand weeding	72515	193690	121175
USG × Refit	68360	201362	133002
USG × Super Clean	65190	205611	140421
USG × Hand weeding	77500	204043	126543

Price of rice and straw are Tk 22.0 kg^{-1}, and Tk 3.5 kg^{-1} respectively. Labour cost Tk 260 day^{-1}.

additional profit of Tk 4,292 ha^{-1}. So, among the weed control methods, using of super clean might be more profitable than refit and hand weeding, and between N-fertilizers, USG was more profitable than PU.

Cost and return of HYV rice cultivation

This experiment was conducted during Aus 2013, T. Aman 2013 and Boro 2013-14 seasons at the west byde of the BRRI HQ farm, Gazipur. The variety BR26, BRRI dhan41 and BRRI dhan29 were used in Aus, Aman and Boro season respectively. The plot size was 25- × 25-m irrespective of season. Labour requirements for different operations such as seedling uprooting, transplanting, weeding, harvesting, threshing and winnowing were done through direct supervision.

Total labour requirements for different operations of rice cultivation in one hectare of land was 264, 267 and 270 md ha^{-1} in Aus, Aman and Boro season respectively (Table 7). Boro season required the highest number of labour due to the higher requirement of labour for shorter type of seedling uprooting, transplanting, harvesting and post-harvest operations than Aus and Aman seasons. Due to higher cost of irrigation, fertilizers and laborers, the total variable cost was the highest in Boro season (Tk 1,20,934) followed by Aman (Tk 1,02,182) and the lowest in Aus season (Tk 93,102). This cost included the cost of labour, diesel and driver, seed, fertilizer, and irrigation (Table 8).

The highest gross return was found in Boro season (Tk 1,92,550) followed by Aman (Tk 1,62,650) and Aus (Tk 1,10,750) season. The gross margin was also the highest in the Boro season (Tk 71,616) followed by Aman (Tk 60,468) and Aus (Tk 17,648) season. The cost of

Table 5. Partial budgeting.

(a) Super Clean versus refit

Debit		Credit	
Cost for using Super Clean	62178	Return from using Super Clean	199238
Revenue forgone for not using Refit	198867	Cost for using Refit	66258
Profit/Loss	+4451		
Total	265496		265496

(b) Super Clean versus hand weeding

Debit		Credit	
Cost for using Super Clean	62178	Return from using Super clean	198867
Revenue forgone for not hand weeding	198867	Cost for hand weeding	75008
Profit/Loss	+12831		
Total	273875		273875

(c) Refit versus hand weeding

Debit		Credit	
Cost for using Refit	66258	Return from using Refit	198867
Revenue forgone for not hand weeding	198867	Cost for hand weeding	75008
Profit/Loss	+8750		
Total	273875		273875

(d) USG versus PU

Debit		Credit	
Cost for using USG	70350	Return from using USG	203672
Revenue forgone for not using PU	194308	Cost for using PU	65278
Profit/Loss	+4292		
Total	268950		268950

Table 6. Summary of partial budgeting.

Partial budgeting	Profit /Loss (Tk ha^{-1})
Super Clean versus Refit	(+) 4451
Super Clean versus hand weeding	(+) 12831
Refit versus hand weeding	(+) 8750
USG versus PU	(+) 4292

Table 7. Labour requirement (md ha^{-1}) for different operations of rice cultivation in Aus, Aman and Boro seasons.

Season	Seedbed preparation, seedling uprooting, etc	Transplanting	1st weeding	2nd weeding	Harvesting	Carrying, threshing, cleaning and drying	Total
Aus	24	55	46	31	43	65	264
Aman	25	57	46	29	44	66	267
Boro	27	59	40	28	48	68	270

Table 8. Cost (Tk ha^{-1}) for rice cultivation in Aus, Aman and Boro seasons.

Cost item	Season		
	Aus	Aman	Boro
Labour	68,640	69,420	70,200
Diesel, driver and labour	4,500	4,500	4,500
Seed	650	650	650
Fertilizer	8,612	8,612	11,584
Insecticide	10,000	10,000	10,000
Irrigation	700	9,000	24,000
Total variable cost	93,102	1,02,182	1,20,934

production of per kg of rice was the highest in Aus season (Tk 23.28) followed by Aman (Tk 16.48) and the lowest in Boro season (Tk 16.34). The BCR was 1.29, 1.71 and 1.72 in Aus, Aman and Boro seasons, respectively (Table 9). It may be concluded that the highest gross margin was in Boro season and the lowest was in Aus season.

Monitoring labour wage rate at different locations
A survey was conducted to find out the laborers' wage rate at different locations around BRRI HQ such as Joydebpur, Chowrasta, Salna, Board Bazar, Tongi, Konabari, etc (Table 10). It was observed that the average wage rate per day was Tk 340-375. The highest wage rate of labourers was in May due to harvesting and post-harvest operations of Boro rice and transplanting of Aus rice. Another higher rate was during July-August due to harvesting and post-harvest operations of Aus and transplanting of Aman rice and the third higher wage rate was observed during December-January due to the peak period for harvesting and post-harvest operation of Aman rice and transplanting of Boro rice. The wage rate during these peak months was Tk 350-400 in May, Tk 350-400 in July-August and Tk 400-450 in December -January.

Another survey was conducted at different locations of Habiganj, Rangpur, Rajshahi, Barisal, Sonagazi, Comilla Satkhira and Khulna (Table 11). It was observed that the wage rate varied from place to place and ranged between Tk 250-300, 250-300, 250-300, 250-300, 250-300, 300-350, 300-350 and 250-300 at Habiganj, Rangpur, Rajshahi, Barisal, Sonagazi, Comilla Satkhira and Khulna repectively.

Rice seed production. In different seasons, this division produced 16,967 kg rice of which 795 kg seed, 2,665 kg non-seed and 13,507 kg mixed rice. These seeds were deposited to BRRI general store. This division also produced 9,247 kg breeder seed and 381 kg TLS. These seeds were deposited to GRS Division.

Land and labour management. Including regional stations, BRRI has about 665 labourers of which 537 regular and 128 irregular (Table 12). In BRRI HQ, total labour number is 423 of which 349 regular and 74 irregular labourers. BRRI has 274 ha of land of which 163 ha is cultivable.

Labour wages. It was observed that total labour wages was Tk 4,41,93,007 of which Tk 2,48,37,532 and Tk 1,72,53,924 and Tk 21,01,551 were paid to the labourers for research work, support service works and leaves respectively.

Labour use. Total labour use in different divisions for research purpose, research related works, support service and leaves was 1,70,358 man days of which 55.19, 38.30 and 6.51% were used for research, support service and holiday purpose respectively.

Land use. A total of 68.43 ha of land were used by different divisions in different seasons of which 4.89 ha in Aus, 32.06 ha in Aman and 31.48 ha in Boro season (Fig. 1).

Irrigation. This division supplies and manages the irrigation of cultivated land as per requirement.

Garden management. This division always manages a visible flower garden to maintain an aesthetic view of the office area and some parts of the campus during summer and winter season.

Table 9. Yield, gross return, gross margin, cost of production of per kg rice and BCR for rice cultivation in Aus, Aman and Boro seasons.

Item	Season		
	Aus	T. Aman	Boro
Grain yield (t ha^{-1})	4.0	6.2	7.4
Straw yield (t ha^{-1})	6.5	7.5	8.5
Gross return (Tk ha^{-1})	1,10,750	1,62,650	1,92,550
Total variable cost (Tk ha^{-1})	93,102	1,02,182	1,20,934
Gross margin (Tk ha^{-1})	17,648	60,468	71,616
Cost of production (Tk kg^{-1} rice)	23.28	16.48	16.34
BCR	1.29	1.71	1.72

Price of rice and straw are Tk 22.0 kg^{-1}, Tk 3.5 kg^{-1} respectively. Labour cost Tk 260 day^{-1}.

Table 10. Labourer's wage rate at different places around BRRI HQ, Gazipur during 2013-14.

Month	Wage rate*	Remark
April	300-350	Normal period
May	350-400	Peak period. Harvesting and post-harvest operation of Boro rice and transplanting of Aus rice.
June	325-350	Normal period
July	350-400	Peak period. Harvesting and post-harvest operation of Aus rice and transplanting of Aman rice.
August	360-380	"
September	340-350	Normal period
October	330-350	"
November	300-330	"
December	400-450	Peak period. Harvesting and post-harvest operation of Aman rice and transplanting of Boro rice.
January	400-450	"
February	300-350	"
March	330-350	Normal period
Average	340-375	

*Wage rate of each month is the average rate of different places such as Joydebpur, Chowrasta, Salna, Board Bazar, Konabari etc.

Table 11. Labourer's wage rate at different locations in 2013-2014.

Location	Wage rate (Tk)
Habiganj	250-300
Rangpur	250-300
Rajshahi	250-300
Barisal	250-300
Sonagazi	250-300
Comilla	300-350
Satkhira	300-350
Khulna	250-300

Table 12. Land and labour strength of BRRI, 2013-2014.

| Station	Total land (ha)	Cultivable land		Labour (no.)		
		Area (ha)	% of total land	Muster roll		Total
				Regular	Irregular	
HQ, Gazipur	76.83	44.45	57.9	349	74	423
Comilla	24.68	16.03	65.0	29	-	29
Habiganj	35.03	25.90	73.9	31	4	35
Sonagazi	45.77	35.90	78.4	26	11	37
Barisal	41.10	10.74	26.1	20	11	31
Rajshahi	13.24	8.92	67.4	23	8	31
Bhanga	11.46	9.55	83.3	13	5	18
Rangpur	6.07	4.05	66.7	26	4	30
Kushtia	0	0	0	11	-	11
Satkhira	20.00	8.10	40.5	9	11	20
Total	274.18	163.64	59.7	537	128	665
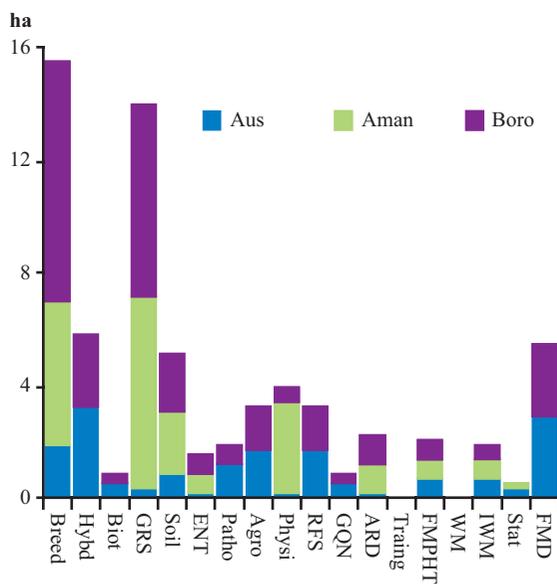
Fig. 1. Land use by different divisions 2013-14.

Farm Machinery and Postharvest Technology Division

SUMMARY

BRRI panicle thresher has the provision of threshing, cleaning, bagging and easy movement facilities and straw remain intact after threshing. The capacity of the thresher in threshing and cleaning is 400 and 1500 kg/h respectively.

A power hand reaper was developed using existing power unit of bush cutter. The reaping part of reaper was fabricated in the FMPHT divisional research workshop as per design. The average field capacity and fuel consumption was found 16~22 decimal/h and 0.8~1.0 lit/h respectively. Cutting efficiency was observed nearly 100 percent.

Field performance of Korean self-propelled reaper, China self-propelled reaper and BRRI power tiller mounted reaper were evaluated in Mithapukur, Rangpur district during Aman season 2013. The actual field capacity of Korean self-propelled reaper, China self-propelled reaper and BRRI power tiller mounted reaper was 0.18, 0.18 and 0.15 ha/h with field efficiency of 66.0, 86.0 and 66.7% respectively. The actual field capacity varied from one to another due to turning loss of the reaper and operator's skill. The fuel consumption of reaper was 0.76, 0.48 and 1.25 l/h and shattering loss during harvesting was 1.66, 1.50 and 1.45% respectively. The break-even area of the reapers was 9.15, 7.82 and 8.43 ha/yr of Korean self-propelled reaper, China self-propelled reaper and BRRI power tiller mounted reaper, respectively.

A study was conducted to identify the effect of growing media on quality seedling in terms of seedling strength and rolling quality of the seedling mat raised for mechanical transplanting during Aman and Boro season of 2013-14. Seedling were raised on plastic tray using sandy loam and clay loam soil mixed with decomposed cow-dung, mustard cake, rice straw organic fertilizer, rice bran, poultry litter and vermicompost at the rate of 0.0, 10, 20, 30 and 40%. BRRI dhan28, BRRI dhan29 and BRRI dhan49 were used as variety in Boro 2013-14 and Aman 2013 respectively. Rolling quality decreased and seedling height increased with the increase of mixing rate of organic fertilizer except rice bran and mustard cake for both types of soil whereas number of seedling per unit area decreased with the increase of organic fertilizer mixture after a certain limit for both types of soil irrespective of season. Aman season showed better performance on rolling quality of the seedling mat irrespective of soil type and organic fertilizer with the rate of mixture 0 to 30% except mustard cake. Around 10 to 30% cow-dung, rice straw organic fertilizer, vermicompost, 10% poultry litter and 20 to 30% rice bran with both types of soil was found suitable for seedling mat.

The optimization of seedling density for mechanical rice transplanter was conducted on the basis of missing hills and number of seedling per hill under different seedling adjustment options. In each tray 130 g for bold grain, 140 g for medium and slender grain and 120 g for extra-long and slender paddy seed was found suitable for mechanical transplanter to avoid missing hill.

A participatory research work was done with Syngenta under public private partnership approach during Aman 2013 and Boro 2014 season in Natoreand Bogra district. BRRI provided one 6-row riding type transplanter and two walk behind mechanical transplanter to Syngenta provided custom hire. Transplanting operation was done in 42.55 ha area in 375 numbers of plots and 205 farmers were benefitted by using BRRI supplied transplanter. Fuel consumption of 6-row ridingtype and walk behind type transplanter obtained 2.44 and 0.60 liter per bigha respectively. Missing hill was found 2%. About 6% tray required in pocket area filling by manual labour due to irregular shape of the plot. Almost 52% times spent in plot to plot movement and idle time. Among the transplanting plots, 70% are uniform, 25% are irregular and 5% were mostly irregular. Seedling tray requirement obtained 24 trays per bigha in Aman season. Two skilled operators were developed during this season. Machine transplanting (MT) produced 14-23% higher grain yield in both the seasons. The total cost of production, gross return, gross margin and BCR were the highest in MT in two seasons. BCR was higher in MT than farmers practice in both seasons due to higher grain and straw yield.

An experiment was carried under public private partnership approach. One DAEDONG

combine harvester was given to the local NGO named SOJAG, Dhamrai, Dhaka to provide rental service to farmers for harvesting rice in Boro 2014 season. Fuel consumption of the combine harvester obtained 40 liter per hectare and field capacity obtained 0.18 hectare per hour. Field efficiency increased with the increase of the length of land due to reduction turning loss.

An improved air blowing type rice mill was designed and fabricated in the FMPHT research laboratory. A 15 kW electric motor and 8 number huller were used to fabricate the mill. The capacity of the modified air blowing type mill was 250-300 kg/h which was two to three times of the capacity of small air blowing type rice mill. Milling yield, head rice and broken rice was found 66, 63 and 2% respectively.

In 2013-14, a total of 132 day-long demonstration cum informal training programmes were conducted at different places of FMTD project areas. About 5,280 participants including farmers, machine operators and Sub-Assistant Agricultural Officer (SAAO) attended the demonstration cum informal training programmes. As a result awareness was created among the farmers on the benefit of using of BRRI farm machinery and they also wanted to purchase the machine with subsidized prices. Drum seeder, BRRI weeder, BRRI rice-wheat reaper, BRRI rice-wheat thresher (TH-7), BRRI open drum thresher, BRRI winnower, BRRI USG applicator and BRRI chula were also displayed during entire period of the fairs. Functions of these machines, advantages and disadvantages were displayed to the spectators by posters, display cards and leaflets.

Field trial of mechanical rice transplanter, BRRI USG applicator, BRRI prilled urea applicator, BRRI weeder and BRRI power weeder were conducted in different locations of Barisal, Jhalkhathi, Patuakhali, Nilphamari, Kurigram and Rangpur district during Boro 2014, Aus 2014 and Aman 2014 seasons. The yield of mechanically transplanted rice was always higher than manually transplanted rice due to use of tender aged seedling. There was no significant yield difference between BRRI USG applicator plot and BRRI prilled urea applicator plot. The urea fertilizer dose was same both in BRRI USG applicator plot

and BRRI prilled urea applicator plot. Field demonstration of seedling raising technique, mechanical rice transplanter, BRRI USG applicator, BRRI prilled urea applicator, BRRI power weeder and BRRI weeder, was conducted in 22, 19 and 19 locations of Barisal, Jhalkhathi, Patuakhali, Nilphamari, Kurigram and Rangpur districts during Boro 2014 and Aus 2014 season respectively.

In total 62 two-day-long training programmes were conducted during Aman and Boro seasons 2013-14 in different locations within the project areas. Altogether 1,240 participants mostly farm machinery operators attended in formal training programmes as trainee. A basic idea (how to operate new engine; when to change air, oil and fuel filter etc) on operation, repair and maintenance of diesel engine was shared with the participants. Trained operator was able to repair minor defects of the machine themselves. After training, the operators used all machinery efficiently.

One manufacturers training programmes were conducted during 2013-14. Fifteen participants from different farm machinery manufacturing workshops attended the five-day-long training. Both the theoretical lecture and the hand on practical sessions were there.

Two three-day residential training on operation and maintenance of farm machinery was conducted at BRRI head office. Farmers and farm machinery operators were invited from IAPP locations. In this training 46 farmers and operators were trained up about practical operation and maintenance of farm machinery. Two one-day-long training programmes were also conducted on the operation and maintenance of promising farm machinery in Rangpur and Kurigram district where 56 LFS farmers were trained up.

A study was conducted at selected 24 upzilas of 12 districts during the Boro 2014 season to assess the present conditions, extent of use and repair and maintenance status of the machines supplied by the project with 60% subsidized price. Data were collected from total 717 machines owners of 5 different types farm machinery from the project areas. Only small amount (2.79%) of machinery were completely damaged (poor

condition) which was usual as reported by the farmers considering 3-4 years expected machine life. BRRI winnower was still less popular among the BRRI machines and BRRI reaper (41.67%) owner did not use their machine efficiently due to lack of technical knowledge.

Two air blow type rice mill were design, fabricate and installed at Raiganj of Sirajganj and Burichang of Comilla district for long term use in farmers field under the supervision of Good Neighbour, a Korean NGO and Community Village Development Programme (CVDP), BARD respectively. The parboiled/unparboiled rice was milled using the Air-blow type rice mill in a single pass. A total 500 A-frame carriers, 100 in each demonstration site were distributed at Raiganj upazila of Sirajganj, Burichang upazila of Commila, Dhirashrom village of Gazipur sadar upazila, Ghatail of Tangail and Fulpur upazila of Mymensingh district.

AGRICULTURAL MACHINERY DEVELOPMENT AND TESTING

Development of BRRI panicle thresher

BRRI panicle thresher was fabricated incorporating bagging and cleaning facility at Farida Engineering Workshops, Bogra under direct supervision of BRRI. B-type V groove pulley were used in threshing drum, blower and delivery chute. Hood was added on the top of the thresher to avoid spilled grain. Four rubber wheels were added for ease of transportation. Length of threshing drum was adjusted to operate the machine by two operators. Diameter of the pulleys of the engine, threshing drum and augur shaft were 3.5, 6.0 and 3.0 inch respectively. Pulley sizes were different due to requirement of various speed in threshing drum, blower and augur shaft. Revolution of the pulleys of engine, blower and augur shaft were 2,600 (maximum), 1,800 and 950 rpm respectively.

Performance test

Initial performance test was done in the research workshop with rice and wheat. **Table 1** shows the preliminary test result of panicle thresher. Only

Table 1. Performance test of BRRI panicle thresher.

Trial no.	Threshing capacity (kg/h)	Cleaning capacity (kg/h)
1	407	1,493
2	400	1,505
3	393	1,502
Average	400	1,500

The general features	Engine type	: 4.5 hp diesel engine
	Threshing capacity (rice)	: 400 kg/h
	Winnowing capacity	: 1500 kg/h
	Operator requirement	: 2 nos.
	Price	: 22,000 (Without engine)

panicle of the rice plant can be threshed by this thresher. Straw remains intact after threshing. The threshing capacity was found 400 kg/h and cleaning capacity of the machine 1,500 kg/h when it is used as winnower only.

Design and development of power operated hand reaper

A hand reaper is one kind of hand tools especially design for harvesting standing paddy, wheat, maize, bushes etc powered by a 1hp petrol engine. A 25 mm diameter aluminum pipe was used as the main axle and handle of the machine. The engine power transmitted to the cutter bar through flexible electrical wear in direct coupling. BRRI hand reaper is suitable for reaping paddy withthe minimum 4,500 rpm of cutting blade. The cutting blade is the most important part of hand reaper. Carbon-steel cutting blade was used in the reaper. One blade of 20 cm diameter having heat treated edges were purchased from market and another cutting blade was designed having 255 mm diameter considering the working feasibility in the field. The rpm of the cutting blade is directly related with the rpm of the engine. Both types of blades were used for cutting paddy. The rpm of the engine was varied 4,000-7,000 based on the operational load.

The hand reaper was operated in no-load and load condition to find out suitable operation position. Afterwards a suggestion or guideline line was made for further proceeds. The machine was evaluated at different height of paddy and different field condition (wet, dry).The performance of the hand reaper was evaluated at an average speed of

2.92 m/minute with a theoretical work width of 75-100 cm (4-5 lines), but actual cutting width was on average 85 cm (average 3-4 lines). The field capacity of the machine was 16~22 decimal/h.

The fuel consumption of BRRI Hand Reaper was 0.8~1.0 liter/h. One operator can operate the hand reaper but for long time operation need alternative operator. The weight of the machine is nine kg which created fatigue and for refueling, tighten the machine with body, getting better capacity need two another operators, who will bundle the paddy at the time of reaping. The harvesting cost of hand reaper was Tk 9,340/ha and manual was Tk 14,940/ha, which was about two times more compared to hand reaper and save Tk 5,600 over traditional methods. The shattering loss of hand reaper and sickle cutting was 1.11% and 0.98% respectively. There was negligible difference (0.13%) between two systems.

The break-even area of hand reaper was 13 bighas land per year **(Fig. 1).** It means that the reaper machine should be operated at least 13 bighas per year to produce break-even outcome with neither loss nor profit.

Performance evaluation of different types of reaper

The experiment was conducted at Mithapukur upazila of Rangpur district during Aman 2013 season. Korean self-propelled reaper, Chinese self-propelled reaper and BRRI power tiller operated reaper were used for conducting the study. The experimental plots were transplanted by mechanical rice transplanter using 12 to 15-day-

old seedlings of BRRI dhan52. Cutting width and height was fixed for every reaper. Fertilizer and crop management were same for all treatments. RCB design was applied with three replications. The treatments were:

T_1=Self-propelled Korean reaper (KR)
T_2=Chinese reaper (CR)
T_3=BRRI power tiller operated reaper (BR)
T_4=Manual harvesting (MH)

The results show that the theoretical field capacity of Korean self-propelled reaper, Chinese self-propelled reaper and BRRI power tiller operated reaper was 0.33, 0.23 and 0.27 ha/h respectively. The actual field capacity of Korean self-propelled reaper, Chinese self-propelled reaper and BRRI power tiller operated reaper was 0.18, 0.18 and 0.15 ha/h respectively. Field efficiency obtained 66, 86 and 66.66% for Korean self-propelled reaper, Chinese self-propelled reaper and BRRI power tiller operated reaper respectively. Fuel consumption of the reaper was obtained 0.76, 048 and 1.25 l/h for Korean self-propelled reaper, Chinese self-propelled reaper and BRRI power tiller operated reaper respectively.

The cost of harvesting (without binding and threshing) was Tk 852, 611 and 1097/ha for KR, CR and BR with Tk 4750/ha for manual harvesting cost **(Fig. 2).** The break-even point of the reapers is 9.15, 7.82 and 8.43 ha/yr for KR, CR and BR

Cost of harvesting, Tk bigha^{-1}

Fig. 1. Break-even analysis of hand reaper.

Harvesting cost, Tk/ha
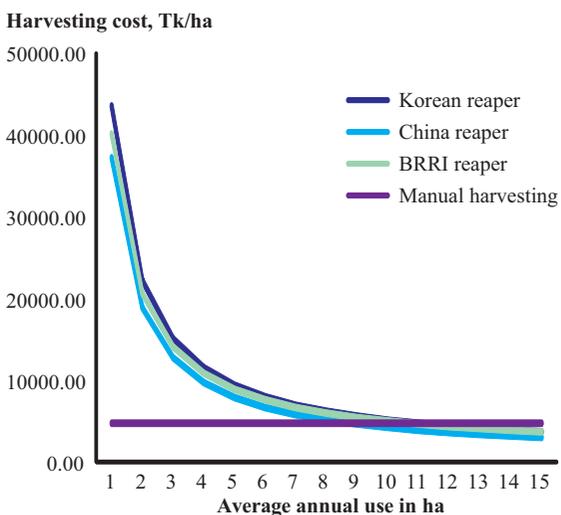
Fig. 2. Break-even analysis of different types of reaper.

respectively. Therefore, it is not economical if the reapers work less than that of area.

Effect of growing media on quality seedling raised for mechanical transplanting

The experiment was conducted at the FMPHT Division, BRRI, Gazipur during Boro 2012-13, Aman 2013 and Boro 2013-14.

Seedling raising on plastic tray conducted with two different types of soil. Soil textural classes, P^H and organic matter content were identified in the BARI soil science laboratory **(Table 2).**

Sample preparation and seedling raising

Sandy clay loam and clay loam soil sample and organic materials (Cow dung, mustard cake, rice straw organic fertilizer, rice bran, poultry litter and vermicompost) were dried separately in the sun and sieved after grinding to remove clod, crop residues and weeds. Organic matter mixed weight basis with soil sample at the desired rate. Seedling tray filled up with mixed soil at a thickness of 2 cm. One hundred forty gram pre-germinated seeds of BRRI dhan28, BRRI dhan29 and BRRI dhan49 were spread in each tray when the radicals and coleoptiles elongate to 1/5 of seed length. The amount of seeds per tray depends on 1000 grains weight (TGW) of the recommended seed. To ensure uniform broadcasting, the whole seeds lot divided into three parts for uniform broadcasting. After sowing, soil mixture was spread over the seeds to 0.3-0.4 cm thick and therefore the trays were kept under a shade to avoid birds attacked.

Agronomic and other parameters of the raised seedling were measured after 18 and 25 days of sowing during Aman and Boro season representing the hot and cold condition respectively.

Data collected

Rolling capacity of the seedling mat were measured in terms of score 10 for excellent (no crack during rolling), eight for good (single and minor crack during rolling), six for medium (More than one crack but possible to roll: Medium crack), four for bad (more than one crack and difficult to roll: Major crack), two for very bad (More than one and large size crack and very difficult to roll: Extreme crack) and one for not possible to roll in any way.

Interaction effect of soil and organic fertilizer on rolling quality of the seedling mat. Interaction of soil type and organic fertilizer showed significant effect on rolling quality of the seedling mat **(Fig. 3).** Cow-dung and rice bran with both sandy loam and clay loam soil and rice straw organic fertilizer, poultry litter and vermicompost with clay loam soil showed significantly better performance on rolling quality of the seedling mat (6 to 6.4 points out of 10) whereas mustard cake showed lowest performance (2.8 to 3.80 points out of 10) with both types of soil followed by poultry litter and rice straw organic fertilizer with sandy loam soil during Boro 2012-13 season. In Aman 2013, cow-dung and rice bran with sandy loam soil showed significant performance on rolling quality of the seedling mat

Table 2. Base soil characteristics of the seedling experiment.

Season	Soil type	Sand %	Clay %	Silt %	Textural class	P^H	% of organic matter
Boro 2012-13	1	51.25	26.54	22.21	Sandy clay loam	7.6	1.04
	2	39.65	37.28	23.07	Clay loam	7.8	0.89
Boro 2013-14	1	49.28	29.28	21.44	Sandy clay loam	7.4	1.01
	2	41.28	36.28	22.44	Clay loam	8.0	0.95
Aman 2013	1	50.72	28.56	20.72	Sandy clay loam	7.5	1.08
	2	40.72	33.56	25.72	Clay loam	7.7	0.98

The following treatments were arranged in a RCB three factors design with three replications.

Soil type (Factor A)	Organic fertilizer (Factor B)	Rate of mixture (Factor C)
Sandy loam soil	Cow dung	0.0% (Control)
Clay loam soil	Mustard cake	10% organic fertilizer
	Rice straw organic fertilizer	20% organic fertilizer
	Rice bran	30% organic fertilizer
	Poultry litter	40% organic fertilizer
	Vermicompost	
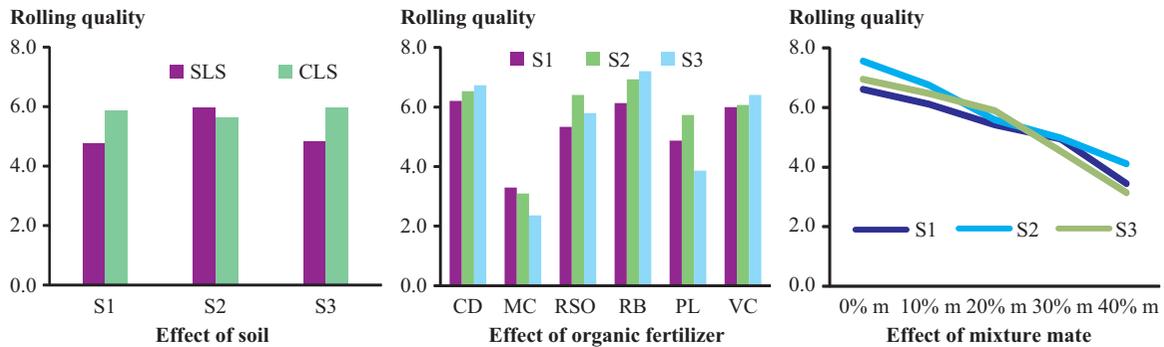
Fig. 3. Effect of soil, organic fertilizer and mixture rate on rolling quality of the seedling mat.

(6.93 to 7.6 out of 10 points) followed by rice bran and rice straw organic fertilizer with clay loam soil (6.3 to 6.6 points out of 10) whereas mustard cake with both the soil types showed the lowest performance (2.6 to 3.6 points) followed by poultry litter with both the soil types (5.73 points). During Boro 2013-14, rice bran with clay loam soil showed significant better performance (8.80 points) followed by cow-dung with both the soil types vermicompost and rice straw based organic fertilizer with clay loam soil (6.6 to 6.8 points). The lowest performance observed for mustard cake and poultry litter with both types of soil (1.93 to 4.27 points).

Interaction effect of organic fertilizer and mixture rate on rolling quality of the seedling mat. Rolling quality of the seedling mat decreased with the increase of organic fertilizer except rice bran. Considering the mixture of organic fertilizer, significantly higher rolling quality of the seedling mat (7.0 to 7.7 points out of 10) was observed for 10 to 30% of cow-dung, 30 to 40% of rice bran and 10% of vermicompost followed by 30% of cow-dung, 10 to 20% of rice straw organic fertilizer, 10 to 20% of poultry litter and 20 to 30% of vermicompost (5.3 to 6.3 points) whereas other combination was found bad quality to roll during Boro 2012. In Aman 2013, significantly higher rolling quality was observed for control along with 10 to 30% of cow-dung, 10% of rice straw organic fertilizer, 10 to 30% of rice bran and 10% of vermicompost (7.0 to 8.0 points) followed by 20% of rice straw organic fertilizer and vermicompost and 10% of poultry litter (6.3 to 6.7 points) whereas all combination

of mustard cake was found very bad to roll (3.5 to 1.2 points). 10 to 20% of cow-dung, 10% of rice straw organic fertilizer, 30 to 40% of rice bran and 10 to 20% of vermicompost demonstrated higher rolling quality of the seedling mat (7.7 to 8.3 points) followed by zero mixture along with 20% of rice bran whereas all combinations of mustard cake showed very bad quality (1.0 to 1.8 points) during Boro 2013-14.

Aman season showed better performance on rolling quality of the seedling mat irrespective of soil type and organic fertilizer with the rate of mixture 0 to 30% except mustard cake, because of more root development with high ambient temperature. Rolling quality of the seedling mat varied among the organic fertilizers with both the soil types in the order of rice bran>cow-dung>vermicompost>rice straw organic fertilizer>poultry litter>mustard cake.

Combined effect of soil, organic fertilizer and mixture rate on seedling strength. Clay loam soil with all combinations of organic fertilizers produced more seedling strength over sandy loam soil except mustard cake. Clay loam soil with 30% of cow-dung and 20 to 40% of rice bran (3.06 to 3.42 mg/cm) demonstrated significantly more seedling strength followed by clay loam soil with 20 and 40% of cow-dung (2.24 to 2.40 mg/cm), 10% of mustard cake (2.05 mg/cm) and sandy loam soil with 40% of rice bran (2.26 mg/cm) whereas all combination of mustard cake except 10% mixture with clay loam soil showed significantly lowest seedling strength during Boro 2012-13 season. In Aman 2013, combined effect of soil, organic fertilizer and rate

of mixture showed insignificant effect on seedling strength. In Boro 2013-14, clay loam soil showed better performance over sandy loam soil with all combinations of the organic fertilizer whereas all combinations of mustard cake showed poorest performance on seedling strength along with 40% of rice straw organic fertilizer with both types of soil and 40% poultry litter with sandy loam soil. In contrary, 10 and 30 to 40% of cow-dung, 10 to 20 and 40% of rice bran and 40% of poultry litter with clay loam soil and 40% of rice bran with sandy loam soil gave significantly higher seedling strength (1.50 to 1.69 mg/cm) followed by 20% of cow-dung and rice bran and 10% of rice straw organic fertilizer with clay loam soil and 40% of cow-dung with sandy loam soil over other combinations.

Interaction effect of soil and organic fertilizer on seedling strength. Rice bran with clay loam soil showed significantly the highest seedling strength (2.51 mg/cm) followed by cow-dung and poultry litter with clay loam soil (1.70 to 2.12 mg/cm) and rice bran and cow-dung with sandy loam soil (1.34 to 1.42 mg/cm) whereas mustard cake produced the lowest seedling strength with both the soil types (0.57 to 0.74 mg/cm) followed by vermicompost and rice straw organic fertilizer during Boro 2012-13 season.

In Aman 2013, vermicompost with clay loam soil showed significantly the highest seedling strength (1.28 mg/cm) followed by rice bran and poultry litter with clay loam soil (1.04 to 1.05 mg/cm) whereas mustard cake produced the lowest seedling strength with both the soil types (0.18 to 0.34 mg/cm) followed by rice straw organic fertilizer, vermicompost and poultry litter with sandy loam soil (0.73 to 0.90 mg/cm) **(Fig. 4).** Rice bran and cow-dung with clay loam soil showed significantly the highest seedling strength (1.45 to 1.49 mg/cm) followed by poultry litter and cow-dung with clay loam and sandy loam soil (1.27 to 1.32 mg/cm) respectively, whereas mustard cake produced the lowest seedling strength with both the soil types (0.38 to 0.42 mg/cm) followed by rice straw organic fertilizer with both the soil types (0.91 to 0.96 mg/cm) and poultry litter with clay loam soil (1.32 mg/cm) during Boro 2013-14 season.

Interaction effect of organic fertilizer and mixture rate on seedling strength. Average of three seasons, seedling strength varied among the organic fertilizers with both the soil types in the order of rice bran>cow-dung>poultry litter> vermicompost>rice straw organic fertilize >mustard cake.

Mustard cake was not found suitable for raised seedling for mechanical transplanting. Based on these parameters, 10 to 30% cow-dung, rice straw organic fertilizer, vermicompost, 10% poultry litter and 20 to 30% rice bran with both types of soil was found suitable. Clay loam soil showted better performance on rolling quality of the seedling mat and seedling strength over sandy loam soil. Sandy loam soil showed better performance over clay loam soil for agronomic parameters. Future studies will be needed to investigate the seedling griping, mortality and root and shoot traits of plants grown in actual field conditions.

Optimization of seedling density as influenced by seed rate for mechanical transplanting

The experiment was conducted in the FMPHT Division during Boro 2013-14. Seedling was raised on same growing media. Short, medium, long and extra-long paddy were used for the study.

Paddy types identification

Size of the sample paddy was identified in terms of length according to FAO standards (FAO, 1972) along with those used by USDA rice workers (Adair *et al.,* 1973) as shown in **Table 3.**

Data collected

Based on objectives of the study, seedling density, seedling height, number of leaves, stem length, stem thickness, seedling strength and rolling capacity of the soil mat, percentage of missing and damage plant under different options of transplanter for different seed rate and cost of seed production were collected. Area of cut of the rice transplanter rotary picker varied with the different adjustment options. Width of cut is always same as 1.2 cm whereas depth of cut varied with the different adjustment options. Area of cut also determined counting the total number of stock per tray.
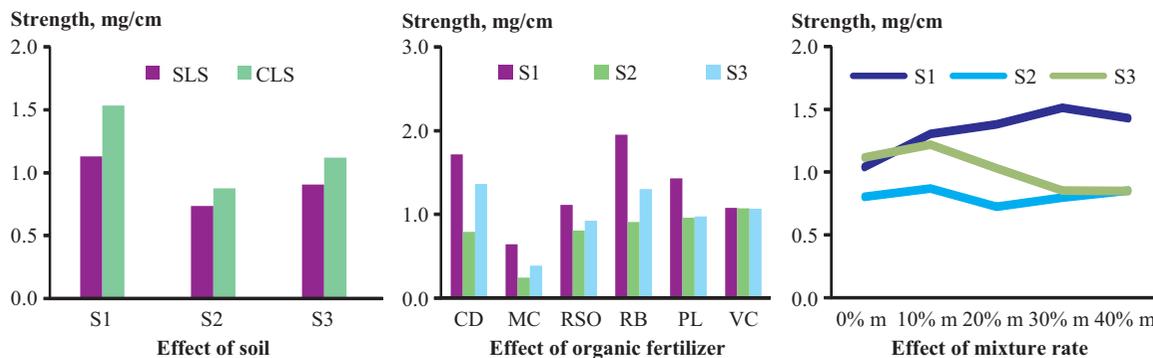
Fig. 4. Effect of soil, organic fertilizer and mixture rate on seedling strength.

Table 3. Paddy type and sub-type identification.

Variety	Average length (L) of paddy, mm	Average breadth (B) of paddy, mm	L/B ratio	Type and sub-type of paddy
BR3	8.52	3.08	2.77	Medium
BRRI dhan28	9.28	2.40	3.87	Slender
BRRI dhan29	8.59	2.37	3.62	Slender
BRRI dhan50	11.48	1.85	6.21	Extra-long and slender
BRRI dhan55	10.48	2.59	4.05	Long and slender

Results

Number of seeds per unit area directly influenced the seedling density in the tray. Number of seeds per unit area varied with seed rate significantly for all types of varieties. Seeds per cm^2 unit varied under six different seed rates from 2.2 to 3.6 for BR3, 2.7 to 4.4 for BRRI dhan28, 2.7 to 4.3 for BRRI dhan29 and 3.1 to 5.0 for BRRI dhan50. TGW and grain type also affected the number of seeds per unit area where more number of seeds per unit area were observed for long grain paddy followed by medium and short grain paddy.

Percent of seed bed area covered. Percentage of seed bed area covered by the seeds varied significantly under different seed rates. It was increased linearly with the increase of seed rate and varied with the grain type. Long grain paddy covered more seed bed area compared to medium and short grain paddy. Percentage of seed bed area covered by the seeds under six different seed rates varied from 59 to 94% for BR3, 61 to 98% for BRRI dhan28, 56 to 90% for BRRI dhan29 and 67 to 98% for BRRI dhan50.

Germinated seeds per unit area. Germinated seeds per unit area depend on seed rate and germination percentage of the paddy. Number of germinated seeds per unit area varied significantly with the seed rate. It was increased linearly with the increase of seed rate. Higher numbers of germinated seeds were observed for long grain paddy followed by medium and short grain paddy for the same seed rate. It was varied under six different seed rates from 2.0 to 3.2 for BR3, 2.3 to 3.7 for BRRI dhan28, 2.4 to 3.9 for BRRI dhan29 and 2.7 to 4.4 for BRRI dhan50.

Seedling per unit area. Seedling per unit area depends on seed rate, germination percentage and survival rate of seedling. Seedling per unit area varied significantly with the seed rate in the plastic tray. Seedling also varied with the varieties because of more number of seeds under the same seed rate. In case of BR3, BRRI dhan28 and BRRI dhan29, the highest number of seedling per unit area was observed for 150 g seed per tray which is statistically similar with 130, 140 and 160 g seed rate and the lowest was observed for 100 g followed by 120 g seed rate. There have also no significant difference of seedling per unit area among 130 to 160 g seeds per tray for BRRI dhan28 and BRRI dhan29 and the lowest number of seedling was observed for 100 g followed by 120 g seed rate. In case of BRRI dhan50, seedling per unit area was not varied with the seed rate of 100 g to 160 g per tray.

Percentage of seedling raised over seeds sown in the tray varied with the seed rate. With the increase of seed rate, percentage of seedling raised over seeds reduced. In BR3, 77 per cent seeds raised effective seedling for 100 g seed rate and gradually reduced to 56% seedling with the increase of seed rate up to 160 g per tray whereas percentage of seedling raised varied from 74 to 57% for BRRI dhan28, 74 to 58% for BRRI dhan29 and 71 to 54% for BRRI dhan50. Percentages of the seedlings emerged from the sown seeds decreased from 71-77% to 54-58% with increasing seed rate irrespective of variety.

Seedling quality as affected under different seed rates and variety

Quality of the raised seedling as affected under different seed rates and variety was measured in terms of seedling length, number of leaf, stem thickness, shoot dry weight, root-shoot ratio and seedling strength.

Stem thickness. Stem thickness of the raised seedling under different seed rate varied significantly irrespective of variety. Statistically similar stem thickness was observed of 100 to 150 g seed rate for BR3 and BRRI dhan28 whereas it was similar of 100 to 130 g seed rate for BRRI dhan29 and 100 to 140 g seed rate for BRRI dhan50. Stem thickness showed reducing tendency with the increase of seed rate.

Shoot-dry weight. Shoot-dry weight of the seedling raised under different seed rates varied significantly irrespective of the variety. Shoot-dry weight decreased with the increase of seed rate. Significantly the highest shoot dry weight was observed of 100 to 130 g seed rate for BR3, 100 to 140 g seed rate for BRRI dhan28, 100 to 120 g seed rate for BRRI dhan29 and 100 to 130 g seed rate for BRRI dhan50.

Root-shoot ratio. Root-shoot ratio of the seedling raised under different seed rate varied insignificantly irrespective of variety. Mathe-matically it showed increasing tendency with the increase of seed rate.

Seedling strength. Seedling strength was measured in terms of mg/cm of shoot-dry weight. Except BR3, seedling strength showed insignificant on seed rate. Generally, the values of seedling strength indicate that it was decreased with the increase of seed rate. The highest seedling strength (2.16 mg/cm) was observed for the seed rate of 100 g of BR3 and the lowest (0.99 mg/cm) for the seed rate of 160 of BRRI dhan28.

Average number of plants per stock of the rotary picker of the rice transplanter increased and percentage of missing hills decreased with increasing both seed rate and seedling adjustment options of the rice transplanter irrespective of variety. In case of bold grain paddy, seedlings per stroke and percentage of missing hills for the seed rate of 130, 140 and 150 g of seeds/tray varied from 3.2-5.4 to 3.5-6.4 and 14-4 to 13-3 respectively for 5 to 8 seedlings adjustment options of the rice transplanter which is almost same. Seedlings per stroke and percentage of missing hills of medium and slender grain paddy (BRRI dhan28 and BRRI dhan29) for the seed rate of 140, 150 and 160 g of seeds/tray was found almost same (2.7-6.8 to 3.0-6.8 and 12-3 to 12-1 respectively) for 5 to 7 seedlings adjustment options of rice transplanter. However, there was minimum difference of seedling per stroke and percentage of missing hills among 120, 130 and 140 gram of seeds/tray (2.5-6.8 to 2.5-8.6 and 12-2 to 11-1 respectively) for the options of 3-7 for extra-long and slender paddy (BRRI dhan50).

Based on missing hills and number of seedling per hills under different seedling adjustment options, 130 g of seed/tray for bold grain, 140 g/tray for medium and slender grain and 120 g/tray for extra long and slender paddy was found suitable for the studied transplanter.

Mechanical transplanting and harvesting under pubic private partnership approach

Mechanical transplanting. The study was conducted in Hatgobindapur, Chandpur of Natore and Kodma, Omorpur, Nandigram of Bogra district during Aman 2013 season and Amin Nagar, Nandigram of Bogra district during Boro season 2014. BRRI provided one riding type transplanter and two walk behind type mechanical transplanter to Syngenta Bangladesh under pubic private partnership approach; provided service to farmers on rental basis. BRRI also provided operator and mechanics to support the transplanting activity.

These machines were operated in the farmers' field. During Aman season, transplanting operation was done in 42.55 ha area of 375 numbers of plots and 205 farmers were benefitted by using BRRI supplied transplanter. Two skilled operators were developed during this season. The soil type was clay loam (Sand 0%, Silt 3% and Clay 97%), AEZ 25 level Barind tract. The experiment was carried out in randomized complete block (RCB) design with two treatments; viz farmers practice (FP) and machine transplanting (MT). In each season, six farmers within one kilometer radius were selected to conduct this study.

In mechanical transplanter, line to line spacing was fixed at 30 cm whereas, plant to plant spacing can be varied. Plant to plant spacing was set at 15 and 17 cm. Plant spacing varied depending on the puddled condition, soil type and water height. In mechanical transplanting, missing hill was observed 1-2% in both seasons. Gap filling was done one day after transplanting. Fuel consumption in walk behind type mechanical transplanter in both season ranged from 4.4 to 4.6 L/ha. In mechanically transplanted plot, hill density ranged from 20-5-21.7 and 18.9 to 20.8 in Aman and Boro season respectively. Hill density was inconsistent in both seasons. It might be due to slippage and skidding of the machine caused by water height, puddled depth and land leveling. In manually transplanted plot, hill density ranged from 14.8-18.3 and 17.46 to 21.2 in Aman and Boro season respectively.

Management practices had significant effect on panicle length. MT produced longer panicle than FP in both seasons. MT produced higher grain per panicle than farmers' practices. Sterile spikelet production was not significantly affected by management practices. MT produced higher 1000-grain mass 6.4g than FP (5.2). MT produced significantly the highest grain yield in both seasons. Grain yield obtained 14-23% higher in MT than FP in both the seasons.

Mechanical harvesting. This study was conducted in different villages under Dhamrai upazila of Dhaka district. BRRI provided one combine harvester (DAEDONG) to the local NGO named SOJAG, Dhamrai, Dhaka, providing rental service to farmers for harvesting rice in Boro 2014

season. BRRI also provided operator to support the harvesting activity. Land size was categorized as small, medium and big land having 15 decimal, 16 to 30 decimal and more than 31 decimal respectively. Data on land size and shape, straw height, turning time, operation time, forward speed, no. of labour required, fuel consumption, problems faced during operation were collected to evaluate the performance of combine harvester. Harvesting operation was done in 16.10 ha area and 93 farmers were benefitted by using BRRI supplied harvester. Two skilled operators were developed during this season. Data were collected from 30 plots. Cost of mechanical harvesting was compared with manual harvesting.

Fuel consumption obtained 40 liter per hectare. Fuel consumption of the combine harvester depends on distance from machine shelter to working place, plot to plot movement, plot size and shape, crop density, lodged crop etc. For densely crop area machine should be operated in slow speed. Cutting of lodged crop takes more time than standing crop. Small plot required more turning time. Hence fuel consumption will be increased. Field capacity of combine harvester obtained 0.18 ha/h. Field capacity increased with the increase in land size. Field capacity of big land increased 64% compared to small land.

It was found that combine harvester reduced time, cost of harvesting and drudgery of the farmers. Field capacity increased with the increase of land size. Rental service of combine harvester appeared as business viable model.

MILLING AND PROCESSING TECHNOLOGY

Improvement of air-blow type engelberg huller
The modification of the small air blow type rice mill was done in the research workshop of FMPHT Division to use in commercial purpose. The following major changes were done in the modified air blowing type rice mill :
- Motor power increased to 15 kW.
- Eight hullers were used to increase milling capacity.
- Use of 60 thw screen then to 75 thw screen for more milling yield.

- Blower pulley changed to 250 to 279.4 mm for more suction air.
- Blower fan revolution increased from 3788 to 4462 rpm.
- Different pieces of weight were added to control delivery and no need to press by finger.
- Screen attachment in the delivery point.
- Blower attachment was changed.
- Cyclone separator was added to collect the husk, bran and small broken mixture.

A 15 kW (3-Phase, 4-wire) electric motor was used for 8 no. hullers to produce around 1,200 rpm for rotor of the milling shaft. Blower fan speed also increased up to 4,462 rpm that also suitable for suction pressure. The capacity of the modified air blowing type is 250-300 kg/h, which was two to three times more capacity of the small air blowing type rice mill. Milling yield, head rice and broken rice was found 66, 63 and 2% respectively. Modified air blowing type (one-pass) mill saves time and produce quality of milled rice than traditional engelburg rice mills. Electricity consumption for milling one ton paddy required 49.5 to 60 kWh. Farmers and millers both will be benefited by getting extra 1.0% rice than traditional engelberg huller.

INDUSTRIAL AND FARM LEVEL EXTENSION OF AGRICULTURAL MACHINERY

Demonstration cum training, training on operation, repair and maintenance manufacturing processes of BRRI farm machinery under FMTD project

The demonstrations cum training, training on operation, repair and maintenance and manufacturing processes of BRRI farm machinery were conducted under farm machinery technology development and dissemination (FMTD) project. BRRI developed Thresher (Open drum, TH-7), BRRI USG/Prilled urea applicator, Power tiller mounted reaper, Winnower and weeder were demonstrated to the farmers' field during crop production seasons of T. Aman, Boro and Aus.

Demonstration cum training

At each programme, altogether 40 participants mostly farmers including male and female were participants as trainee for a day long demonstration cum training programme. DAE officials, NGO workers, local elites, manufacturers and machinery operators were also present in the programme. Introductory sessions were arranged to familiarize with machines and its performance, profitability over traditional practices, operation, repair and maintenance of the machines. Machines were operated before the participants for about 1-2 hours. Most of the trainee operated the machines one by one. Discussion session was arranged to collect participant's reaction on the prospects and drawbacks of the machines.

During Aus, Aman and Boro 2013-14 seasons 132 demonstrations cum informal trainings were conducted in the project areas. About 5,280 participants including farmers, machine operators and Sub-Assistant Agricultural Officers (SAAO) attended the demonstration cum informal training programmes.

The awareness among the farmers on the benefit of using BRRI farm machinery was created through the demonstration cum training, training on operation, repair and maintenance and manufacturing process. At present, more farmers have been using BRRI machines including weeder, thresher and winnower. As a result, the use of agricultural machinery has been increasing day by day. Many engineering workshop around the country manufactured different types of farm machinery. Through the training, skill has also been developed among the target people about manufacturing of BRRI developed machinery.

Evaluation of farm machinery status
- Two training programme for 6 days were organized at Corona Industry and MAWTS, Mirpur, Dhaka for workshop personals.
- One-week training programme on engineering drawing by AutoCAD Tools was organized for BRRI Engineers.
- Five 3-days training programme on transplanter operation, repair and maintenance for mechanic.

- Nine day-long demonstration cum training programme on seedling raising technique, transplanter and combine harvester operation, repair and maintenance for mechanic.

Awareness was created among the farmers and other stakeholders on the benefit of using modern farm machinery. The farmers wanted financial support for purchasing costly machine. Most of the farmers wanted to use rice transplanter and combine harvester on rental hire basis.

Validation of BRRI prilled urea applicator

Adaptive trial of BRRI prilled urea applicator was conducted at 40 different locations of Gazipur, Sherpur, Gaibandha, Rangpur, Kushtia, Bandarban.

The comparative yield performance of different N-management practices in different parts of the country. In case of BRRI dhan28, prilled urea application by BRRI prilled urea applicator plot obtained 12.5% higher grain yield compared to hand broadcasting of prilled urea in three equal splits. USG application by BRRI USG applicator plot also produced 9.15% higher grain yield compared to hand broadcasting. In case of BRRI dhan29, prilled urea application by BRRI prilled urea applicator plot obtained 8.74% higher grain yield compared to hand broadcasting of prilled urea in three equal splits. Almost similar yield was obtained in BRRI dhan50 and Subarna-3. In case of Hira2, prilled urea application by BRRI prilled urea applicator plot obtained 7.5% higher grain yield compared to hand broadcasting of prilled urea in three equal splits. Irrespective of variety, prilled urea placement by BRRI prilled urea applicator produced similar or higher grain yield compared to hand broadcasting of prilled urea in three equal splits in Boro season. Around 30% urea was saved by using BRRI prilled urea applicator in rice production.

Workshop Machinery and Maintenance Division

SUMMARY

A gear box of self-propelled power unit was developed in BRRI research workshop. Power transmission unit of the reaper was tested in paddy and wheat field and its performance was found satisfactory. This gear box 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 will be done very soon.

Experiments were conducted at Harinakundu upazila, Jhenidah district in Boro and Aman 2014 seasons to determine paddy yield as influenced by different tillage depths. Tillage is an important agronomic practice to make soil physically, chemically, and biologically suitable to improve seed germination, seedling emergence and for optimal plant growth and crop productivity. There were three tillage depths such as: 4-5, 5-6 and 6-7 inches. The tillage depths were maintained by a power tiller. Tillage depths significantly affected both the yield of BRRI dhan28 in Boro 2014 and BRRI dhan56 in Aman 2014 season. The highest grain yield of BRRI dhan28 was found 7.50 t/ha in the tillage depth up to 6-7 inches and the lowest yield 6.88 t/ha was found in the tillage depth up to 4-5 inches in Boro season. On the other hand, in Aman 2014 season, the highest grain yield of BRRI dhan56 was found 5.40 t/ha in 6-7 inches tillage depth and the lowest yield was found 4.40 t/ha in 4-5 inches tillage depth. The highest yields of both 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. Higher tillage depth might have favoured the roots to proliferate down into the deeper layers of the soil profile to extract more nutrients and moisture that has led to yield of paddy in both seasons.

The study was conducted preliminary on solar energy use in BRRI winnower. To operate BRRI winnower, Photovoltaic system consists of 200 W solar panel, energy storage, converter, charge controller and Balance-Of-System (BOS) components were installed at BRRI automobile workshop. The battery storage accompanied by a charge controller was used in order to prevent the batteries from reaching either an overcharged or over discharged condition. In BRRI winnower 0.5 hp 48 volt DC motor was used to clean paddy. A connector and an accelerator were used to start and control the DC motor. Stored solar energy was used in winnowing paddy at BRRI threshing yard. In other times, this energy was used as illumination of four bulbs of each 15 W at BRRI automobile workshop.

Power tiller operated grain cleaner has been developed at BRRI research workshop and tested at BRRI threshing yard. Two flat bars of 68 cm length were taken and both ends of the bars were made curved in same direction. Then those were fixed with a pulley as cross blade and fitted rigidly with the flywheel of a power tiller engine. Then a cover was made as safety measures to protect the operators/users from any accident. The cover was made with MS wire (1/8th) and it was tightly fitted with chassis and oil tank by nut bolts. Before operation, it should be fixed with the engine flywheel well. Air flow rate was found 7 m/s at a linear distance of 1 m and it is decreased to 3 m/s at 5 m from center of flywheel. It will be tested to evaluate its overall performances.

Repair and maintenance works of transport/vehicles and different farm machinery of BRRI were done under WMM Division. There were 37 vehicles (4-wheeler), 107 motor cycles, three tractors with accessories (one scrapper, three harrows, five rotaries, three discs and three scissors), 23 power tillers, seven hydro-tillers, one reaper, one BRRI field mower, 18 pumps, one open drum thresher, two engines, and other farm machinery 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 43,87,474 from July 2013 to June 2014. 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

A gear box of self-propelled power unit was developed and fabricated in the BRRI research workshop (Fig. 1). Power unit of the reaper was tested in paddy and wheat field. The performance of reaper was found satisfactory. The existing gear box has a provision of two forward speeds with a backward speed. When engine is started, all gears in the gear box move either engaging or disengaging clutch. Backward gear always moves but keeps idle when the reaper is in forward motion. Power is transmitted in reduced form gear box to axle through chain and sprocket. This gear box is functionally well but it is little bit heavy. So, it is necessary to design a new gearbox with compact size and reduced weight.

Design consideration

The following criteria have been considered to design the self-propelled reaper and mini-power tiller:

- Simple, lightweight, and sturdy in design
- Functionally perfect for harvesting crops for which it has been designed
- Locally available materials have been used for construction of the different parts of the

reaper due to avoid facing difficulties of unavailability of raw material

- The machine has been designed for a specific crop as well as multipurpose type without sacrificing its merits
- Small in size due to compact design
- The light duty low cost diesel engine has been used as a prime mover for the reaper. Therefore, the cost of machine per unit length is low, and thus the cost of harvesting operation is also low.
- Harvesting losses have been controlled within acceptable limit
- Trouble free machine

Power transmitting unit

Figure 2 shows the compact size with reduced weight power transmission unit of self-propelled reaper with different components such as:

- Chassis of the power unit
- Power transmission system
- Prime mover
- Control accessories etc.

Figure 3 shows the compact size and reduced weight gearbox of a power-transmitting unit. It should be simple in construction with forward and backward speed and a neutral gear position. In this gearbox, there is a provision to move gear along with shaft carrying load for forward speed of the reaper. The gearbox consists of different parts as

Fig. 1. Actual view of BRRI developed self-propelled reaper.
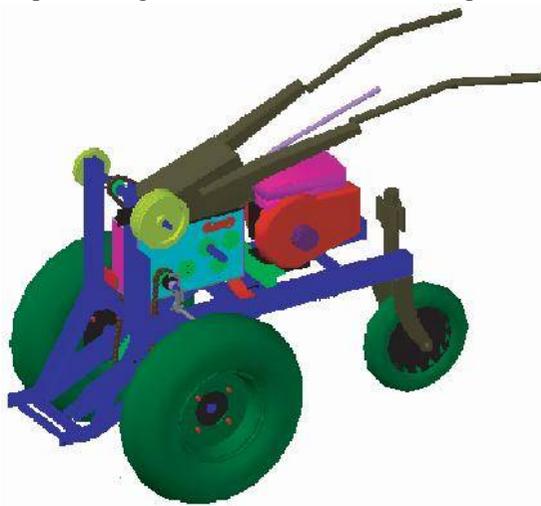
Fig. 2. Power transmission unit of BRRI self-propelled reaper.
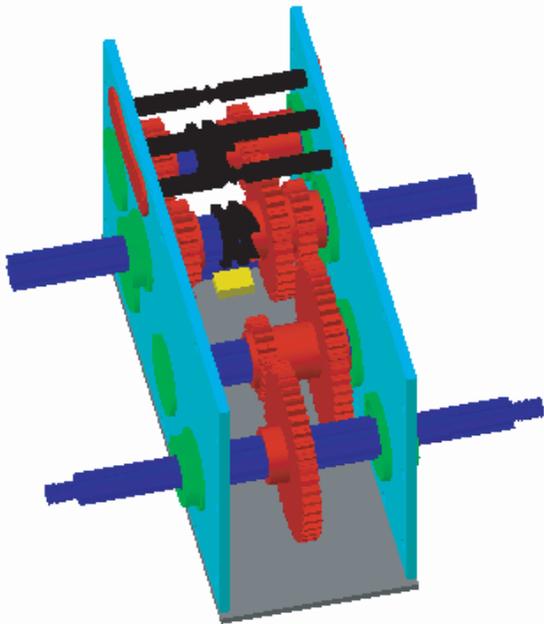
Fig. 3. Gearbox of BRRI self-propelled reaper.

sprocket, casing, shaft and key, gear pinion, ball bearing and journal bearing, positive clutch slider and main power transmission shaft. Fabrication of reaper will be completed very soon and this will be used in the next season.

Modification of reaper travelling wheel for wet-land condition

Harvesting is the first and major post-harvest operation for separation, processing and storage of grains. Harvesting of cereal grains by machines is an important part of mechanized agriculture. Delayed harvesting due to shortage of labour and vagaries of weather conditions often causes yield loss which can be minimized by use of reaper/harvester. Paddy is grown round the year whereas wheat is grown only in the winter season (Rabi) in Bangladesh. These crops are harvested traditionally by using sickle, which is very tedious and time consuming. Due to fragmented land, self-propelled reaper is more suitable for harvesting rice and wheat in our land condition. WMM Division of BRRI has developed a low cost self-propelled reaper using locally available material for harvesting rice and wheat and 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. At present, there is no suitable reaper in our country for wet-land condition. During harvesting in wet-land, it does not move forward because its wheel goes down the soil and rotates in the same place. So, there is a scope to modify a reaper-wheel for wet-land condition for harvesting rice and wheat. For this reason, this experiment has been undertaken at research workshop, Bangladesh Rice Research Institute (BRRI), Gazipur, during 2013-14 to modify a self-propelled reaper wheel using locally available materials.

The complete design of self-propelled reaper wheel has been executed with the help of AutoCAD tools (Fig. 4). Fabrication of the reaper wheel will be started very soon using the locally available materials at BRRI Research Workshop.

Design and development of a power tiller operated grain cleaner

Threshed grain contains all kinds of impurities, which should be removed as soon as possible after harvesting and certainly before storage. Clean grain:

● Has a higher value than grain that is contaminated with straws, chaff, weed seeds, soil, rubbish, and other non-grain materials
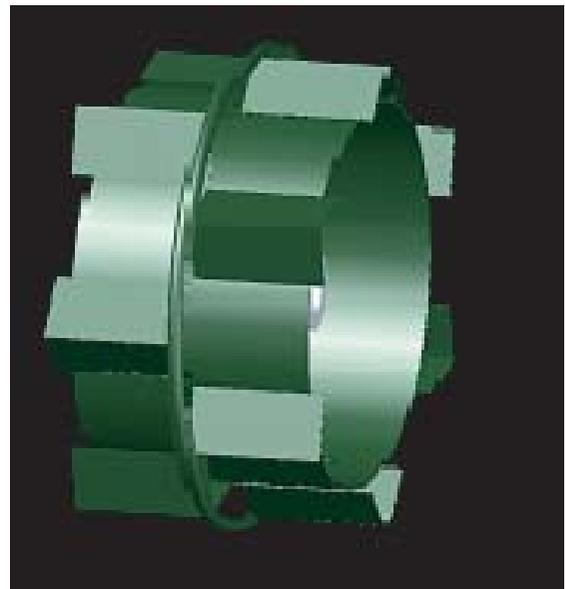
Fig. 4. Reaper travelling wheel.

- Improves the storability of grain
- Reduces price penalties at the time of selling
- Improve milling output and quality.

Winnowing by *cula* is a traditional cleaning method that uses wind or a stand fan to remove light foreign matter from the grain. Mechanical winnowers that use a fan and several superimposed reciprocating sieves or screens are now used in many countries. These can be operated manually or by electric motor. Traditional cleaning methods are laborious and mechanical winnowers are costlier for a farmer. These are the reason why power tiller operated grain cleaner will be developed.

Power tiller operated grain cleaner has been developed at BRRI research workshop and tested at BRRI threshing yard. Two flat bar of 68 cm length were taken and both ends of the bars were made curved in same direction. Those were fixed with a pulley as cross blade and fitted rigidly with the flywheel of a power tiller engine (Figs. 5 and 6). Before operation, it should be fixed with the engine flywheel well. Then a cover was made as safety measures to protect the operators/users from any accident. The cover was made with MS wire (1/8th) and it was tightly attached with chassis and oil tank by nut bolts. Air flow rate was found 7 m/s at a linear distance of 1 m and it is decreased to 3 m/s at 5 m from center of flywheel. No

Fig. 6. Blade fitted with engine flywheel with cover.

foreign matter was observed in cleaned grain during operation (Fig. 7). Farmers are also using this type of cleaner without safety cover which is very risky. We tested such type of cleaner in farmers' yard (Fig. 8). About 1,200-1,600 kg paddy can be cleaned in an hour. Male or female can use this easily. Its fuel consumption is 700-800 ml/hr.

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,

Fig. 5. Blade.

Fig. 7. BRRI threshing yard.

Fig. 8. Power tiller operated grain cleaner without safety cover tested in farmers' yard.

seedling emergence and for optimal plant growth. Tillage improves soil conditions by altering the mechanical impedance to root penetration, aggregate size distribution, hydraulic conductivity and water holding capacity, which in turn, affects plant growth of rice. 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.

Experiments were conducted at the Jhenidah district in Boro 2014 and Aman 2014 seasons. There were three tillage depths such as: 4-5, 5-6 and 6-7 inches. The tillage depths were maintained by a power tiller. BRRI dhan28 was cultivated in Boro 2014 season and BRRI dhan56 was cultivated in Aman 2014 season. 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 dhan28 in Boro 2014 and BRRI dhan56 in Aman 2014 season were varied from different tillage depths. Table 1 shows that the highest grain yield of BRRI dhan28 was found 7.50 t/ha in the tillage depth up to 6-7 inches and the lowest yield was obtained 6.88 t/ha in the tillage depth up to 4-5 inches in Boro 2014 season. Table 1 also shows that the highest grain yield of BRRI dhan56 in Aman 2014 season was found 5.40 t/ha in the tillage depth up to 6-7 inches and the lowest yield was found 4.40 t/ha in the tillage depth up to 4-5 inches. The highest yields of both 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 (Table 1). The deep tillage (6-7 inches) might have favoured the roots to proliferate down into the deeper layers of the soil profile to extract more nutrients and moisture that has led to higher growth and yield of both the seasons. Higher tillage depth favourably influenced the soil-water-plant ecosystem, thereby improved crop yields.

Feasibility study of solar energy use in agricultural machinery

The population of Bangladesh is about 150 million and per capita energy consumption is 273 kW. Share of traditional energy is about 60%. Access to electricity is 30% of the population and area coverage by electrification is 40%. Huge amount of foreign currency is spent in agricultural sector to buy fossil fuel (diesel). Recently fuel crisis prevails all over the world. The use of solar energy can boost up country's food production three times and cut the increasing demand of fuel and electricity drastically. Solar energy will be substituting to fill the gap in this sector. Solar energy can reduce dependency on imports of fossil fuel. It is also able to create new employment opportunities.

Bangladesh is richly endowed with solar energy. Solar photovoltaic (PV) system seems to be the only appropriate form of renewable energy despite the monsoon type of climate in Bangladesh. However, sun's energy is continuous, clean and pollution free. Emphasis should be given on this renewable energy, particularly to avoid environmental disaster. "Bangladesh has a total area of 1.47E + 11 m^2 and an average of 3.5 kWh/m^2 solar intensity falls on this land over 300 days per annum. Even if one percent of this land is used to harness solar energy for power generation at an efficiency of 10%, a total of 5.2E + 09 kWh electricity can be generated annually" (Source: Sarkar *et al.,* 2001, p. 183 and 184). So, the prospect of solar energy in Bangladesh is quite favourable. Bangladesh is situated between 20.30-26.38 degrees north latitude and 88.04-92.44 degrees east which is an ideal location for solar energy use. Daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available during March-

Table 1. Yield of paddy with different tillage depths.

Season	Paddy	Tilling depth (inch)	Paddy yield (t/ha)
Year 2014			
Boro	BRRI dhan28	4-5	6.88
		5-6	6.96
		6-7	7.50
Aman	BRRI dhan56	4-5	4.40
		5-6	4.84
		6-7	5.40

April and minimum on December-January. There is a good prospect of harnessing solar power in Bangladesh. That is why, we want to use solar power in operating agricultural machinery.

The study was conducted preliminary on solar energy use in BRRI winnower. To operate BRRI winnower, Photovoltaic system consists of 200 Watt solar panel, energy storage, converter, charge controller and Balance-Of-System (BOS) components were installed at BRRI automobile workshop.

Four 50-watt solar panel were installed at BRRI automobile workshop roof in series configurations to produce enough power and connected with a battery to store solar energy (Fig. 9). The battery storage accompanied by a charge controller in order to prevent the batteries from reaching either an overcharged or over discharged condition was used. Four battery of each 12 volt was connected in series to make it 48 volt. Then 0.5 hp 48 volt DC motor was used in BRRI winnower to clean paddy. A connector and an accelerator were used to start and control the DC motor. It has three options to operate. One is using solar energy directly to winnow, other one is using to store solar energy in battery. Then stored solar energy is using in winnowing and another one is using solar energy directly and storing solar energy in battery simultaneously (Fig. 10). Stored

energy was used in winnowing paddy at BRRI threshing yard. In other times this energy is used as illumination of four bulbs of each 15 W at BRRI automobile workshop (Fig. 11).

Repair and maintenance works of transports/ vehicles and different farm machinery
Repair and maintenance works of transport/ vehicles and different farm machinery of BRRI were repaired and maintained under WMM Division. There were 37 vehicles (4-wheeler), 107 motor cycles, three tractors with accessories (one scrapper, three harrows, five rotaries, three discs and three scissors), 23 power tillers, seven hydro-tillers, one reaper, one field mower, 18 pumps, one open drum thresher, two engines and other farm machinery. The repair and maintenance works have been divided into two groups:
- Major repair and maintenance work
- Moderate/minor repair and maintenance work

Major repair and maintenance work
Major repair and maintenance works have been classified into seven groups those are as follows:
- Major spare parts change and repair
- Overhauling
- CNG conversion
- Denting-painting
- Tyre-tube

Fig. 9. Installed solar panel on the roof of BRRI automobile workshop.
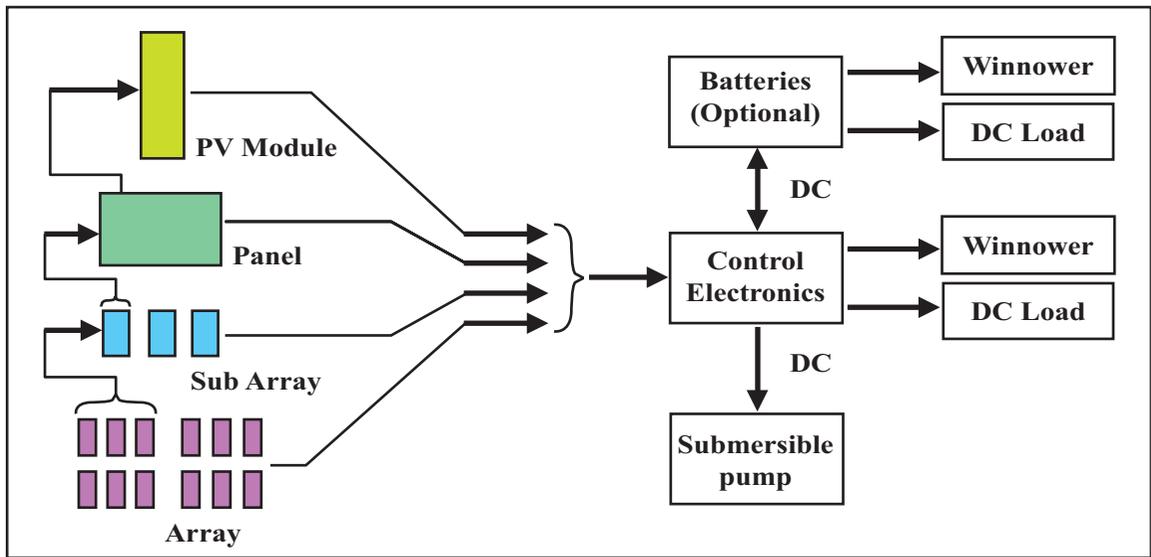
Fig. 10. Design of the solar photovoltaic system.

Fig. 11. Illumination of bulb at BRRI automobile workshop using solar energy.

● Battery
● Major CNG related trouble shooting

Major repair and maintenance works have been done in BRRI workshop and outside BRRI. Some of the major spare parts change, overhauling and repair works have been done in BRRI workshop but major works were done outside BRRI due to fund limitation and some of the major works have been done by direct contracting through BRTC (a Government Workshop),

Tejgaon, Dhaka; NAVANA Toyota 3S center, Tejgaon, Dhaka; Karl Benz, Tejgaon, Dhaka, Roky Motors, Tejgaon, Dhaka. On the other hand, most of the CNG related works (CNG conversion, any kinds of CNG related trouble shooting) have been done by direct contracting through Rupantorito Prakritic Gas Co. Ltd., Joar Sahara, Dhaka, a Government Workshop but electrical works and denting-painting works have totally been done outside BRRI. Purchasing the battery and tyre-tube or taking the tyre-tube from BRRI store (if available) through requisition were attached to the vehicles/transports in BRRI workshop. The major repair and maintenance cost and times of work of individual vehicles (4-wheeler), motor cycles, tractor/ power tiller/hydro-tiller from July 2013 to June 2014 are given in Table 2. A total of 37 vehicles (4-wheeler) in 101 times, tractor in 1 time, power tiller in 2 times, and others were repaired and change of spare parts was done in BRRI workshop and outside BRRI under major repair and maintenance work. The total cost of major repair and maintenance work was Tk 32,42,508 from July 2013 to June 2014 (Table 2).

Moderate/minor repair and maintenance work
Moderate/minor repair and maintenance work have been classified into three groups:
● Moderate/minor spare parts change and repair

Table 2. Cost and times of repair and maintenance work of different vehicles/transports and farm machinery of BRRI from July 2013 to June 2014.

Type of vehicle	Vehicle/ machine no.	Time of major works	Time of moderate/ minor works	Total number of works	Cost of major works (Tk)	Cost of moderate/ minor works (Tk)	Total cost (Tk)
Bus	0004	5	51	56	367740	20740	388480
Bus	3831	4	65	69	292855	38740	331595
Minibus	8430	2	69	71	31140	14370	45510
Micro	0034	4	38	42	39000	12430	51430
Micro	0076	1	51	52	43500	26554	70054
Micro	3870	3	34	37	91000	48855	139855
Micro	0052	3	30	33	53531	36657	90188
Micro (Ambulance)	0053	6	45	51	76956	28143	105099
Micro	005	4	59	63	88075	25300	113375
Micro	0009	2	10	12	27465	14704	42169
Micro	0010	1	8	9	22144	10300	32444
Jeep	0170	8	30	38	479857	54885	534742
Jeep	0188	5	15	20	150500	10330	160830
Jeep	0189	5	39	44	143750	33412	177162
Jeep	0190	6	42	48	461243	20740	481983
Jeep	0194	2	40	42	35870	22505	58375
Jeep	0150	3	35	38	163540	30315	193855
Jeep	0123	2	42	44	30362	18850	49212
Jeep	0103	6	54	60	95300	32116	127416
Jeep	0024	3	10	13	62968	12100	75068
Jeep	0025	0	17	17	0	17150	17150
Jeep	0026	0	22	22	0	17180	17180
Pickup	0005	4	41	45	58535	25240	83775
Pickup	0017	6	40	46	81617	33468	115085
Pickup	0056	2	39	41	30800	19320	50120
Pickup	0057	0	31	31	0	35360	35360
Pickup	0058	4	70	74	77271	24944	102215
Pickup	0089	2	6	8	23517	1360	24877
Pickup	0090	4	54	58	39500	38590	78090
Pickup	0109	2	47	49	31495	29159	60654
Pickup	0002	1	3	4	12892	720	13612
Pickup	0008	0	0	0	0	0	0
Pickup	0018	0	12	12	0	3820	3820
Pickup (Carry boy)	0011	0	8	8	0	4260	4260
Truck	0020	0	24	24	0	18218	18218
Truck	0101	1	18	19	13800	5583	19383
Truck	0001	0	3	3	0	2330	2330
Sub total		**101**	**1202**	**1300**	**3126223**	**788748**	**3914971**
Motor cycle (107 Nos.)		0	565	565	0	176989	176989
Tractor (3 Nos.)		1	17	18	11320	20160	31480
Power tiller (23 Nos.)		2	52	54	32860	58159	91019
Hydro tiller (7 Nos.)		1	29	30	17855	38250	56105
Pump+mower		2	40	42	22100	29420	51520
Tyres and tubes		0	0	0	0	0	0
Others		3	25	28	32150	33240	65390
Sub total		**9**	**728**	**737**	**116285**	**356218**	**472503**
Grand total		**110**	**1930**	**2037**	**3242508**	**1144966**	**4387474**

● Minor CNG related trouble shooting and electrical works of vehicles
● Transport/vehicles/machinery cleaning and servicing

Moderate/minor spare parts change and repair works of all the vehicles and different farm machinery were done day to day in BRRI except CNG and electrical related trouble shootings of these vehicles because there was no trained manpower in BRRI regarding CNG and electrical related trouble shootings. As a result, major/ moderate/minor/or any kind of CNG and electrical

related trouble shootings of these vehicles was totally done outside BRRI. A total of 37 vehicles (4-wheeler) in 1202 times, 107 motor cycles and other farm machinery in 728 times were repaired and spare parts changed under moderate/minor repair and maintenance work (Table 2). The total cost of moderate/minor repair and maintenance was Tk 11,44,966 from July 2013 to June 2014 (Table 2).

The total cost of major and moderate/minor repair and maintenance was Tk 43,87,474 from July 2013 to June 2014 (Table 2). Among them, major repair and maintenance cost was Tk 32,42,508 and moderate/minor repair and maintenance cost was Tk 11,44,966 which were also shown in Fig. 12. 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 the revolving fund.
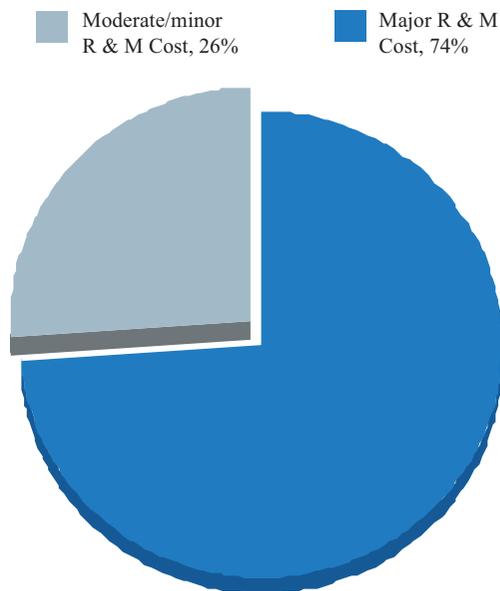
Fig. 12. Major and moderate/minor repair and maintenance cost of different vehicles and farm machinery of BRRI from July 2013 to June 2014.

Adaptive Research Division

SUMMARY

During the reporting period 24 advanced breeding lines for different seasons were evaluated by conducting eight advanced line adaptive research trials (ALART) in different agro ecological regions of Bangladesh according to the objectives of varietal improvement programme. Considering speciality on some important characteristics like grain yield, shorter growth duration, grain size, good grain quality, stress tolerance, micronutrient-dense, non-shattering habit, phenotypic acceptability and farmers' opinion, twelve advanced lines for different seasons were recommended for proposed variety trial (PVT). Among them, nine were selected for T. Aman and three for Boro season. During Aus 2014, none of the advanced lines was found to be more suitable than the check varieties. During T. Aman 2013, IR78761-B-SATBI-28-3-24 and IR78761-B-SATBI-28-3-26 for salt tolerance, IR83383-B-B-129-4 and IR82589-B-B-84-3 for drought tolerance, BR7357-11-2-4-1-1 and BR7369-16-5-2-3-1 for premium quality, BR7528-2R-19-HR10 for zinc, BR7472-16-2-1-2-3 and BR7622-5-1-1-1 for rainfed lowland rice ecosystem were found suitable for PVT. During Boro 2014, BR7671-37-2-2-3-7 as zinc enriched genotype, IR83140-B-36-B-B and IR83142-B-71-B-B as low water demanding genotypes were selected for PVT.

During Aus 2013, Aman 2013 and Boro 2014, SPDPs were conducted by using different BRRI varieties and other technologies at different locations of Bangladesh under different projects like GOB, AFACI, IAPP, MIADP, EQSS etc. Under these projects, 238 demonstrations were conducted in 77 upazilas of 33 districts, from which about 211 tons of paddy grains were produced and 36 tons were retained as seeds by the farmers for next year cultivation.

During Aman 2013 and Boro 2014, adaptive trials were conducted in different locations of southern and northern regions of Bangladesh under IAPP to indentify the most suitable varieties for those specific areas. BRRI dhan41 and BRRI dhan44 were found most suitable varieties for southern region and BRRI dhan49, BRRI dhan52 and BRRI dhan57 for northern region during T.

Aman season. In Boro season, BRRI dhan47 and BRRI dhan58 were found most suitable for southern region and BRRI dhan50 and BRRI dhan58 for northern region.

Under yield gap minimization in rice using integrated crop and resource management (ICRM) practices under KGF, on-farm farmers' participatory adaptive research trials were conducted in nine upazilas of five districts during T. Aman 2013 and Boro 2014. It was found that yield increased in ICRM practices was 0.8-1.3 t/ha over farmers' practice during Aman season and 0.7-1.1 t/ha during Boro season. So, yield gap can be minimized using ICRM practices. In another project under the Minimizing Rice Yield Gap Project (BRRI part) under MoA, research activities were carried out in 75 upazilas under 25 districts of Bangladesh. By using BRRI recommended management practices, 5% and 5.25% yield gap were minimized during T. Aman 2013 and Boro 2014 season respectively.

During the reporting period, the Adaptive Research Division (ARD) conducted 61 farmers' training at differnt locations of the country in which 2,135 trainees (1,830 farmers and 305 SAAOs of DAE) participated. The division also conducted 83 field days at different locations of the country. A total of 13,000 persons participated in those occasions.

A total of 8,300 kg quality seeds of popular and recently released rice varieties were produced at the BRRI farm, Gazipur for adaptive trials in different locations of the country in Aus, Aman and Boro seasons.

TECHNOLOGY VALIDATION

Advanced line adaptive research trial (ALART) T. Aus 2013 (Partially irrigated). Two advanced lines: BR7566-4-4-2 and BR7577-9-1-2 along with BR26 and BRRI dhan48 as checks were tested in west byde (BRRI Gazipur), Chittagong (Sitakundu), Comilla (Muradnagar), Bagerhat (Kochua), Barisal (Bakergonj), Bogra (Shahjahanpur), Moulovibazar (Srimongol) and Jhinaidah (Sadar) in T. Aus 2013. The overall performance of the tested entries was not so much

good compared to the standard check BRRI dhan48 (Table 1). Considering the growth duration, grain yield, disease infections and farmers' opinion, none of the advanced lines was found to be more suitable than the check variety BRRI dhan48. So, none was recommended for PVT.

Upland Aus 2013. Five advanced lines: BR7587-2B-3, BR7182-2B-1-2-HR4, BR7178-2B-19, BR6976-2B11-1 and BR7384-2B-5 along with BRRI dhan43 as check were tested in west byde (BRRI Gazipur), Gazipur (Kapasia), Noakhali (Sadar), Feni (Sonagazi), Sylhet (Biswanath), Faridpur (Modhukhali) and Jhinaidah (Sadar) in B. Aus 2013 (Table 2). But unfortunately, the trial at Jhinaidah (Sadar) was damaged due to some local unfavourable situations like drought and very low rainfall. Although there were some advantages in respect to grain yield and growth duration, none of the advanced lines was found to be more suitable than the check variety BRRI dhan43 based on plant height, lodging tendency and disease reactions. So, none was recommended for PVT.

T. Aman 2013 (Salinity). Three advanced lines IR78761-B-SATBI-28-3-24, IR78761-B-SATBI-28-3-26 and IR78761-B-SATB2-4-25-3 along with BRRI dhan53 and BRRI dhan54 as checks were tested in west byde (BRRI Gazipur), Khulna (Batiaghata), Khulna (Dumuria), Bagerhat (Rampal), Patuakhali (Kalapara), Borguna (Amtoli), Satkhirah (Debhata) and Satkhira (Shamnagar) in T. Aman 2013 (Table 3). Among the tested entries, IR78761-B-SATBI-28-3-26 produced the highest grain yield in five locations out of eight having average yield of 4.59 t/ha which was about 0.5 t/ha higher than the check variety BRRI dhan53 (3.95 t/ha) and BRRI dhan54 (4.16 t/ha). With an average yield of 4.45 t/ha, the 2nd highest yielder IR78761-B-SATBI-28-3-24 also produced the highest yield in two locations out of eight. Growth durations of the entries varied from 119 to 126 days whereas the highest grain yielder IR78761-B-SATBI-28-3-26 matured in the shortest period of time (119 days) followed by IR78761-B-SATBI-28-3-24 (121 days). The above

Table 1. Grain yield (t/ha), growth duration, 1000-grain weight (TGW) and plant height of some advanced lines under ALART grown in different locations of Bangladesh during T. Aus 2013.

Genotype	Location									Growth duration (day)	TGW (g)	Plant ht (cm)
	Grain yield (t/ha)											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR7566-4-4-2	4.36	4.59	4.42	4.30	4.94	5.26	5.46	4.64	4.75	109	23.02	100
BR7577-9-1-2	4.42	4.49	4.87	3.99	4.70	4.64	5.27	4.90	4.66	109	23.26	100
BR26 (ck)	4.26	3.90	4.62	3.73	4.22	4.08	5.19	4.77	4.34	109	23.46	100
BRRI dhan48 (ck)	4.59	4.19	4.51	5.04	4.34	4.40	5.18	5.05	4.67	110	22.74	97
LSD (5%)	0.53									0.18	0.25	0.20	1.26

L1-Gazipur, L2-Bagerhat, L3-Bogra, L4-Comilla, L5-Barisal, L6-Jhinaidah, L7-Moulovibazar, L8-Chittagong.

Table 2. Grain yield (t/ha), growth duration, TGW and plant height of some advanced lines under ALART grown in different locations of Bangladesh in B. Aus 2013.

Genotype	Location							Growth duration (day)	TGW (g)	Plant ht (cm)
	Grain yield (t/ha)									
	L1	L2	L3	L4	L5	L6	Mean	Mean	Mean	Mean
BR7587-2B-3	3.9	3.9	2.6	4.6	4.5	3.7	3.87	98	23.7	129
BR7182-2B-1-2-HR4	3.4	3.5	2.7	3.9	4.0	3.2	3.45	102	23.4	121
BR7178-2B-19	3.2	3.2	3.1	3.7	3.6	3.5	3.38	98	23.1	113
BR6976-2B-11-1	3.0	2.9	2.3	4.1	4.1	3.1	3.25	101	23.2	93
BR7384-2B-5	3.5	3.6	2.8	3.8	4.2	3.2	3.52	102	23.5	111
BRRI dhan43 (ck)	3.1	3.1	2.7	3.9	4.0	3.1	3.32	102	22.8	114
LSD (5%)	0.43							0.17	0.00	0.30	2.35

L1-Noakhali, L2-Sonagazi, L3-Gazipur, L4-Sylhet, L5-BRRI HQ, L6-Faridpur.

Table 3. Grain yield (t/ha), growth duration, TGW and plant height of some advanced lines under ALART (Salinity) in T. Aman 2013.

Genotype	Location									Growth duration (day)	TGW (g)	Plant ht (cm)
	Grain yield (t/ha)											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
IR78761-B-SATBI-28-3-24	4.24	3.47	4.00	5.17	5.47	4.41	4.43	4.44	4.45	121	22.4	123
IR78761-B-SATBI-28-3-26	4.50	3.99	3.39	5.72	5.42	4.30	4.76	4.60	4.59	119	24.6	124
IR78761-B-SATB2-4-25-3	4.02	3.79	2.70	4.20	4.90	4.18	4.17	4.38	4.04	120	23.6	119
BRRI dhan53 (ck)	4.07	3.50	2.81	4.23	4.55	4.31	4.05	4.06	3.95	124	23.2	110
BRRI dhan54 (ck)	4.12	3.57	2.57	5.45	4.75	4.52	4.44	3.86	4.16	126	24.8	119
LSD (0.05)	0.41									0.14	0.20	0.24	0.98

L1-Rampal, Bagerhat, L2-Amtoli, Borguna, L3-Kolapara, Patuakhali, L4-Gazipur, L5-Shymnagar, Satkhira, L6-Dumuria, Khulna, L7-Debhata, Satkhira, L8-Batiaghata, Khulna.

mentioned 1st and 2nd highest grain yielder were 5-7 days earlier than the check varieties. The advanced lines IR78761-B-SATBI-28-3-26 and IR78761-B-SATBI-28-3-24 might have the better capability than the check varieties in respect to salinity, grain yield and growth duration. Most farmers also preferred IR78761-B-SATBI-28-3-24 and IR78761-B-SATBI-28-3-26 for their better yield, shorter growth duration, less disease infection and also good grain size. Considering the overall advantages, IR78761-B-SATBI-28-3-24 and IR78761-B-SATBI-28-3-26 were recommended for PVT.

T. Aman 2013 (Drought). Four advanced lines IR83383-B-B-129-4, IR83373-B-B-27-4, IR87707-446-B-B-B and IR82589-B-B-84-3 along with BRRI dhan56 as check were tested in west byde (BRRI Gazipur), Rajshahi (Godagari), Jhinaidah (Sadar), Chapainawabganj (Gomostapur), Naogaon (Porsha), Joypurhat (Sadar), Dinajpur (Fulbari) and Rangpur (Sadar) during T. Aman 2013 (Table 4). Most of the tested entries performed better than the check variety BRRI dhan56. The tested entries IR83383-B-B-129-4, IR83373-B-B-27-4 and IR82589-B-B-84-3 produced very similar average yield which was 3.90, 3.81 and 3.86 t/ha respectively and these yield were higher than the check variety BRRI dhan56 (3.53 t/ha). Among the entries, IR83383-B-B-129-4 produced the highest yield in one location, IR83373-B-B-27-4 in three locations and IR82589-B-B-84-3 in four locations. Average growth duration of the above three advanced lines ranged from 117-119 days which was 3-5 days longer than the check variety BRRI dhan56 (114 days). Most farmers preferred IR83383-B-B-129-4 and IR82589-B-B-84-3 for its good yield, grain quality, drought tolerance and phenotypic acceptability. Based on drought tolerance, growth duration, grain yield, grain quality, phenotypic acceptability and farmers' opinion, IR83383-B-B-129-4 and IR82589-B-B-84-3 were recommended for PVT.

T. Aman 2013 (PQR and MN). Two advanced lines BR7357-11-2-4-1-1 and BR7369-16-5-2-3-1 for premium quality rice (PQR) and another two lines BR8417-2-1-2 and BR7528-2R-19-HR10 as micronutrient enriched along with BRRI dhan37 (as PQR check) and BRRI dhan39 (as MN check) were tested in west byde (BRRI Gazipur), Rajshahi (Godagari), Barisal (Sadar), Chittagong (Hathazari), Comilla (Muradnagar), Rangpur (Pirganj), Sylhet (Sadar) and Jessore (Jhikoregacha) during T. Aman 2013 (Table 5). Two PQR advanced lines produced about 1 t/ha yield advantage over PQR check BRRI dhan37 along with 4-5 days shorter growth duration and having almost similar plant height. Although grain size was slightly larger than BRRI dhan37, these two lines were found promising considering other advantages. On the other hand, two MN enriched lines gave statistically similar yield (4.6 t/ha) with check BRRI dhan39 (4.5 t/ha) having almost similar growth duration. But considering micronutrient and disease tolerance, the line BR7528-2R-19-HR10 was found promising. Finally for overall advantages two PQR lines BR7357-11-2-4-1-1, BR7369-16-5-2-3-1 and one

Table 4. Grain yield (t/ha), growth duration, TGW and plant height of some advanced lines under ALART (Drought) during T. Aman 2013.

Genotype	Location									Growth duration (day)	TGW (g)	Plant ht (cm)
	Grain yield (t/ha)											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
IR83383-B-B-129-4	5.01	3.97	2.69	4.32	4.09	4.37	3.43	3.31	3.90	119	23.83	105
IR83373-B-B-27-4	5.06	4.10	2.15	4.00	4.00	3.88	3.75	3.54	3.81	119	25.08	100
IR87707-446-B-B-B	4.78	3.20	2.58	3.88	3.78	3.40	3.34	3.43	3.55	116	24.79	100
IR82589-B-B-84-3	4.82	3.60	3.24	4.35	3.68	4.50	3.04	3.64	3.86	117	23.65	107
BRRI dhan56 (Ck)	4.50	3.00	2.61	3.99	3.52	3.91	3.22	3.51	3.53	114	24.00	106
LSD (0.05)	0.43									0.15	0.20	0.21	1.18

L1-Rangpur, L2-Joypurhat, L3-Gazipur, L4-Chapainawabganj, L5-Naugaon, L6-Rajshahi, L7-Dinajpur, L8-Jhinaidah.

Table 5. Grain yield (t/ha), growth duration, TGW and plant height of some advanced lines under ALART (PQR and MN) in T. Aman 2013.

Genotype	Location									Growth duration (day)	TGW (g)	Plant ht (cm)
	Grain yield (t/ha)											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR7357-11-2-4-1-1	5.18	4.93	4.64	5.15	4.80	4.85	4.06	3.55	4.65	130	20.2	124
BR7369-16-5-2-3-1	4.7	4.74	4.51	5.02	4.70	4.89	4.11	3.70	4.55	131	20.9	122
BR8417-2-1-2	4.06	4.86	4.60	4.46	4.34	5.01	4.78	4.67	4.60	123	22.9	106
BR7528-2R-19-HR10	4.6	4.92	4.89	5.16	4.08	5.00	3.50	4.68	4.60	128	24.0	114
BRRI dhan37(ck)	3.56	3.79	3.70	2.99	3.53	3.96	3.92	3.48	3.62	136	16.8	125
BRRI dhan39(ck)	4.8	4.2	4.07	4.89	4.52	4.80	4.98	4.09	4.54	125	23.8	106
LSD (0.05)	0.39									0.14	0.18	0.20	1.84

L1-Barisal, L2-Chittagong, L3-Rangpur, L4-Gazipur, L5-Sylhet, L6-Rajshahi, L7-Comilla, L8-Jessore.

MN enriched line BR7528-2R-19-HR10 were recommended for PVT.

T. Aman 2013 (RLR). Three advanced lines BR7472-16-2-1-2-3, BR7622-5-1-1-1 and BR7639-68-2-1-1 along with BRRI dhan39 and BRRI dhan49 as checks were tested in west byde (BRRI Gazipur), Rajshahi (Godagari), Barisal (Sadar), Chittagong (Hathazari), Comilla (Muradnagar), Rangpur (Pirganj), Sylhet (Sadar) and Jessore (Jhikoregacha) during T. Aman 2013 (Table 6). All the advanced lines out yielded (averaged yield ranged from 4.58 to 4.68 t/ha) the check variety BRRI dhan39 (4.33 t/ha) but it was statistically similar to that of another check variety BRRI dhan49 (4.74 t/ha). Average growth duration of all the tested entries ranged from 124-128 days which was 4-8 days earlier than the check variety BRRI dhan49 (132 days). However, it was 123 days for another check BRRI dhan39. Most farmers preferred the check variety BRRI dhan49 for its good yield and excellent grain quality. Some

farmers preferred BR7472-16-2-1-2-3 and BR7622-5-1-1-1 for good yield and shorter growth duration than BRRI dhan49. Based on growth duration, grain yield, acceptable grain quality and farmers' opinion, BR7472-16-2-1-2-3 and BR7622-5-1-1-1 were recommended for PVT.

Boro 2014 (Micronutrient). Two micronutrient-dense advanced lines: BR7671-37-2-2-3-7 and BR7833-11-1-1-2-1-2B5 along with BRRI dhan28 and BRRI dhan60 as checks were tested in eight locations such as west byde (BRRI Gazipur), Jessore (Jhikorgacha), Chittagong (Hathazari), Comilla (Muradnagar), Jhalokathi (Sadar), Rajshahi (Godagari), Dinajpur (Sadar), Sylhet (Golapgonj), Faridpur (Modhukhali), Kishoreganj (Pakundia) and Khulna (Dumuria) in Boro 2014 (Table 7). Having the highest average yield (7.09 t/ha) among the advanced lines and check varieties, the tested entry BR7671-37-2-2-3-7 produced the highest yield, ranged from 6.61 to 8.10 t/ha, in eight locations out of 11. Another

Table 6. Grain yield (t/ha), growth duration, TGW and plant height of some advanced lines under ALART (RLR) in T. Aman 2013.

Genotype	Location									Growth duration (day)	TGW (g)	Plant ht (cm)
	Grain yield (t/ha)											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR7472-16-2-1-2-3	4.98	4.81	5.28	4.94	5.30	4.38	3.93	3.84	4.68	128	23.6	109
BR7622-5-1-1-1	4.07	5.04	5.00	5.19	4.65	4.21	4.27	4.20	4.58	124	24.4	110
BR7639-68-2-1-1	4.55	4.91	4.71	4.96	4.77	4.18	4.75	4.39	4.65	127	24.1	104
BRRI dhan39(ck)	4.51	4.34	3.97	4.47	4.34	4.16	4.67	4.14	4.33	123	23.5	103
BRRI dhan49(ck)	5.40	5.07	4.88	4.21	4.93	4.52	3.84	5.10	4.74	132	21.4	99
LSD (0.05)				0.47						0.21	0.27	0.31	2.49

L1-Barisal, L2-Chittagong, L3-Rangpur, L4-Gazipur, L5-Sylhet, L6-Rajshahi, L7-Comilla, L8-Jessore.

Table 7. Grain yield (t/ha), growth duration, TGW and plant height of some advanced lines under ALART (MN) in Boro 2014.

Genotype	Location												Growth duration (day)	TGW (g)	Plant ht (cm)
	Grain yield (t/ha)														
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	Mean	Mean	Mean	Mean
BR7671-37-2-2-3-7	7.56	8.06	5.76	7.10	7.06	7.36	8.10	7.75	6.61	7.19	5.24	7.07	156	27.7	92
BR7833-11-1-1-2-1-2B5	6.96	6.67	6.43	6.84	6.66	6.90	6.99	6.62	5.46	6.92	5.09	6.50	144	19.6	100
BRRI dhan28 (ck)	6.82	6.75	5.44	6.29	6.29	6.49	6.87	7.14	5.68	6.38	5.22	6.31	147	22.6	101
BRRI dhan60 (ck)	7.14	7.14	5.65	7.20	6.58	6.85	7.82	7.44	6.51	6.38	6.31	6.82	151	23.9	92
LSD (0.05)						0.42						0.17	0.18	0.18	2.47

L1-Dinajpur, L2-Khulna, L3-Rajshahi, L4-Kishorganj, L5-Faridpur, L6-Gazipur, L7-Comilla, L8-Jessore, L9-Chittagong, L10-Jhalokathi, L11-Sylhet.

entry BR7833-11-1-1-2-1-2B5 produced the highest yield (6.43 t/ha) in only one location (Rajshahi), having average yield of 6.50 t/ha which was higher than the check variety BRRI dhan28 (6.31 t/ha) but lower than another check variety BRRI dhan60, which yielded 6.82 t/ha. The growth duration of the highest yielder BR7671-37-2-2-3-7 was found to be 156 days, which was five and nine days longer than the check varieties BRRI dhan60 and BRRI dhan28 respectively. BR7833-11-1-1-2-1-2B5 matured in 144 days which was the shortest among the entries. Although the growth duration was longer (5-9 days) than the check varieties BRRI dhan28 and BRRI dhan60, most farmers preferred BR7671-37-2-2-3-7 for its higher yield, lodging tolerance, green erect flag leaf and less insect and disease infestation. Farmers also preferred another tested entry BR7833-11-1-1-2-1-2B5 due to its shorter growth duration, higher yield, fine grain, attractive grain type and colour. But it has shattering habit at maturity stage which might be a cause of dissatisfaction of the farmers in future. So, based on micronutrient (zinc), higher yield, growth duration and farmers' opinion, BR7671-37-2-2-3-7 was recommended for PVT.

Boro 2014 (Aerobic/Low water). Three advanced lines: IR83140-B-36-B-B, IR83142-B-71-B-B and PSBRC82 along with BRRI dhan28 as check were tested in west byde (BRRI Gazipur), Rajshahi (Godagari), Natore (Sadar), Lalmonirhat (Sadar), Rangpur (Sadar), Dinajpur (Sadar) and Thakurgaon (Sadar) during Boro 2014 (Table 8). The plot was selected in a representative Boro area and high land and free from water stagnation. It was selected in those areas where water holding capacity of soil is comparatively low and water is drained out very quickly after irrigation. Overall yield performance of the tested genotypes was good in different locations without some minor exception (Rajshahi). Having the highest mean grain yield (7.32 t/ha) among the entries, the tested advanced line IR83140-B-36-B-B produced consistently the highest yield in all individual locations, which ranged from 6.15 t/ha (Rajshahi) to 7.97 t/ha (Lalmonirhat). Except Rajshahi it

Table 8. Grain yield (t/ha), growth duration, TGW and plant height of some advanced lines under ALART (Aerobic/Low water) in Boro 2014.

Genotype	Location								Growth duration (day)	TGW (g)	Plant ht (cm)
	Grain yield (t/ha)										
	L1	L2	L3	L4	L5	L6	L7	Mean	Mean	Mean	Mean
IR83140-B-36-B-B	7.97	7.26	7.40	7.51	7.77	7.15	6.15	7.32	158	24.8	87
IR83142-B-71-B-B	6.47	6.71	6.72	6.86	7.04	6.82	5.97	6.66	153	26.6	93
PSBRC82	6.23	6.44	6.44	7.04	6.97	6.32	5.60	6.43	152	24.5	93
BRRI dhan28 (ck)	6.40	6.09	6.12	6.46	7.08	5.79	6.00	6.28	148	22.5	99
LSD (0.05)				0.48					0.18	0.27	0.24	2.66

L1-Lalmonirhat, L2-Thakurgaon, L3-Dinajpur, L4-Natore, L5-Rangpur, L6-Gazipur, L7-Rajshahi.

ranged from 7.15 to 7.97 t/ha. Another tested advanced line IR83142-B-71-B-B produced the 2nd highest mean yield (6.6 t/ha) followed by PSBRC82 (6.43 t/ha). All the advanced lines except PSBRC82 produced higher mean yield than the check variety BRRI dhan28. Regarding growth duration, the highest yielder IR83140-B-36-B-B had the highest growth duration (158 days) followed by the 2nd highest yielder IR83142-B-71-B-B (153 days). Although the growth duration was longer (5-10 days) than the check variety BRRI dhan28, most farmers preferred the tested entries IR83140-B-36-B-B and IR83142-B-71-B-B for higher yield, lodging tolerance, green erect flag leaf and less insect and disease infestation. Based on higher yield, grain quality, growth duration and farmers' opinion the tested entries IR83140-B-36-B-B and IR83142-B-71-B-B were recommended for PVT.

TECHNOLOGY DISSEMINATION

Seed production and dissemination programme (SPDP)
For rapid dissemination of newly released BRRI varieties among the farmers, ARD conducts seed production and dissemination programme (SPDP) in every season of the year. This is an effective programme for the adoption of BRRI varieties through quality seed production. During 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 are demonstrated in farmers' fields.

SPDP with USG, T. Aman 2013 (GOB funded). SPDPs with USG were conducted in 17 upazilas of 10 districts (Gazipur, Jhenadha, Mymensingh, Rajshahi, Pabna, Dinajpur, Gaibandha, Jessor, Cox·s Bazar and Chittagong) under GOB core programme. BRRI dhan49 and BRRI dhan57 were used as varieties in that programme. Averaged on 17 locations, the grain yield of BRRI dhan49 and BRRI dhan57 were 4.89 and 4.08 t/ha respectively. Total production of BRRI dhan49 and BRRI dhan57 were 11,049 kg and 8,805 kg respectively as well as 700 kg and 1,885 kg quality seeds were retained for next year use. About 770 and 1,350 farmers/people were motivated to grow these varieties and learned about the benefits of USG application through field visits, discussion and knowledge sharing. They also showed interest to use these technologies next year. About 4,455 farmers gained knowledge from USG application and its beneficiary effect on grain yield in those varieties. In case of BRRI dhan49, seed retained and motivated farmers are comparatively very low because, most of the farmers opined that BRRI dhan49 is highly susceptible to false smut disease.

SPDP with USG, Boro 2014 (GOB funded). A total of seven SPDPs with USG were conducted at seven upzilas of seven districts (Mymensingh, Norsingdhi, Panchogor, Gaibandha, Bogra, Sathkhira and Moulovibazar) during Boro 2014. BR16, BRRI dhan50, BRRI dhan55 were used in those demonstrations. On average, BR16, BRRI dhan50, BRRI dhan55 produced yield of 5.76, 5.81 and 5.94 t/ha respectively. About 5,393, 5,449 and 5,569 kg grains of the respective varieties were produced and 1,073, 1,120 and 1,295 kg of BR16,

BRRI dhan50 and BRRI dhan55 were retained by the farmers for next year use. A total of 1,171 farmers were motivated and 2,623 farmers gained knowledge about USG and varieties through those demonstrations.

Integrated agricultural productivity project (IAPP)

SPDP, Aus 2013. SPDPs were conducted under IAPP in eight upazilas of four districts (Barisal, Patuakhali, Jhalokathi and Barguna) of Barisal region. BRRI dhan27 and BRRI dhan48 were used in the trials. Mean growth duration of BRRI dhan27 and BRRI dhan48 were 118 and 113 days with an average yield of 3.84 and 4.38 t/ha respectively. Total produced grains of BRRI dhan27 and BRRI dhan48 were 6,346 and 7,960 kg and retained seeds by the farmers were 1,265 and 1,445 kg respectively for further use. The farmers preferred both the varieties for their short growth duration. Farmers preferred BRRI dhan27 due to tall plant type and better yield compared to the local variety like Gotalia. They opined that due to tall plant type, they get more straw to feed their cattle. Farmers choosed BRRI dhan48 due to higher yield and shorter growth duration than BRRI dhan27 and also for its attractive grain size. It was not possible to establish the trial at Nolchiti, Jhalokathi due to damage of the seed bed for submergence under high tidal water.

SPDP with USG, T. Aman 2013. SPDPs with USG were conducted in eight upazilas of four southern and four northern districts under IAPP in T. Aman 2013. The southern districts were Barisal, Jhalokathi, Patuakhali and Borguna as the saline or non-saline coastal tidal submergence rice ecosystem. On the other hand, the northern districts Rangpur, Nilphamari, Lalmolnirhat and Kurigram are in the drought prone ecosystem. BRRI dhan41 and BRRI dhan44 were selected for southern districts while BRRI dhan49 and BRRI dhan57 were selected for northern districts.

Southern districts. Mean growth duration of BRRI dhan41 and BRRI dhan44 was 146 days while grain yield was 4.18 and 4.54 t/ha respectively in different upazilas of southern districts. Grain yield of BRRI dhan41 fluctuated from 4.00 to 4.35 t/ha while it was 4.20 to 4.83 t/ha

for BRRI dhan44. Across the locations, BRRI dhan44 produced the highest yield (4.83 t/ha) in Amtali of Barguna district. Due to tidal submergence, the crop of Barisal site was damaged. In general, BRRI dhan44 performed better than BRRI dhan41 in the southern districts. Total production of BRRI dhan41 and BRRI dhan44 were 1,666 kg and 1,825 kg respectively in three upazilas from which 174 kg and 221 kg were retained as seeds by the farmers for next season cultivation. About 412 farmers gained knowledge about BRRI dhan41 and 121 farmers were motivated to cultivate this variety. BRRI dhan44 was a good variety for non-saline tidal area. Farmers were impressed for its bold grain and good yield and 151 farmers were motivated to cultivate this variety.

Northern districts. In northern districts, BRRI dhan49 performed well and yielded from 4.10 to 4.95 t/ha. Mean grain yield was 4.51 t/ha and growth duration was 133 days which was almost one week earlier than BR11. However, BRRI dhan49 was severely affected by false smut disease in some locations. Total produced grains of this variety was about 3,070 kg and farmers retained 491 kg as seeds for next season. Number of motivated farmers was 96 who decided to cultivate this variety in next season. The average growth duration of BRRI dhan57 was only 107 days and produced a satisfactory grain yield from 3.34 to 4.45 t/ha. A total of 1,968 kg grains were produced in four upazilas from which 322 kg were retained as seeds by the farmers for next season. Farmers opined that after harvesting of BRRI dhan57, there was enough time to establish Rabi crops in optimum time. About 251 farmers gained knowledge about BRRI dhan57 through demonstration conducted in four upazilas and 97 farmers were motivated to cultivate in the next season.

SPDP with USG, Boro 2014. SPDPs with USG were conducted in 14 upazilas of three southern and four northern districts under IAPP in Boro 2014. The southern districts were Barisal, Jhalokathi and Patuakhali and the northern districts were Rangpur, Nilphamari, Lalmolnirhat and Kurigram. BRRI dhan47 and BRRI dhan58 were selected for Barisal region, whereas BR16, BRRI

dhan50 and BRRI dhan55 were selected for Rangpur region.

Southern districts. Across the locations, BRRI dhan58 out yielded the BRRI dhan47 and mean yield of the varieties were 5.82 and 6.57 t/ha respectively. Grain yield of BRRI dhan47 ranged from 5.52 to 6.10 whereas it was 5.37 to 7.50 t/ha for BRRI dhan58. The average growth duration of BRRI dhan47 and BRRI dhan58 were 149 and 155 days respectively. A total of 11.68 tons grains of BRRI dhan47 were produced in seven upazilas from which 1.04 ton was retained as seeds by the farmers for next season in southern districts. About 1,103 farmers gained knowledge about BRRI dhan47 and 272 farmers were motivated to cultivate this variety. BRRI dhan58 was a good variety and produced 4.40 tons grains from which 1.10 ton was retained as seeds in the southern region. Farmers preferred BRRI dhan58 for its higher yield and good crop stand.

Northern districts. BRRI dhan55 produced the highest mean yield (5.80 t/ha) followed by BR16 (5.43 t/ha) while the lowest yield (5.43 t/ha) was in BRRI dhan50. Grain yield of BR16, BRRI dhan50 and BRRI dhan55 varied from 3.97 to 6.41, 3.54 to 6.00 and 3.83 to 6.80 t/ha with the mean of 5.43, 5.21 and 5.80 t/ha respectively. The grain yield variation caused might be due to location effect, cold injury and irrigation water scarcity. Mean growth duration was the highest (165 days) in BR16 followed by BRRI dhan50 (156 days) and the lowest (151 days) was in BRRI dhan55. Growth duration ranged from 162 to 167, 153 to 157 and 148 to 153 days in BR16, BRRI dhan50 and BRRI dhan55 respectively. Total produced grains of these varieties were 39.25 t and farmers retained 7.74 t as seeds for next season. A total of 4,848 farmers gained knowledge about the varieties of which 2,077 farmers were motivated to cultivate these varieties in next season. Despite the milling problem of BRRI dhan50, farmers preferred it for its Basmati type grain and good yield. Some farmers choose BRRI dhan55 for its higher yield and comparatively lower growth duration.

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. Through this trial farmers are able to compare the cultivated varieties in their local condition and it will help the farmers to choose one or two or more varieties on the basis of local demand and agro-ecological condition of that location.

T. Aman 2013. Eight adaptive trials were conducted in eight upazilas of four southern and four northern districts under IAPP in T. Aman 2013. The southern districts were Barisal, Jhalokathi, Patuakhali and Borguna. On the other hand, the northern districts were Rangpur, Nilphamari, Lalmonirhat and Kurigram. BRRI dhan41, BRRI dhan44, BRRI dhan49, BRRI dhan53, BRRI dhan54 and Sadamota as local check were selected for southern districts with two replications whereas BRRI dhan37, BRRI dhan38, BRRI dhan49, BRRI dhan52, BRRI dhan57 and Swarna as local check were selected for northern districts with two replications.

Southern districts. Among the varieties under adaptive trials, BRRI dhan44 produced higher yield in most locations having the highest mean yield (4.10 t/ha) followed by BRRI dhan41 (3.89 t/ha), which was almost similar to BRRI dhan49 (3.83 t/ha). The lowest mean yield (3.01 t/ha) was in the local check Sadamota. Grain yield of BRRI dhan49 fluctuated 2.73 to 4.50 t/ha across the locations. Growth duration of the tested modern rice varieties varied considerably across the locations. Among the varieties, mean growth duration was the highest (158 days) in the local check Sadamota followed by BRRI dhan41 (145 days). The lowest mean growth duration (128 days) was found in BRRI dhan53 followed by BRRI dhan54 (135 days). BRRI dhan44 and BRRI dhan41 were found suitable to cultivate in the southern districts of Bangladesh.

Northern districts. Across the varieties and locations, the highest mean grain yield (4.93 t/ha) was found in the local check Swarna followed by BRRI dhan49 (4.82 t/ha) and BRRI dhan52 (4.51 t/ha). The lowest was in BRRI dhan37 (3.29 t/ha) that was almost similar to that of BRRI dhan38 (3.38 t/ha). Among the varieties, none of the BRRI

varieties competed with the local check Swarna. The highest yield (5.50 t/ha) was obtained at sadar upazila of Kurigram district. BRRI dhan52 also performed better throughout the locations along with BRRI dhan49. Though the yield and grain quality of BRRI dhan49 is very good, its susceptibility to false smut creates a different impression. BRRI dhan57 also performed better considering its shorter growth duration that could create wider options to establish Rabi crop in optimum time. The highest mean growth duration (147 days) found in BRRI dhan52 followed by Swarna (144 days) while the lowest (106 days) was in BRRI dhan57. Mean growth duration of BRRI dhan49 was 136 days. Local popular variety Swarna looked most popular variety and thereafter BRRI dhan52 and BRRI dhan57. If we can take proper measure against false smut of BRRI dhan49 then it would be one of the most popular variety in the northern districts. Farmers preferred BRRI dhan57 due to its shorter growth duration and fine grain.

Boro 2014. Seven adaptive trials were conducted in seven districts of southern and northern regions under IAPP in Boro 2014. Southern districts were Barisal, Jhalokathi and Patuakhali. On the other hand, the northern districts were Rangpur, Nilphamari, Lalmolnirhat and Kurigram. BR16, BRRI dhan47, BRRI dhan55, BRRI dhan58 and Bhajan (local check) were used in southern districts while BR16, BRRI dhan50, BRRI dhan55, BRRI dhan58 and BRRI dhan28 (Farmer's seed as local check) were used in northern districts.

Southern districts. Across the locations and varieties, BRRI dhan58 performed the best and produced the highest mean grain yield (6.70 t/ha) and the lowest yield (5.44 t/ha) was in the local check variety Bhajan. The highest grain yield (6.92 t/ha) was obtained in BRRI dhan58 followed by BRRI dhan47 (6.22 t/ha) while the lowest yield (5.45 t/ha) was in BR16 at sadar upazila of Barisal. Growth duration of the rice varieties was significantly affected by the locations, variety and the interaction of variety and location. Across the location and variety, the highest growth duration (167 days) was recorded for the local check variety Bhajan at Nalchiti, Jhalokati followed by BR16

(165 days). The mean highest growth duration (166 days) was found in Bhajan followed by BR16 (164 days), BRRI dhan58 (155 days) and the lowest was in BRRI dhan55 (148 days). Based on grain yield and growth duration BRRI dhan58 and BRRI dhan47 were found suitable for southern districts.

Northern districts. Irrespective of location, BRRI dhan58 produced the highest mean grain yield (6.42 t/ha) that was significantly higher than the other tested varieties. This was followed by BRRI dhan55 (5.80 t/ha), which was almost similar to that of BRRI dhan50 (5.69 t/ha) and the lowest (5.20 t/ha) was in the check variety BRRI dhan28 (used farmer's seed). Growth duration was also significantly varied within locations and varieties. Irrespective of location, the highest mean growth duration (166 days) was recorded in BR16 followed by BRRI dhan50 and BRRI dhan58 (156 days) while the lowest growth duration (148 days) found in BRRI dhan28 as local check. Based on grain yield, growth duration and farmers' comments, it is found that BRRI dhan58 and BRRI dhan50 is suitable for northern districts.

Mujibnagar integrated agricultural development project (MIADP)

In the middle western regions of Bangladesh and in the western part of the Ganges river floodplain there are predominantly four districts viz Kushtia, Meherpur, Chuadanga and Jhenaidah and called the High Ganges River Floodplain. The land type is predominantly high and medium high and climate is dry with low rainfall. High lands are well drained. In that situation Boro rice cultivation is not cost effective for high cost of irrigation because of low water holding capacity of the lands. Then only very short duration Boro rice can be grown which needs less irrigation. Predominantly short duration upland or T. Aus and T. Aman varieties need to be disseminated to increase overall production of that region.

SPDP, T. Aus 2013. SPDPs were conducted in 16 upazilas of four districts under MIADP. BRRI dhan48 was selected for each upazila and the plot size was two bighas. The average growth duration of BRRI dhan48 was 113 days and the average grain yield was 4.1 t/ha. Total production

was 17,751 kg and farmers retained 1,881 kg seeds for next season cultivation. A total of 1,069 Farmers gained knowledge about BRRI dhan48 through demonstrations by discussion, field visit and idea sharing and 610 farmers were motivated to cultivate BRRI dhan48 in the next year.

SPDP, T. Aman 2013. SPDPs were conducted in 12 upazilas of four districts under MIADP. BRRI dhan49 and BRRI dhan57 were selected for each upazila and the plot size was one bigha for each variety. The average growth duration of BRRI dhan49 and BRRI dhan57 were 135 and 106 days respectively. The average grain yield of BRRI dhan49 was 4.91 t/ha and BRRI dhan57 was 4.10 t/ha. Total grain production of BRRI dhan49 and BRRI dhan57 were 7,840 kg and 5,996 kg respectively. A total of 1,625 kg and 1,820 kg of BRRI dhan49 and BRRI dhan57 were retained as seeds by the farmers for next season. A total of 863 farmers gained knowledge about BRRI dhan49 and 1,047 farmers about BRRI dhan57. A total of 113 farmers were motivated to cultivate BRRI dhan49 and BRRI dhan57 in the next year.

SPDP, Boro 2014. SPDPs with USG were conducted in eight upazilas of four districts under MIADP. BRRI dhan50 and BRRI dhan58 were used in each upazila. Mean growth duration of BRRI dhan50 and BRRI dhan58 were 154 and 157 days respectively. The average grain yield of BRRI dhan50 and BRRI dhan58 were 5.8 and 7.2 t/ha respectively. Total production of BRRI dhan50 and BRRI dhan58 were 12,412 and 7,708 kg respectively. Farmers retained 1,687 kg and 1,433 kg seeds of BRRI dhan50 and BRRI dhan58 for next season use. A total of 2,349 and 2,628 farmers gained knowledge from the demonstrations of BRRI dhan50 and BRRI dhan58 and 1,686 and 1,200 farmers were motivated to cultivate BRRI dhan50 and BRRI dhan58 in the next year.

Enhancing quality seed supply project (EQSS)
Quality seed production and dissemination programme (QSPDP), T. Aman 2014. QSPDP was conducted in 10 upazilas of five districts under EQSS project. BRRI dhan46 and BRRI dhan57 were selected for each upazila. BRRI dhan49 was selected for Narayanganj. The growth duration of BRRI dhan46, BRRI dhan49 and BRRI dhan57

varied from 104-147 days in different locations. The average growth duration of BRRI dhan46, BRRI dhan49 and BRRI dhan57 were 147, 137, 104 days respectively. Grain yield of those varieties varied from 4.3-6.5 t/ha. The average grain yield of BRRI dhan46 and BRRI dhan57 were 4.6 and 4.3 t/ha respectively. Total production of BRRI dhan46, BRRI dhan49 and BRRI dhan57 were 11,147, 1,733 and 11,466 kg and the farmers retained seeds were 1,900, 300 and 1,975 kg respectively for further use and for distribution to other interested farmers. A total of 295, 75 and 485 farmers were motivated to cultivate those varieties.

Boro 2014. QSPDPs were conducted in 10 upazilas of five districts under EQSS project. BR16, BRRI dhan50, BRRI dhan55 and BRRI dhan58 were selected for each upazila. The growth duration of BR16, BRRI dhan50, BRRI dhan55 and BRRI dhan58 varied from 149-165 days in different locations. The average growth duration of BR16, BRRI dhan50, BRRI dhan55 and BRRI dhan58 were 162, 154, 152 and 155 days respectively. Grain yield of those varieties varied from 5.4-7.5 t/ha. The average grain yield of BR16, BRRI dhan50, BRRI dhan55 and BRRI dhan58 were 6.20, 5.90, 6.70 and 6.90 t/ha respectively. Total production of BR16, BRRI dhan50, BRRI dhan55 and BRRI dhan58 were 7524, 7202, 8018 and 8312 kg and retained seeds by the farmers were 876, 1085, 1040 and 785 kg respectively for further use and for distribution to other interested farmers. A total of 362, 305, 331 and 380 farmers were motivated to cultivate those varieties.

AFACI food security project
Rice production using USG applicator, T. Aman 2013. Progressive farmers were selected in Chandina, Comilla. The farmers were provided with seeds of BRRI dhan49, BRRI dhan52 and BRRI hybrid dhan4. BRRI dhan49 produced the highest grain yield, 5.4 t/ha with medium growth duration of 135 days. Majority farmers at Comilla were interested to grow BRRI dhan49 for better yield along with fine grain and medium growth duration and high market price although affected by false smut and sheath blight diseases. However, some farmers showed discouraging attitude

towards BRRI dhan49 for false smut disease although it produced better yield. BRRI dhan52, the submergence tolerant variety produced 5.1 t/ha grain yield with growth duration of 144 days. Farmers did not prefer for long duration and large grain size. BRRI hybrid dhan4 produced 4.9 t/ha grain yield with shorter growth duration of 119 days. Some farmers preferred it mainly for shorter growth duration although grain yield was lower than those of BRRI dhan49 and BRRI dhan52. Some farmers showed very less interest towards hybrid rice for low market price and taste though shorter growth duration. The farmers retained about 30% of produced grains of BRRI dhan49 in demonstrated plots as seeds for next season cultivation.

Minimizing rice yield gap project (MoA)

T. Aman 2013. Yield gap of 15.59% was observed in T. Aman 2012, which was reduced to 10.53% in T. Aman 2013 ie 5% yield gap was minimized within this period using BRRI technologies. Twenty-five field days were executed in 25 districts in T. Aman 2013. Five thousand farmers, DAE personnel and NGO representatives participated in those field days. All the farmers showed their interest to apply BRRI management packages with BRRI varieties which were used in those trials.

Boro 2014. Yield gap of 15.23% was observed in Boro 2011-12 which was reduced to 9.98% in Boro 2013-14 ie 5.25% yield gap was minimized in this period using BRRI technologies. It was further observed that yield gap was 13.18% in Boro 2012-13 which was reduced to 9.98% in Boro 2013-14 ie 3.20% yield gap was minimized in this period. Fifty field days were executed in 25 districts in Boro 2013-14. Ten thousand farmers, DAE personnel's and NGO representatives participated in those field days. All the farmers showed their interest to apply BRRI management packages with BRRI varieties which were used in those trials.

Yield gap minimization in rice using integrated crop and resource management (ICRM) practices

On-farm adaptive trials were conducted using ICRM practices in nine upazilas of five districts during Aman 2013 and Boro 2014. BRRI implemented the project activities in five upazilas: Kapasia (Gazipur), Pakundia, Kotiadi (Kishoreganj), Monohordi and Polash (Norshingdi) where as Social Progress Services (SPS) implemented in four upazilas: Madarganj (Jamalpur), Sadar, Nokhla and Nalitabari (Sherpur). Three villages were selected in each upazila, 10 farmers in each village with land area 1 bigha for each farmer. Each farmer's field divided into two parts to assign two treatments- 1) ICRM practices and 2) Farmers' Practices (FP). BRRI dhan49 was used in T. Aman and BRRI dhan28 in Boro seasons.

T. Aman 2013. Optimum aged seedlings, healthy seedlings, balanced fertilization, proper management of weeds, insects and diseases were adopted in ICRM production package which resulted to 0.8-1.3 t/ha increased grain yield over farmer's practice.

Boro 2014. Optimum aged seedlings, use of healthy seedlings, balanced fertilization, proper management of weeds, insects and diseases were adopted in ICRM production package which resulted to 0.7-1.1 t/ha increased grain yield over farmer's practice.

Farmers' opinion about BRRI varieties and other technologies

During the reporting period, ARD has conducted a lot of demonstrations using different BRRI varieties with some other associated technologies in different seasons under different projects and BRRI core fund. Farmers expressed their opinions about the BRRI varieties (Table 9). ARD personnel collected farmers opinion by direct interview with farmers and using data sheet of the DAE personnel.

Farmers' opinions about USG

Higher grain yield compared to prilled urea as it supplies N throughout the season. No needs of split application of urea that save labour cost. Rice leaves that remain always deep green and reduces loss of urea. Less weed infestation and disease infection and requires less urea and gave uniform flowering. However, high irrigation cost is the drawback of this technology. Besides, for deep

Table 9. Farmers' opinions about BRRI varieties.

Variety	Reason for liking	Reason for disliking
	Aus varieties	
BRRI dhan48	Higher yield, high market price, good grain quality, shorter duration, lower disease and pest infestation, lodging tolerant.	None
	Aman varieties	
BRRI dhan41	Salt tolerant, lodging tolerant, tall plant type, bold grain, more straw and higher market price in Barisal region.	BLB disease, longer growth duration.
BRRI dhan49	Higher grain yield like BR11 but one week earlier than BR11, rice is palatable, grain quality like Nizershail, high market price, lodging tolerant.	BLB infection and false smut disease in some areas.
BRRI dhan57	Shorter duration which can eacape drought along with better yield, lodging tolerant, higher market price for attractive grains.	Infection of false smut disease in some areas.
	Boro varieties	
BR16	Diabetic rice, slender grain, high market price.	Longer duration
BRRI dhan47	Salt tolerant, lodging tolerant, bold grain, high market value in southern areas.	Shattering problem at maturity and infection by blast in some areas.
BRRI dhan50	Higher yield, very long slender grains along with aroma, good taste, higher market price.	In normal mills, it is broken during milling
BRRI dhan55	Attractive grain yield and grain size, high milling recovery, shorter growth duration.	Cooked rice become soft and clode, irregular flowering.
BRRI dhan58	Attractive grain size with grain yield near to BRRI dhan29 and about 5-7 days earlier than BRRI dhan29.	None

placement of USG required extra labour which increases production cost and simultaneously creates back pain of the farmers resulting health problem. So it needs a suitable USG applicator machine.

Farmers training and promotional activities
Farmers' training. ARD conducted 61 Farmers' Training at different locations in which a total of 2,135 trainees (1830 farmers and 305 SAAOs of DAE) participated.

Field day/Farmers' rally. ARD conducted 83 field days at different locations under different projects (IAPP, MIADP, EQSS, AFACI, YGM) and GOB funds during Aus 2013, Aman 2013 and Boro 2014. A total of about 13,000 persons participated in those occasions. These programs also generated much enthusiasm about modern rice production technologies and BRRI varieties which help rapid dissemination of technologies.

Seed production at BRRI farm
A total of 8,300 kg quality seeds of different BRRI varieties were produced at BRRI farm during the reporting period for conducting adaptive research trials. During T. Aus 2013, a total of 500 kg seeds were produced and the whole amount were used in research programme. In T. Aman 2013 total produced seeds of nine BRRI varieties were 3,600 kg from which 2,800 kg were used in divisional research programme. From remaining 800 kg of seeds, 200 kg were distributed to other divisions for research purpose and the rest 600 kg was sent to the central store. During Boro 2014, a total of 4,300 kg seeds of nine different BRRI varieties were produced from which 3,000 kg were used in different adaptive research trials and remaining 1,300 kg were distributed among the BRRI scientists and other staffs for cultivation in their own locations so that the variety dissemination could be more rapid.

Training Division

SUMMARY

The Training Division has conducted 77 training programmes in the reporting period with course duration from one day to two months. A total of 1,621 participants from different government and non-government organizations and farmers 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) followed by farmers. The overall improvement of knowledge for scientists were 286% and 215% for theory and skill respectively in the two-month rice production trainng course. In case of one-week rice production training (RPT) for extension personnel, improvement of knowledge varied widely and ranged from 196 to 550%. The improvement result indicates the importance of rice production training (RPT) for extension personnel. The updated training information shows that up to June 2014 BRRI completed 2,751 training programmes through which 90,726 participants were trained on different aspects of rice production technologies. Effectiveness of imparted trainings was determined on the basis of feedback remarks on different aspects. Most of the trainees expressed positive views about the course content and method of training. However, participants of all courses, specially the one-week course, suggested for increasing duration of the course from one-week to at least 2-3 weeks. Most of the BRRI's speakers' performance was very good to excellent. Bangladesh Rice Knowledge Bank (BRKB) is redesigned and updated with latest rice informations. Training Division also conducted two training programmes and one workshops on development and use of BRKB.

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 1,546 responses on different issues were received from the trainees of which 356 from regular batches, 961 from EQSSP, 59 from NGO and 170 from scientists (Table 1). Though the participants were of different categories and from different region and environment of the country, their expectations were very much similar. Specially the SAAO and scientists showed high expectation about insect and disease management followed by variety ralated issues. On the other hand, NGO participants showed highest interest about seed followed by variety and fertilizer relatated issues.

CAPACITY BUILDING AND TECHNOLOGY TRANSFER

Two-month rice production training for BRRI scientists
The main objectives of the course was 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. Table 2 provides the particulars of the participants.

Knowledge improvement was measured on the basis of marks obtained in the benchmark and final evaluation of individual participant. The improvement of knowledge through this training was very attractive. On an average, it was 286% for theory and 214% for skill respectivelly (Table 3). Table 4 presents the performance status of two-month rice production training.

One-week rice production training for SAAO (Regular)
The main objectives of the course was to train the grass root level extension workers of DAE and the project staff (SA and scientists). The course curriculum was designed based on the priority of field problems related to rice production and rice based technologies. A total of 618 personnels were trained (118 SAAO from ragular batches, 461

Table 1. Expectations by the participants of RPT on different subjects/issues in need conducted by BRRI during 2013-14.

Subject/issue	Expectation (%)							
	SAAO				NGO	Rank	Scientist	Rank
	Regular	Rank	EQSSP	Rank				
Insect	35	1	19	1	4	7	14	4
Disease	32	2	17	2	4	7	17	2
Seed	2	7	15	3	27	1	2	
Variety	12	3	12	5	21	2	21	1
Fertilizer	3	5	9	6	10	4	6	5
IWM	1	7	7	7	8	5	-	
Hybrid	2	6	3	8	3	8	-	
Rice growth	4	4	2	9	3	8	15	3
Soil	1	8	2	9	3	8	-	
Crop manag	0	-	2	9	0	0	-	
Weed	1	8	1	10	7	6	-	
Statistics	-	-	-	-	-	-	14	4
Others	10			14		13		10
Total	100		100		100		100	
Response no.	356		961		59		170	

Table 2. Particulars of the two-month long rice production training.

Batch (no.)	Duration	Participants (no.)			Designation	Organization
		Total	Male	Female		
1	16 February-16 April	30	24	6	SSO/SO	BRRI
Total		30	24	6		

Table 3. Knowledge improvement through two-month long rice production training.

Category of valuation	Benchmark evaluation	Final evaluation	Improvement (%)
Theory	25 (9-42)	83 (80-90)	286
Skill	24 (5-40)	83 (61-91)	217

Table 4. Performance status of two-month long rice production training.

Category/certificate	Participants (no.)	Percentage
Distinction (80-100% marks)	30	100
Satisfactory (60-79% marks)	-	-
Participatory (Less than 60% marks)	-	-
Average	30	100

SAAO and NGO personnels from EQSSP and 39 scientists, SA and SAAO from IAPP) (Table 5).

Knowledge improvement was assessed based on the marks obtained in benchmark and final evaluation of individual participants. On average improvement of the participants from regular, EQSSP and IAPP was 285, 315 and 155% respectively (Table 6). Table 7 presents the performance status of one-week rice production training for different categories of participants.

Quality rice seed production and storage
A total of 356 training programme on seed production, processing and storage for the Assistant Director (AD) and Senior Assiatant Director (SAD) of BADC, SAAO of DAE, SA and Community Facilitator (CF) of IAPP were conducted using the fund of EQSSP and IAPP. Table 8 presents the details of the training.

Farmers training
BRRI Training Division also conducted some farmer's training courses. During the reporting period 19 one-day rice production training programmes were conducted in collaboration with DAE using GOB and EQSSP fund. In total 567 farmers were trained through this training (Table 9).

Table 5. One-week long rice production training conducted by BRRI in 2013-14.

Project	Batch (no.)	Participants (no.)			Designation	Organization
		Total	Male	Female		
Regular	6	118	105	13	SAAO	DAE
EQSSP	25	461	419	42	SAAO, NGO	DAE, PKSF
IAPP	2	39	32	7	Scientists, SAAO, SA	DAE, BRRI, IAPP
Total	618	556	62			

Table 6. Knowledge gain and improvement through one-week long rice production training in 2013-14.

Project	Batch (no.)	Evaluation (average mark %)		Improvement (%)
		Benchmark	Final evaluation	
Regular	6	17.66	66.50	285
EQSSP	25	17.16	68	315
IAPP	2	33	76	155

Table 7. Performance status of one-week long rice production training in 2013-14.

Project	Batch (no.)	Categories of results/certificates		
		Distinction	Satisfactory	Prticipatory
Regular	6	20	79	19
EQSSP	25	104	286	71
IAPP	2	22	14	3

Table 8. Particulars of quality rice seed production and storage training in 2013-14.

Project	Batch (no.)	Participants (no.)			Designation	Organization
		Total	Male	Female		
EQSSP	12	199	162	37	AD, UAO,AEO and NGO Off.	BADC, DAE, PKSF
IAAP	8	157	139	18	SAAO, CF	DAE, IAPP
Total	20	356	301	55		

Table 9. Rice production training courses for farmers in 2013-14.

Project	Training (no.)	Participants (no.)		
		Total	Male	Female
GOB	5	147	125	22
EQSSP	14	420	406	14
Total	19	567	531	36

Details of the training courses

During the reporting period, 463 training programmes have been conducted by the BRRI Training Division, other divisions and regional stations of BRRI. Out of them 77 were conducted by Training Division, 272 were conducted by other divisions and 115 were conducted by regional stations (Table 10).

Until June 2014, 2,751 training courses have been conducted for 90,726 participants of different organizations (Table 11). Table 12 presents the categories of the participants under long and short courses in BRRI up to 2014.

EFRFECTIVENESS OF IMPARTED RICE PRODUCTION TRAINING

It is important to determine the impact of different aspects of imparted rice production training for its better planning and execution in future. This study was conducted at the end of each batch to collect the relevant information. After the completion of data collection, information were compiled and analyzed. This study revealed that one week RPT course is very much helpful for the trainees to build up their capacity for modern rice production activites.

Table 10. Total training courses conducted by BRRI 2013-14.

Name of the training		Training (no.)	Duration	Participants (no.)			Designation
				M	F	Total	
Training Division							
Rice production training		1	2 Month	24	6	30	SSO/SO
Rice production training (Regular)		6	1-week	105	13	118	SAAO
Integrated rice production (Mujibnagar)		1	5 days	20	0	20	SA/SSA
Integrated rice production (IAPP)		2	1-week	32	7	39	Scientist, SAAO/SA/CF
Rice production training (EQSSP)		25	1-week	419	42	461	SAAO/NGO
Quality Rice Seed Production, Processing and Storage (IAPP)		8	3-day	139	18	157	SAAO/ CF
Seed Production, Processing and Storage (EQSSP)		12	3-day	162	37	199	DAE/BADC/PKSF
Utilization of BRKB		2	3-day	30	0	30	Scientist
Farmers training		19	1-day	531	36	567	Farmers
Sub total		77		1462	159	1621	
Other divisions							
IWM	Increasing rice production through irrigation management	12	1-day	365	42	407	Farmers, SAAO
WM	Training on engineering drawing and design of small equipment by auto CAD tools	01	4-day	18	0	18	Scientists
Statistics	Training on data collection	01	3-day	9	0	9	SAAO
ARD	Rice production train.	42	1-day	1160	310	1470	SAAO/Farmers
Entomology	Training on BPH management	-	-	285	15	300	SAAO/ Farmers
FMPHT	Training on agriculture machineries/ Field demonstration/SAAO/SO/ driver	216	1-5 days	6513	644	7157	Driver/Farmers/ SAAO/Scientist
Sub total		272		8350	1011	9361	
Regional stations							
Kushtia	Modern rice production technologies	36	1 day	1166	44	1210	Farmers
Satkhira	Boro rice production training	16	1 day	462	48	510	Farmers, Others
Comilla	Rice production technology	7	1 day	210	0	210	Farmers
Barisal	Rice production technology	29	1 day	652	218	870	Farmers
Rangpur	Rice production technology	10	1 day	280	20	300	Farmers
Rajshahi	Rice production technology	17	1 day	536	19	555	Farmers
Sub total		115		3306	349	3655	
Grand total		463		13118	1519	14637	

Table 11. Training conducted by BRRI up to June 2014.

Division	Name of training	Duration	Training (no.)	Participants (no.)
Training Division	Rice Production Training (RPT)	1-4 months	94	2472
	RPT and others	1-3 weeks	447	10874
	RPT and others	1-5 days	522	15403
	Sub total		1,065	28,749
Other divisions	RPT and others	1-2 weeks	09	103
	RPT and others	1-5 days	1637	44853
	Sub total		1,646	44,956
Regional stations	RPT and others	1-3 days	505	17021
	Sub total		505	17021
	Grand total		2,751	90,726

Other than RPT were water management, fertilizer management, seed production and preservation, hybrid rice seed production, farm machinery, IPM, BRKB etc.

Performance of BRRI speakers

One batch of two-month and ten batches of one-week RPT were considered for this evaluation. At first batch wise analysis was done on the basis of five criteria for each speakers. The five criteria were as follows: a. style of presentation; b. question handling; c. use of training materials; d. time management and e. quality and relevance of handout and its timely supply. Average of five criteria was used to determine the performance of

Table 12. Categories of participants under long and short courses up to June 2014.

Types and training	Participants categories												Total
	Scientist		DAE/other officer		BS[1]/SAAO/SA/SSA		Others[2]		NGO		Farmer		
	M	F	M	F	M	F	M	F	M	F	M	F	
Long course (94)	407	71	1729	18	112	-	98	-	36	-	-	-	
Total	478		1,747		112		98		36		-		2,472
Short course (2658)	1812	229	5291	329	14814	1406	1640	345	1049	84	55695	4658	
Total (2751)	2041		5620		17125		1985		1,130		60353		88253
Grand total	2519		7367		17237		2084		1166		60353		90726

[1]BS=Block Supervisor. SSAO=Sub Assistant Agriculture Officer, SA=Scientific Assistant. [2]Others=(Teacher, Fertilizer dealer, Seed dealer, Local representative, BRRI staff). M=Male, F=Female.

individual speaker in each batch. The over all performances of BRRI's speakers' were very good to excellent in both long and short courses.

UPDATING OF BRKB

Training Division is working to develop and update all BRRI released technologies in a digital form through BRKB using SPGR-NATP project fund. One of the objectives of this is to train the BRRI technology clients about the use of BRKB so that they can get recent rice technological information using BRKB. Two 2-day training programmes on utilization of Bangladesh Rice Knowledge Bank and one workshop were organized during the reporting period (Tables 12 and 13). The BRKB is redesigned and updated with latest rice information.

Table 13. Three-day training on Utilization of Bangladesh Rice Knowledge Bank in 2013-14.

Duration	Participants (no.)			Designation	Organization
	Total	Male	Female		
22-24 Dec 13	15	15	0	Scientists	BRRI
29-31 Dec 13	15	15	0	Scientists	BRRI
Total	30	30	0		

Table 14. Particulars of workshop on development and utilization of BRKB in 2013-14.

Duration	Participants (no.)			Participants
	Total	Male	Female	
29-31Dec 13	20	20	0	Scientists of BRRI from different disciplines/divisions
Total	20	20	0	

BRRI RS, Barisal

SUMMARY

A total 76 progenies of F_2 population and 397 from F_6 generations were selected in the pedigree nursery for submergence tolerant rice genotypes. In observational trial (OT), 58 lines were selected and 21 were sent for the next PYT. In the Boro RYT, one advanced line each for Favourable Boro (FB) and premium quality rice (PQR), six lines for micronutrient enriched rice (MER), nine lines for green super rice (GSR), and three lines for disease resistant rice (DRR) were selected. AYT for tidal wetland submergence tolerant rice were conducted at five locations of Barisal, Jhalokati, Pirojpur and Bagerhat districts. Irrespective of test site, BR7941-30-1-1-1 and BR7941-116-1-2-1 performed better. In the PVT, salt tolerant advanced Boro BR7100-R-6-6 and IR78794-B-Sat29-1 at Patharghata and Nazirpur, BR7830-16-1-5-3 and weed tolerant rice at Nolcity, Jhalokati, green super Boro line HUA 565 at Barisal produced higher yield than the tested check varieties. However, rainfed lowland T. Aman season line BR7611-31-5-3-2, produced lower yield than BR11 (ck) at Babuganj, Barisal. In long-term missing element trial, omission of nitrogen from complete treatment (NPKSZn) decreased one ton ha^{-1} yield in T. Aman and 2.98 ton ha^{-1} in Boro season. BRRI dhan46 in Aman and BRRI dhan29 in Boro season performed better under stability analysis experiment. Total amount of 3,745 kg and 12,200 kg breeder seed was produced in T. Aman 2013 and Boro 2013-14 respectively. According to the validation trial of Integrated Agricultural Productivity Project (IAPP), BRRI dhan41 produced higher yield in Barisal and Jhalokati, BRRI dhan44 in Patuakhali and BRRI dhan52 in Barguna district. In Boro, BRRI dhan60 and in Aus season, BRRI dhan48 produced the highest yield at different locations of Barisal region. Test results from FSR and D sites suggested about 20 to 38% more grain yield increased by replacement of HYV instead of local Aman and local Boro in rice-rice system. Inclusion of Mustard and/or Mung bean in single T. Aman pattern increased the yield level of about 142 to 174% more. Boro (HYV) followed by fish cultivation increased about 330% rice equivalent yield (REY) over single local Boro pattern. The stakeholders improved their vegetable production system by 'Sorjan' method. Small scale poultry, pigeon, goat rearing and fish cultivation increased household income and protein consumption. Integrated Agricultural Development Project conducted production programme at Bagerhat and Pirojpur districts and reported that BRRI dhan48 produced the highest grain yield in Aus and BRRI dhan55 at Boro season.

VARIETAL DEVELOPMENT

Development of tidal submergence tolerant rice

The objectives of the project was to select taller seedling with sturdy and strong plant type, large and compact panicle, more tillering ability with less unproductive tiller and less lodging that can compatible to tidal submergence condition. A total of 76 progenies were selected from F_2 and 397 from F_6 generations. In total 58 lines were selected in OT and 21 were sent for PYT.

Preliminary yield trial

Preliminary yield trial (PYT) was done to evaluate the genotypes tolerant to the tidal non-saline and stagnant water condition. Thirty genotypes were evaluated in this trial at BRRI regional station Barisal. The trial was conducted using 2-3 seedlings per hill with a spacing of 20- × 20-cm. The field layout was RCB design with three replications. The unit plot sizes were 5.4 m × 8 rows. Fertilizer doses and management practices were done following standard procedure. Sadamota, Dudhkolom and BRRI dhan44 were used as checks. On the basis of maximum yield production and seedling height, only eleven entries namely: BR8165-8-1-1HR3, BR8173-39-1-1-HR1, BR7941-34-2-2-1-2, BR7941-41-2-2-2-4, BR7941-45-2-2-2-1-1, BR7941-45-2-2-2-1-1, BR7941-119-2-3-1-4, BR7844-3-2-2-2-1-1, BR7847-47-3-3-2-2-2-1, BR7849-5-2-2-2-2-4, BR7943-53-1-2-1 were selected for further evaluation.

Regional yield trial

The regional yield trial (RYT) was conducted to

test the yield potential and adaptability of advanced lines in on station. Five RYT trial were done for Favourable Boro (two advanced lines and two checks), MER (five advanced lines and two checks), PQR (six advanced lines and two checks), GSR (nine advanced lines and one check), and DRR (five advanced lines and two checks) during Boro 2013-14 with three replications. The unit plot size for each entry was 5.4 × 12 rows. About 49-day-old seedling was transplanted at 25- × 15-cm spacing. All fertilizers except urea were applied as basal dose and urea was applied in equal splits at 10-15 DAT, 30-35 DAT and 5-7 days before PI stage. Other standard management practices were followed as necessary. Advanced line for FB (BR7988-10-4-1), MER (BR7800-63-1-7-3, BR7881-10-1-5-3-1, BR7833-11-1-1-3-4, BR7669-11-1-2-8-2-1, BR7830-16-1-5-9-9 and BR7833-11-1-1-2-1-2B5), PQR (BR7781-10-2-3-2), GSR (IR83140-B28-B, IR83142-B-19-B, IR83142-B-60-B, HHZ5-SAL10-DT1-DT1, HUANG HUA ZHAN, HHZ17-DT6-Y1-DT1, HHZ17-Y16-Y3-Y2, HHZ23-DT16-DT1-DT1 and HHZ12-SAL2-Y3-Y2), and DRR (BR7986-2-3, BR7986-7-4 and BR7986-29-4) were selected for their respective performances.

AYT for tidal wetland submergence tolerant rice
In T. Aman 2013, five genotypes were evaluated (BR7941-1-1-2-1, BR7941-20-1-1-1-HR1, BR7941-20-1-1-1-HR2, BR7941-30-1-1-1 and BR7941-116-1-2-1) at Pirojpur sadar, Fakirhat, Bagerhat, Bakerganj, Barisal, Shaitpakia, Jhalokati and Matibhanga, Nolcity for the tidal non-saline and stagnant water condition. The trials were conducted using 2-3 seedlings per hill with a spacing of 20- × 20-cm. The field layout was RCB design with three replications. The unit plot sizes were 5.4 m × 12 rows. Fertilizer doses were 80-15-40-20 kg NPKS/ha with split application of N (40+20+20). Total amount of P, K, and S were applied at the time of final land preparation. Dudhkolom and BRRI dhan44 were used as checks. Irrespective of location, advanced line BR7941-30-1-1-1 and BR7941-116-1-2-1 performed better than the other tested lines and produced similar yield to check variety BRRI dhan44.

PROPOSED VARIETY TRIAL

Proposed variety trial (PVT) done at different locations of Barisal to evaluate the performance of varieties for salt tolerant Boro, FB, GSR and rainfed lowland rice. The trials were conducted using 2-3 seedlings per hill with a spacing of 25- × 15-cm. The field layout was RCB design with three replications. The unit plot sizes were 5- × 5-m. Fertilizer doses were 120-20-60 kg NPK/ha + 100 kg gypsum/ha + 10 kg $ZnSO_4$ with split application of N (60+30+30). Total amount of P, K, S and $ZnSO_4$ were applied at the time of final land preparation. The proposed variety for salt tolerant Boro, BR7100-R-6-6 and IR78794-B-Sat29-1 produced higher yield than the check variety BRRI dhan47 at Patharghata, Barguna and Nazirpur, Pirojpur. In the FB trial, the highest grain yield obtained by the proposed variety BR7830-16-1-5-3 followed by weed tolerant rice. However, growth duration of both the advanced lines was seven to nine days more than the check variety BRRI dhan28 at Nolcity, Jhalokati. Green super Boro rice HUA 565 produced higher yield than the check variety BRRI dhan33 at Babuganj, Barisal. Rainfed lowland rice BR7611-31-5-3-2 produced lower yield than the check variety BR11 at Barisal.

Long-term missing element trial
The Experiment was initiated on a permanent layout at the BRRI Sagardi farm, Barisal in Boro 2009. Six treatments were adopted in RCB design with three replications. The fertilizer rate was N-P-K-S-Zn @ 150-15-50-10-1 kgha^{-1} for Boro and 60-15-50-10-1 kgha^{-1} for T. Aman. In both the cropping seasons, omission of any nutrient element from complete fertilizer treatment (NPKSZn) decreased rice grain yield. Omission of N from complete treatment decreased one ton ha^{-1} grain yield in T. Aman season. However in Boro season, it decreased to 2.98 ton ha^{-1}. In T. Aman, P omission also reduced rice yield significantly. N is the most yield limiting nutrient both in T. Aman and Boro season.

Stability analysis of BRRI released variety
Different BRRI released varieties were grown in T. Aman and Boro seasons at BRRI RS, Sagardi farm,

Barisal to find out the suitable rice cultivars in this region. Three replications with RCB design were followed. Crop management practices were adopted as per BRRI recommendations. In Aman season, the highest yield 5.65 t ha^{-1} was found in BRRI dhan46 followed by BRRI dhan54 (5.35 t ha^{-1}). The lowest yield 2.31 t ha^{-1} was observed in BRRI dhan34. In Boro, the highest yield was observed in BRRI dhan29 (6.29 t ha^{-1}) followed by BRRI dhan47 (5.41 t ha^{-1}). The lowest yield was recorded in BRRI dhan27 (3.89 t ha^{-1}).

Test and evaluation of BRRI prilled urea applicator

Prilled urea applicator is a device that can place prilled urea in 5-6 cm soil depth in paddy field. In planned experiments four N management treatments were tested. These were: T_0=N control, T_1=Hand broadcasting of prilled urea (recommended rate), T_2=USG application by applicator (2.7 g/4 hills) and T_3=Prilled urea application by applicator (70% of total urea in broadcasting). Each plot received a flat dose of 20, 40, 24, and 10 kg ha^{-1} P, K, S and Zn respectively. The design of the experiment was RCB with three replications. Hand broadcasting of prilled urea (recommended rate) produced the highest grain yield but agronomic efficiency was found higher with prilled urea application by applicator (70% of total urea in broadcasting).

RICE FARMING SYSTEMS

Improvement of existing cropping pattern

Three different experiments were conducted to increase the productivity of the existing cropping pattern at nine dispersed farmers' field at Banaripara upazila. BR22, BRRI dhan34, BRRI dhan41, BRRI dhan46 and BRRI dhan49 were cultivated instead of local cultivar 'Sadamota' in T. Aman season. About 24 to 35% yield advantage was observed in HYVs over Sadamota. Local variety 'Bhojon' was replaced with BRRI dhan28, BRRI dhan29, BRRI dhan47, BRRI dhan50, BRRI dhan55 and BRRI dhan58. About 20 to 38% yield advantage was observed in improved cropping pattern over existing pattern.

About 27 to 34% yield advantage was observed in improved cropping pattern over existing pattern. Under this programme, Sadamota was replaced by BRRI dhan44, BRRI dhan51 and BRRI dhan52 in Aman season and in Boro, Bhojon was replaced by BRRI dhan28 and BRRI dhan47. Bari Sarisa14 (Mustard), BARI Mug5 and BARI Mug6 (Mung bean) were introduced after T. Aman. About 174% yield advantage was found through inclusion of mung bean and mustard with BRRI dhan44. Carp fish was cultured in T. Aman season in single Boro pattern. Standard cultivation procedure and fertilizer doses were used as per BRRI, BARI and DoF recommendations. Rice-fish culture improved REY by 38 t/ha.

Year round vegetable production in homestead, Sorjan bed and Roof top

Eleven different types of summer vegetables and fourteen different types of winter vegetables were produced through Lebukhali model and Sorjan method by sixteen participatory farmers with an average area of approximate 10 decimal. Investment of Tk 100 return Tk 185 in summer and Tk 410 in winter season.

Establishment of farm yard manure production

About 25-30 percent use of chemical fertilizer was reduced for winter vegetables production in the same field compared to the previous year.

Small scale chicken, duck, pigeon and goat rearing in the farmer's household

Each of the twelve selected farmers was distributed six Khaki Campbell duck and chicks maintaining 1:5 male female ratios. Each farmer was supplied one waterer for easy medication. Pigeons were distributed to six selected farmers and each of them got three pairs. They sold 80% and consumed 20% squab which increased their income and nutritional uptake. Pigeon rearing was profitable and it provides additional income of Tk 450 per farmer per month by squab production. Six farmers' under small and marginal group were selected and each of them has given one Black Bengal doe collected from local market. Nine kids were produced from six families. The average return was Tk 2,250 per family per year.

Poly-culture (Carp) technique in perennial ponds under low cost management

Six farmers were selected having perennial ponds and four were selected for seasonal pond. Different compatible species of fishes ie *Catla, Mrigel*, Silver Carp, *Rohu*, Telapia and Thai sorputi of different tropic and spatial niches were released in the same pond to use all sorts of natural foods available in the ponds. Average fish production of the selected farmer was 12.5 kg/decimal pond areas with the range of 10 kg to 14 kg. The average net benefit was Tk 920.

TECHNOLOGY TRANSFER

Farmers' training

Farmers' training is a day long programme where generally 30-35 farmers participated. This training programme was conducted at FSR and D site, Banaripara, Fakirhat, Mollarhat and Necharabad with the collaboration of DAE. BRRI RS, Barisal conducted 43 farmers' training in Barisal region. Total 1290 persons (1118 males and 172 females) were trained. These programmes certainly helped the farmers to create awareness for adopting the BRRI rice production technologies and to accelerate the dissemination rate of BRRI varieties in those areas and increase the farmers' income as well as improve the livelihood through practicing the farming systems approach.

Field day

This event is very useful tool for generating consciousness and interest among the farmers and concerned extension agent about the modern rice production technologies. One field day was conducted with the collaboration of DAE in Nolcity of Jhalokati district. About 150 farmers (113 male and 37 female), researchers, extension providers, NGO personnel, administrative people, public leaders etc participated in field day. In this event, BRRI developed varieties and farm machinery were demonstrated.

Breeder seed production

T. Aman rice varieties of BR23, BRRI dhan41, BRRI dhan44 and BRRI dhan52 were produced at Sagardi farm during T. Aman 2013. Cultivar BR26, BRRI dhan28, BRRI dhan29 and BRRI dhan47 were cultivated during Boro 2013-14 season at Sagardi and Charbadna farm. The total amount of 3,745 and 12,200 kg breeder seed was produced in T. Aman and Boro season respectively.

Validation and demonstration trials of BRRI varieties through IAPP

The project is focused on specific agro-ecological areas including the salt-affected tidal surge areas in the southern (approx. two million hectares) part of Bangladesh. In 2013-14 cropping season IAPP-BRRI, Barisal conducted 22 validations (16 in T. Aman and six in Boro) and 31 demonstrations (13 in T. Aman, six in Boro and 12 Aus) trial at different locations of Barisal region. In Aman 2013 season the selected area average yield of BRRI dhan41 was higher followed by BRRI dhan44 and BRRI dhan52. According to location, BRRI dhan41 performed better in Barisal and Jhalokati district and yield was higher in Jhalokati than the Barisal district. In Patuakhali district BRRI dhan44 performed better than the other varieties and BRRI dhan41 performed better followed by BRRI dhan52 in Barguna district. Demonstration trials with BRRI dhan52 out of 13 were conducted in four locations. BRRI dhan52 produced highest yield on average of 4.35 t/ha followed by BRRI dhan46 (4.22 t/ha) and BRRI dhan49 (3.79 t/ha).

In Boro season 2013-14 the average yield of all the BRRI varieties in the selected areas were found more than 6 t/ha whereas BINA dhan8 produced 5.8 t/ha. BRRI dhan60 produced the highest average yield of 6.6 t/ha followed by BRRI dhan28 (6.4 t/ha). In demonstration trials BRRI dhan47 were in four locations. BRRI dhan29 produced the highest yield of 7.62 t/ha followed by BRRI dhan28 (7.24 t/ha) and BRRI dhan47. In Barguna sadar BRRI dhan47 produced the lowest yield due to scarcity of irrigation and poor management practices. In Aus 2014 the average yield of all the BRRI varieties in the selected areas were found more than 4 t/ha. The highest average yield was found with BRRI dhan48 (5.19 t/ha) followed by BRRI dhan43 (4.32 t/ha) in all the demonstrated locations. Farmers choosed the BRRI

dhan48 for high yield and no lodging at harvesting period.

Production programme of high yielding Aus and Boro varieties under PGB project
In Aus, the highest yield of 5.34 t ha^{-1} and 5.21 t ha^{-1} was produced from BRRI dhan48 in both of the Nesarabad, Pirojpur and Mollahat, Bagerhat. In Boro season, the yield level of BRRI dhan28 was 6.23 t/ha at Fakirhat, Bagerhat. Among the tested varieties (ie BRRI dhan26, BRRI dhan28, BRRI dhan29, BRRI dhan47, BRRI dhan55) BRRI dhan55 produced the highest grain yield of 7.47 t ha^{-1} irrespective of location. BRRI dhan28 and BRRI dhan55 produced higher yield at Mollarhat upazila than Nazirpur and Fakirhat. The yield level was very similar among BRRI dhan29, BRRI dhan47 and BRRI dhan55 whereas BRRI dhan29 showed some yield advantage at Nazirpur upazila. BRRI dhan26 produced the lowest grain yield of 5.52 t ha^{-1} at Fakirhat upazila in Bagerhat district.

BRRI RS, Bhanga

SUMMARY

BRRI RS, Bhanga, Faridpur conducted five experiments under varietal development programme. As an extended breeding programme of Plant Breeding Division, BRRI HQ, Gazipur. Development of micronutrient enriched rice was the major programme of the station. Also, evaluation of different elite breeding lines in regional yield trial (RYT) was conducted as regular activity. A total of 1,856 individual progenies were selected from segregating population and 33 fixed lines were bulked. Six uniform entries were selected from observational trial of 98 genotypes considering yield advantage over check varieties having similar or less growth duration, amylose content and grain zinc content for further evaluation in replicated trial. Five promising lines were selected from PYT based on yield advantage and growth duration similar to or less than the check varieties, amylose content and brown rice zinc content. Another 23 genotypes having higher grain yield than the check varieties and considerably higher amylose content but low in zinc content were also selected for further advancement under favourable Boro rice programme.

In regional yield trial (RYT), RYT-FB, the test entries yielded higher than the check varieties. BR7988-10-4-1 and BR 7800-63-1-7-3 had yield advantage of 0.8 t/ha and 0.5 t/ha over BRRI dhan55 respectively with almost similar growth duration. In case of RYT-PQR, BR7376-19-1-6-1 produced the highest grain yield (7.2 t/ha), followed by BR7369-10-5-2-3 (7.0 t/ha) and BR 7358-35-3-2-1 (7.0 t/ha) with 5-6 days longer growth duration than BRRI dhan50 (154 days). Among nine genotypes in RYT-GSR, HHZ17-DT6-Y1-DT1 and HHZ12-SAL2-Y3-Y2 yielded the highest (8.0 t/ha) with 10-12 days longer growth duration (154-156 days) than check variety BRRI dhan28. In RYT-MER, BR7830-16-1-5-9-9 produced the highest grain yield (8.5 t/ha) followed by BR7669-11-1-2-8-2-1 (7.9 t/ha) and BR7833-11-1-1-2-1-2B5 (7.5 t/ha). BR7830-16-1-5-9-9 had yield advantage of 2.3 t/ha over BRRI dhan28 and 1.1 t/ha over BRRI dhan60 with similar growth duration. BR7813-1-1-3-1 of RYT-

Cold had 1.7 t/ha yielded advantage over BRRI dhan28 with same growth duration (141 days). Another two genotypes, IR77496-31-2-1-3-1 and BR7812-19-1-6-1-P4 also had yield advantage of 1.7 t/ha over BRRI dhan28 but they matured three days later.

In a proposed variety trial (PVT) of B. Aus in two sites, OM1490 produced 0.25 t/ha higher at Gopinathpur, Gopalganj and 0.79 t/ha higher in at Tambulkhana, Faridpur than the check variety BRRI dhan43 with almost similar growth duration.

In stability analysis of BRRI released modern rice variety for Boro season, BRRI dhan29 yielded the highest (8.3 t/ha) followed by BRRI dhan58 (7.9 t/ha).

An experiment to determine optimum fertilizer dose for getting maximum grain yield showed that the highest yield could be obtained from NPKSZn (114-20-60-12-13kg/ha) treated plot (8.85 t/ha), followed by NPKZn treated plot (7.68 t/ha) and NKSZn (7.73 t/ha). The application of appropriate fertilizer dose may increase rice yield in farm soil. In a three year experiment for optimization nitrogen dose showed 200 Kg N application per hectare can give the highest yield of BRRI dhan29 in BRRI RS, Bhanga farm condition.

Validation and adoption trial of BRRI dhan60 and BRRI dhan29 at Gopalganj district under PGB-IADP conducted in eight farmers plot showed higher grain yield of BRRI dhan29 (8.55 t/ha) than BRRI dhan60 (8.24 t/ha) with 10-14 days delayed maturity. Farmers showed interest to grow BRRI dhan60 for its early maturing ability and slender type grain.

Seed production at BRRI RS farm was about 31 tons during Boro season in 2013-14. Enhancing Quality Seed Supply Project provided support to produce about 15 tons of breeder seed. With HarvestPlus project support around nine tons of quality seed was produced. Also, around seven tons of TLS of different varieties was produced in this farm using GOB fund. About 11 tons of good quality seed of BRRI dhan28, BRRI dhan29 and BRRI dhan60 were produced in ten farmers' field in greater Faridpur region under EQSS project. BRRI RS, Bhanga arranged 19 training programmes and educated 570 farmers on modern

varieties and crop management techniques. Rice yield gap was minimized by 13.04% in Gopalganj and 11.39% in Faridpur districts in T. Aman 2013 and 6.3% in Gopalganj and 7.2% in Faridpur district in Boro 2013-14 through intervention of quality seeds, new varieties and modern crop management techniques.

VARIETAL DEVELOPMENT

Evaluation of segregating population in pedigree nursery

A total of 1005 segregating progenies comprising F_5 to advanced generations were evaluated. At maturity superior plants with respect to agronomic performance and tolerant to major diseases and insect-pests were selected individually. A total of 1,856 individual progenies comprising 649 F_4, 384 F_5, 570 F_6, 43 F_7 and 210 F_8- advanced generations were selected from pedigree nurseries. Also, 33 fixed lines were bulked (Table 1).

Observational trial

A total of 98 fixed lines were evaluated along with BRRI dhan28 and BRRI dhan29 as standard check varieties. At maturity, 53 uniform entries were harvested based on visual field performance and yield was recorded. Considering grain yield, growth duration (days), zinc and amylose content only six genotypes were selected for further evaluation (Table 2) in replicated yield trial.

Preliminary yield trial

A total of 106 advanced breeding lines were evaluated in seven sets. BRRI dhan28 and BRRI dhan29 were used as standard check varieties.

Table 1. List of progenies selected from pedigree nurseries and bulk population, Bhanga, Boro 2013-14.

Pedigree nurseries	No. of cross	No. of plant selected	No. of fixed lines bulked
F_4 Generation	15	649	-
F_5 Generation	22	384	6
F_6 Generation	38	570	11
F_7 Generation	3	43	6
F_8 Advanced generation	32	210	10
Total		1856	33

Data on plant height (cm), days to flowering, days to maturity, phenotypic acceptance (PAcp), and yield per plot were recorded. Considering yield advantage (at least 0.5 t/ha) over check varieties having similar growth duration, amylose content (at least 23%) and brown rice zinc content (24 mg/kg), 5 genotypes were selected for further evaluation in replicated trial for confirmation of yield potential (Table 3). Among the selected genotypes, BR7528-2R-19-HR16-13-3-2 yielded 1.6 t/ha higher than BRRI dhan29 with two days shorter growth duration. Another 23 genotypes having higher grain yield than the check varieties and considerably higher amylose content but zinc content lower than the acceptable limit (24 mg/kg) were also selected for further advancement under favourable Boro rice programme (Table 4).

Regional yield trial

Thirty-two advanced breeding lines comprising two of favourable Boro rice, six of premium quality rice, nine of green super rice, five of micronutrient enriched rice, five of disease resistant rice and five of cold tolerant rice were evaluated in six sets against standard check varieties- BRRI dhan28, BRRI dhan29, BRRI dhan50 or BRRI dhan55. In RYT-FB, the test entries yielded higher than the check varieties. BR7988-10-4-1 and BR7800-63-1-7-3 had yield advantage of 0.8 t/ha and 0.5 t/ha over BRRI dhan55 respectively with almost similar growth duration (Table 5). In case of RYT-PQR, BR7376-19-1-6-1 produced the highest grain yield (7.2 t/ha), followed by BR7369-10-5-2-3 (7.0 t/ha) and BR 7358-35-3-2-1 (7.0 t/ha) with 5-6 days longer growth duration than BRRI dhan50 (154 days). Among nine genotypes in RYT-GSR, HHZ17-DT6-Y1-DT1 and HHZ12-SAL2-Y3-Y2 yielded the highest (8.0 t/ha) with 10-12 days longer growth duration (154-156 days) than the check variety BRRI dhan28. In RYT-MER, BR7830-16-1-5-9-9 produced the highest grain yield (8.5 t/ha) followed by BR7669-11-2-8-2-1 (7.9 t/ha) and BR7833-11-1-1-2-1-2B5 (7.5 t/ha). BR7830-16-1-5-9-9 had yield advantage of 2.3 t/ha over BRRI dhan28 and 1.1 t/ha over BRRI dhan60 with similar growth duration. BR7813-1-1-3-1 of RYT-cold had 1.7 t/ha yield advantage over BRRI

Table 2. Characteristics of selected genotypes from observational trial, Bhanga, Boro 2013-14.

Designation	Growth duration (day)	Plant ht (cm)	Yield (t/ha)	Amylose (%)	Zinc content (mg/kg)
BR8263-50.1-1	154	110	8.2	24.0	24
BR7812-30-1-3-5-1	153	122	7.7	25.0	24.5
BR7813-92-2-9-7-1	154	98	8.4	24.0	24.1
BR7815-18-1-3-2-1	153	125	8.6	23.0	25.2
BR8611-26	154	93	7.4	25.0	24.1
BR8254-63-4-5-1B6-P2	158	115	9.4	24.0	27.4
BRRI dhan28 (ck)	153	106	7.4	27.3	16.8
BRRI dhan29 (ck)	163	107	8.4	27.6	16.9

Table 3. Characteristics of selected genotypes from preliminary yield trial (PYT), Boro 2013-14.

Designation	Growth duration (day)	Seedling ht (cm)	Plant ht (cm)	Yield (t/ha)	Amylose (%)	Zn (mg/kg)	Grain size and shape
BR8410-89-2-4	161	24.2	104.7	7.8	23	25.1	LS
BR8643-6-4-4	159	27.0	99.8	7.5	24	26.4	MS
BR7528-2R-19-HR16-13-3-2	167	30.7	107.3	9.7	26	27.7	LS
BR 8640-1-1-2	166	26.0	99.3	7.6	23	25.4	LS
IR91167-199-1-2	169	23.3	98	8.3	25	26.6	MS
BRRI dhan28 (ck)	156	33.7	97.2	6.9	27.3	16.8	
BRRI dhan29 (ck)	169	24.4	101	8.1	27.6	16.9	

Table 4. Characteristics of selected genotypes from preliminary yield trial (PYT), Boro 2013-14.

Designation	Growth duration (day)	Seedling ht (cm)	Plant ht (cm)	Yield (t/ha)	Amylose (%)	Zn (mg/kg)	Grain size and shape
BR8643-34-2-1	157	30	110.3	7.7	24	20	MS
BR8611-10	159	19.3	79.5	7.5	24	15.1	MS
BR8247-3-2-2-2	159	19.3	79	7.8	23	18.6	MS
BR7813-9-2-4-HR1-4-1	160	24	101.3	8.1	25	17.1	LS
BR8626-25-6-1-6	161	26.6	104.8	8.1	24	19.4	LS
BR8626-1-4-2-3	162	22.9	84.8	7.4	25	14.5	MS
BR8634-7-4-3	163	22	91.3	7.6	23	14.6	MS
BR8415-57-1-1	163	29.4	92.7	7.6	24	20.3	LS
BR8626-20-4-1-1	163	24.3	104.9	9.0	23	20.7	MB
BR8634-41-5-4	163	27.7	102.9	7.6	23	22.8	MB
BR8410-17-2-3-2	164	23.3	86.3	8.4	24	16.6	MS
BR8643--34-1-3	164	25	97.1	7.6	24	22.7	LS
BR8410-107-1-1	164	29.7	106.9	8.1	24	19.6	MS
BR8923-14-1	164	31.8	104.9	9.5	23	19.8	LS
BR8626-28-7-1-3	165	27.9	99.1	8.6	24	18.0	MB
BR8633-4-1-4	166	23	108.6	10.7	26	21.4	LS
IR85601-RIl101-1-1-1-1-3	166	24.6	83	8,0	25	20.9	LS
BR8626-19-4-1-1	167	28.6	108.3	9.1	23	17.4	MB
BR8643-6-4-3	168	24.3	100.9	7.6	25	22.3	MS
BR8626-28-12-1-4	168	21.3	99.7	8.4	24	17.7	SB
BR8626-20-9-1-3	172	19.7	97.7	7.6	26	19.9	MS
BR8626-19-5-1-2	172	28.1	97.7	8.6	26	18.3	LS
BR7528-2R-19-HR16-12-1-3	174	25.8	95.9	8.7	24	18.5	MS
BRRI dhan28 (ck)	156	33.7	97.2	6.9	27.3	16.8	LS
BRRI dhan29 (ck)	169	24.4	101	8.1	27.6	16.9	MS

dhan28 with same growth duration (141 days). Another two genotypes, IR77496-31-2-1-3-1 and BR7812-19-1-6-1-P4 also had yield advantage of 1.7 t/ha over BRRI dhan28 but they matured three days later.

Proposed variety trial of drought tolerant direct seeded Aus rice

The proposed variety OM1490 was evaluated with standard check variety BRRI dhan43 and a local check in farmer's field of Gopinathpur of

Table 5. Grain yield and ancillary character of RYT-FB in Boro 2013-14 at BRRI, Bhanga.

Entry	Plant ht (cm)	Duration (day)	Grain yield (t/ha)
RYT-FB			
BR7988-10-4-1	91.8	145	7.9
BR7800-63-1-7-3	98.6	146	7.7
BRRI dhan28 (ck)	101.0	143	6.2
BRRI dhan55 (ck)	93.8	149	7.1
CV%	2.03	0.30	10.6
LSD (0.05)	3.85	0.88	0.7
RYT-PQR			
BR7376-19-1-6-1	104.1	159	7.2
BR7369-10-5-2-3	112.7	160	7.0
BR7358-35-3-2-1	79.8	159	7.0
BRRI dhan28 (ck)	101.0	144	6.1
BRRI dhan50 (ck)	89.0	154	6.0
CV%	11.3	0.45	7.0
LSD (0.05)	7.6	1.23	0.3
RYT-GSR			
HHZ17-DT6-Y1-DT1	94.0	152	8.0
HHZ12-SAL2-Y3-Y2	106.5	152	8.0
BRRI dhan28 (ck)	102.9	142	6.1
CV%	5.2	3.3	8.0
LSD (0.05)	3.1	3.1	0.4
RYT-MER			
BR7669-11-1-2-8-2-1	94.7	144	7.9
BR7830-16-1-5-9-9	110.6	146	8.5
BR7833-11-1-1-2-1-2B5	104.3	140	7.5
BRRI dhan28 (ck)	104.9	142	6.2
BRRI dhan60 (ck)	94.6	144	7.4
CV%	8.3	1.7	11.3
LSD (0.05)	6.1	1.8	0.8
RYT-DR			
BR7986-2-3	111.3	146	7.8
BR7986-29-4	107.3	144	7.8
BR7840-18-1-1	120.7	147	7.8
BRRI dhan28 (ck)	103.8	143	6.3
BRRI dhan29 (ck)	101.3	156	7.7
CV%	6.5	3.9	7.4
LSD (0.05)	4.3	3.6	0.7
RYT-Cold			
IR77496-31-2-1-3-1	91.1	144	7.7
BR7812-19-1-6-1-P4	101.8	144	7.7
BR7813-1-1-3-1	100.8	141	7.8
BRRI dhan28 (ck)	99.5	141	6.0
BRRI dhan55 (ck)	102.4	147	7.5
CV%	5.8	3.3	8.3
LSD (0.05)	3.7	3.0	0.4

Gopalganj and Tambulkhana of Faridpur district. OM1490 produced 0.25 t/ha higher at Gopinathpur and 0.79 t/ha higher in at Tambulkhana than the check variety BRRI dhan43 with almost similar growth duration (Table 6).

SOCIO-ECONOMIC AND POLICY

Stability analysis of BRRI released Boro varieties

A total of 28 BRRI released modern Boro rice varieties were evaluated as a long-term experiment to understand the yield stability of the released varieties. Table 13 presents the grain yield (t/ha), days to maturity (DTM), plant height, tiller and panicle production. BRRI dhan29 produced the highest grain yield (8.3 t/ha) followed by BRRI dhan58 (7.9 t/ha). BR17, BR18, BR19 and BR8 lodged at maturity stage (Table 7).

CROP-SOIL-WATER MANAGEMENT

Soil fertility management in single cropped area of low Ganges River Floodplain of Bangladesh

An experiment, with seven treatments- NPKSZn, PKSZn(-N), NKSZn(-P), NPSZn(-K), NPKZn(-S), NPKS(-Zn) and no fertilizer, was conducted for consecutive three years starting from 2012 to 2014 to determine optimum fertilizer dose for getting maximum grain yield. BRRI dhan29 was used as the test variety. The highest yield was obtained from NPKSZn (114-20-60-12-13kg/ha) treated plot (8.85 t/ha), followed NPKZn(-S) treated plot (7.68 t/ha) and NKSZn(-P) (7.73 t/ha) (**Table 8**). Using three years mean data, marginal benefit from investment in nutrient inputs optimum N, P, K dose were calculated following Driessen (1996) and BRRI (2004). The optimum N, P, K doses were estimated as 66.21, 2.83 and 12.85 kg/ha respectively.

Optimum N, P and K dose will be calculated following Driessen (1996)

$$N = [(Y_{NPK}-Y_{PK})/N_U] \times 18$$
$$P = [(Y_{NPK}-Y_{NK})/P_U] \times 2.5$$
$$K = [(Y_{NPK}-Y_{NP})/K_U] \times 20$$

Where, Y_{NPK}=yield in NPK plots, Y_{PK}=yield in N omission plot, Y_{NK}=yield in P omission plot, Y_{NP} = yield in K omission plot.

Regression analysis of 6 levels of N dose on yield of BRRI dhan29 using quadratic N response equation (Colwell, 1994) showed that 200 Kg N application per hectare can give the highest yield in BRRI RS, Bhanga farm condition (Fig. 1).

Table 6. Grain yield and growth duration of advanced lines/variety in PVT, drought tolerant direct seeded rice (Aus), 2013.

Advanced line/Variety	Growth duration (day)			Grain yield (t/ha)		
	Gopinathpur	Tambulkhana	Mean	Gopinathpur	Tambulkhana*	Mean
OM1490	101	99	100	1.7	4.3	3.0
BRRI dhan43 (ck)	103	102	102.5	1.9	3.5	2.7
Kala Shitta (L. ck)	93	-		1.7	-	

*Irrigation was given two times during crop establishment.

Table 7. Grain yield, days to maturity of BRRI released Boro varieties at BRRI RS, Bhanga, Faridpur, Boro 2013-14.

Variety	Growth duration (day)	Grain yield (t/ha)	Variety	Growth duration (day)	Grain yield (t/ha)
BR1	152	5.7	BR26	143	5.7
BR2	155	5.2	BRRI dhan27	152	5.7
BR3	163	7	BRRI dhan28	142	6.7
BR6	143	4.7	BRRI dhan29	155	8.3
BR7	158	4.8	BRRI dhan35	153	5.8
BR8	157	6.4	BRRI dhan36	143	5.8
BR9	156	6.6	BRRI dhan45	142	7.1
BR12	161	6.1	BRRI dhan47	148	6.8
BR14	157	6.8	BRRI dhan50	153	6.8
BR15	163	6.1	BRRI dhan55	149	7.5
BR16	160	6.6	BRRI dhan58	151	8.0
BR17	148	6.7	BRRI dhan59	148	7.8
BR18	163	6.8	BRRI dhan60	144	8.1
BR19	163	6.8	BRRI dhan61	151	7.1

Table 8. Mean grain yield of BRRI dhan29 at BRRI RS, Bhanga.

Treatment	Grain yield (t/ha)			
	2012	2013	2014	Mean
NPKSZn	8.42	8.34	8.85	8.54
PKSZn(- N)	7.25	7.12	6.82	7.06
NKSZn(- P)	7.94	7.92	7.73	7.86
NPSZn(- K)	8.19	8.2	7.68	8.02
NPKZn(- S)	8.31	8.23	7.82	8.12
NKSP(- Zn)	8.34	8.3	7.38	8.01
No fertilizer	6.67	6.64	6.44	6.58

Grain yield (t/ha)

$$y = -0.00007x^2 + 0.02809x + 5.77418$$
$$R^2 = 0.89821$$
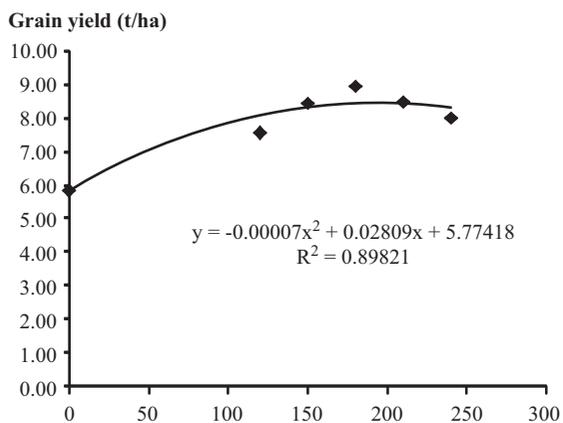
Fig. 1. Optimum N dose from the regression trend line of different N level in Boro 2013-14 at BRRI RS, Bhanga, Faridpur.

TECHNOLOGY DISSEMINATION

Validation of modern rice variety in Gopalganj district under PGB-IADP

Four validation trials with BRRI dhan29 and BRRI dhan60 were conducted at eight farmers' field of four upazilas of Gopalganj district. The study was conducted through participatory appraisal of farmers selected by the Agricultural Officer and SAAOs of DAE. Mean grain yield of BRRI dhan29 (8.55 t/ha) was higher than BRRI dhan60 (8.24 t/ha) with 14 days longer duration (Table 9). Farmers showed interest to grow BRRI dhan60 for its early maturing ability that may escape the risk of flood at harvesting time of Boro and the slender type grain was highly preferred to the farmer.

Yield gap minimization through BRRI technologies

This study was conducted using quality seeds of BRRI released high yielding varieties and modern crop production technologies in the farmers field of Faridpur and Gopalganj districts in Boro and T. Aman seasons. In Boro, quality seeds of BRRI dhan28 and BRRI dhan29 and in T. Aman, BRRI

Table 9. Grain yield and duration of BRRI dhan60 and BRRI dhan29 produced at Gopalganj by PGB-IADP.

Location	Grain yield (t/ha)	Mean yield (t/ha)	Growth duration (day)	Mean duration (day)	Plant ht (cm)
		BRRI dhan60			
Gopalganj Sadar	8.51	8.24	150	148	96
Tungipara	8.81		148		97
Kashiani	7.61		148		99
Muksudpur	8.01		147		102
		BRRI dhan29			
Gopalganj Sadar	7.97	8.55	163	162	101
Tungipara	8.98		161		102
Kashiani	8.58		159		103
Kotalipara	8.66		164		102

dhan33, BRRI dhan39 and BRRI dhan51 were used. These studies showed that the intervention with quality seeds and modern production technologies could minimize yield gap of 11-13% in T. Aman and 6.3-7.2% during Boro in greater Faridpur region (Table 10).

Seed production and dissemination
A total of 15,025 kg breeder seed of BRRI dhan28 and BRRI dhan29 was produced at the BRRI RS farm. Also, 16,010 kg TLS of different varieties including BRRI dhan62 was produced to distribute among farmers. In total 31,035 kg quality seed were produced in BRRI RS, Bhanga during Boro 2013-14 (Table 11).

Seed production and dissemination in farmer's field
Enhancing Quality Seed Supply (EQSS) project provided of partial support to ensure quality seed production in ten farmer's field in Boro 2013-14. BRRI RS, Bhanga supplied quality seeds to farmers and shouldered cost of fertilizers, insecticides and training under this project. At maturity, one field day at each site was arranged

with the help of DAE. During field day the trial farmers shared their experience to neighbouring farmers, which built interest among them to grow these varieties in their own plots and thereby a demand for quality seed was generated. An amount of 11.29 ton seed was produced in farmer field to meet the local demand (Table 12).

Training/Agricultural fair
BRRI Regional Station, Bhanga participated in different agricultural and seed fair in Faridpur and Gopalganj districts. This station conducted three farmer's training on crop production and seed production technologies in different upazilas of Faridpur, Gopalganj, Madaripur and Shariotpur districts with GOB fund. EQSS project also funded to conduct 15 farmers training in Tungipara, Kotalipara, Kashiani, Muksudpur and Gopalganj sadar of Gopalganj district; Sibchar of Madaripur district; Nogarkanda, Charbhadrasan, Boalmari, Alfadanga and Bhanga upazila of Faridpur and Rajbari sadar of Rajbari district. One farmers training was conducted in Tungipara upazila of Gopalganj district under Pirojpur-Gopalganj-Bagerhut Integrated Agricultural

Table 10. Rice yield and yield gap minimizing in farmers' field condition in Faridpur and Gopalganj.

District	Grain yield (t/ha)		
	BRRI recommended practice	Farmer's practice	% grain yield (t/ha) increased over FP
	T. Aman		
Gopalganj (3 upazila)	5.20	4.60	13.04
Faridpur (3 upazila)	4.66	4.19	11.39
	Boro		
Gopalganj (3 upazila)	9.28	8.73	6.3
Faridpur (3 upazila)	7.56	7.05	7.2

Table 11. Breeder seed and TLS production at BRRI RS, Bhanga in Boro 2013-14.

Variety	Breeder seed (kg)	HarvestPlus project (kg)	TLS(kg)	Total seed (kg)
BRRI dhan28	9,511	-	1,488	10,999
BRRI dhan29	5,514	-	4,304	9,818
BRRI dhan50	-	-	208	208
BRRI dhan57	-	-	104	104
BRRI dhan60	-	-	541	541
BRRI dhan62	-	9,025	340	9,365
Total	15,025	9,025	6,985	31,035

Table 12. Seed production at farmer's field at Gopalganj and Faridpur district in Boro 2013-14.

Farmer's name	Sex	Age	Village	Block	Upazila	District	Seed produced (ton)
Md Vhulu Sharif	M	50	Taghoria	Pachuria	Gopalganj Sadar	Gopalganj	1.07
Nasima Choudhory	F	43	Bolashur	Bolashur	Kashiani	Gopalganj	1.02
Md Rubel Shakh	M	55	Dik nagar	Dik nagar	Muksedpur	Gopalganj	0.97
Md Akkas Ali	M	60	Mazhikandda	Mazhikandda	Bhanga	Faridpur	1.11
Md Azad Talukder	M	48	Hamirdi	Madhobpur	Bhanga	Faridpur	1.13
Md Kamrul Shakh	M	27	Pobnar par	Mandra Kushla	Kotalipara	Goplaganj	1.40
Md Rasul Fakir	M	67	Purbo Sadardi	Purbo Sadardi	Bhanga	Faridpur	1.67
Goplal Dhali	M	60	Labu tola	Labu tola	Tungipara	Gopalganj	0.72
Md Habibur Rahman	M	39	Hamirdi	Madhobpur	Bhanga	Faridpur	1.02
Polash Matubbor	M	32	Monsurabad	Monsurabad	Bhanga	Faridpur	1.18
Total quality seed production in farmers field (ton)							11.29

Development project (PGB-IADP) at the time of seed distribution of BRRI dhan62. A total of 570 farmers and SAAOs were trained through these training programmes (Table 13).

Table 13. Number of training conducted and the farmers trained up by BRRI RS, Bhanga in 2013-14.

Fund source	No. of training	Participant farmers
GOB	3	90
EQSS project	15	450
PGB-IADP	1	30
Total participants	19	570

BRRI RS, Comilla

SUMMARY

Thirty crosses were made and 24 crosses were confirmed during T. Aman and Boro at BRRI RS, Comilla. Five hundred and forty, 1449, 293, 171 and 14 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. Seven homozygous lines were bulked under the varietal development programme. Forty-one genotypes were selected from observational trial (OT) for uniformity in desirable characters and high yield potential. Nine genotypes 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 and IIRON respectively during T. Aman and Boro seasons.

During T. Aus, considering the yield performance (4.13-4.48 t/ha) genotypes BR7716-49-1-3, BR7413-14-3-3, BR7566-39-6-1, BR7417-6-1-2 and BR7708-62-1-1 were selected from AYT.

During T. Aman, in PYT (Com) considering the yield performance (3.33-4.28 t/ha) and disease reaction IR80431-B-44-4, BRC273-3-4-4-2, BRC273-6-2-1-1, BR7465-3-2-6-3 and BR7155-20-1-3-HR2 were selected for further evaluation in SYT during next T. Aman season.

For Boro, BR7781-10-2-3-2, BRC266-1-2-1-6, BRC266-5-1-2-1, BRC266-5-1-2-6, BRC266-5-2-2-2 and BRC266-1-2-1-4 were selected from PYT (Com) for giving satisfactory yield (4.5-5.7 t/ha) and growth duration (148-160 days) as compared with all the standard checks for further evaluation and BR7781-10-2-3-2, BR7372-18-3-3 and BRC306-6-2-5-2-1 were selected from SYT for giving higher yield (5.6-5.7 t/ha) than standard checks BRRI dhan28 and BRRI dhan58 (4.8-5.3 t/ha).

For T. Aman, in RYT (PQR) BR7369-52-3-2-1, BR7697-15-4-4-2-2, BR7697-16-2-2-1-1 and BR7697-15-4-4-2-1 were selected for giving 0.5-0.9 t/ha higher yield than all standard checks and showing 2-3 weeks and one week earlier than standard check BRRI dhan37 and BRRI dhan34 respectively. In RYT (RLR), considering the yield potential (4.3 t/ha) BR7468-12-1-1-1-1 and BR7638-7-2-5-2 were selected. In RYT (Collection), Sumon Swarna (5.7 t/ha) was selected for giving the highest yield and WK-1 was selected for yield (4.1 t/ha) and earliness (12 days earlier) as compared with BR11. In RYT (GSR) and RYT (MN) all tested gave lower yield than standard checks. So, none of the genotypes were selected from these two trails.

For Boro, in RYT (Favourable Boro) BR7800-63-1-7-3 was selected for giving higher yield (6.2 t/ha) than BRRI dhan28 (5.1) with 153 days growth duration which was almost similar to BRRI dhan50 (150 days). In RYT (MDR) BR7833-11-1-1-3-4 and BR7881-10-1-5-3-1 were selected for their high yield potential (6.2-6.3 t/ha) as compared with all standard checks. In RYT (PQR), BR7781-10-2-3-2, BR7358-35-2-1-1 and BR7369-10-5-2-3 were selected for their high yield potential (6.0-6.4 t/ha). In RYT (GSR), eexotic lines HZ23-DT16-DT1-DT1 and HHZ17-Y16-Y3-Y2 were selected for their high yield performance (5.6-6.2 t/ha) as compared with standard check BRRI dhan28. In RYT (Disease), BR7986-7-4 and BR7986-2-3 were selected for their high yield performance (7.0-6.7) as compared with standard check BRRI dhan28 and BRRI dhan29 and showed 150 days growth duration which was 11 days earlier than BRRI dhan29. In RYT (Cold), considering the yield potential and earliness BR8245-2-1-4 (7.1 t/ha and 157 days) and BR7812-19-1-6-1-P4 (6.3 t/ha and 149 days) were selected.

In PVT-RLR-T. Aman, proposed genotype BR7611-31-5-3-2 was recommended for releasing as a variety by field evaluation team of NSB for its higher yield and earliness than the check variety BR11. In PVT-GSR-T.Aman proposed genotype HUA565 and check variety BRRI dhan33 were completely damaged due to RTV (Score 7), Sheath blight (score 7) and FSm (Score 3) disease infection and rat attack (Score 9).

In PVT-Boro, proposed genotypes BR7830-16-1-5-3 gave higher yield (8.30 t/ha) than the standard check BRRI dhan28 (8.01 t/ha). On the other hand, proposed genotype weed tolerant rice gave 8.93 t/ha yield which was 0.92 t/ha higher than standard check BRRI dhan28. But these two

genotypes showed 10-12 days longer than BRRI dhan28 (141 days). Considering the high yield potential, weed tolerant rice (8.93) and BR7830-16-1-5-3 (8.30 t/ha) were recommended for releasing as varieties by field evaluation team of NSB.

In T. Aman, 4500 kg of breeder seeds from BRRI dhan49, 650 kg BRRI dhan56 and 560 kg BRRI dhan57 were produced. In Boro, breeder seeds of 8250 kg from BRRI dhan28, 14250 kg BRRI from dhan29, 980 kg from BRRI dhan50 and 975 kg from BRRI dhan58 were produced.

Recorded major diseases were false smut, tungro, sheath blight and blast. Among the diseases false smut was the most prevalent and found in most of the varieties/lines. Incidence and severity of false smut disease was more (30%) in BRRI dhan49 compared to other varieties/ lines. Tungro disease was also found in 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 7, 10, 2, 7 and 5% in BR5, BRRI dhan34, BRRI dhan37, BRRI dhan38 and IR64 respectively with medium severity index ranged from 3-5. The lower incidence and severity of sheath blight disease was observed in BR10, BR11, BRRI dhan30 and BRRI dhan40 and ranged from 5-8% incidence and 3-5 DI.

It was observed that 160 kg/ha N level produced the highest grain yield and 200 kg N produced maximum straw yield. Among the four varieties BRRI dhan60 produced maximum straw yield.

Twenty-seven T. Aman and 28 Boro rice varieties were evaluated at BRRI RS, Comilla farm to identify stability index. Considering yield performance, the top five varieties were BRRI dhan44 (5.07 t/ha), BRRI dhan46 (4.71 t/ha), BRRI dhan41 (4.7 t/ha), BRRI dhan31 (4.58 t/ha) BRRI dhan40 (4.45 t/ha) in T. Aman and BRRI dhan29 (6.96 t/ha), BRRI dhan60 (6.84 t/ha), BRRI dhan58 (6.77 t/ha), BRRI dhan55 (6.77 t/ha) and BRRI dhan59 (6.56 t/ha) in Boro seasons respectively.

In Boro, average yield and growth duration of BRRI dhan58 over the nine locations of greater comilla region were 8 t/ha and 150 days respectively.

Day long sixteen training programmes on rice production technologies were conducted by BRRI RS, Comilla in 11 upazilas of three districts-Comilla (Adarsa sadar, Barura, Chandina, Debidwar, Muradnagar, Laksam and Burichang), Chandpur (Hajiganj and Haimchar) and B. Baria (Nabinagor, Akhaura and B. Baria sadar) during the reporting year. Out of these 16 training programmes six and ten were funded by GOB and Enhancing of Quality Seed Supply (EQSS) project, BRRI HQ, Gazipur respectively. Four hundred and eighty farmers (350 male and 130 female) were trained on these training programmes. Besides, ten field days were conducted in the three districts in the reporting year.

BRRI RS, Comilla also participated in three agricultural fairs of Comilla town hall, Shilpokala Academy and Daudkandi upazila in the reporting year. BRRI RS, comilla was awarded first prize from one agricultural fair at Shilpokala Academy during 11 May-14 May 2014 conducted by DAE.

VARIETAL DEVELOPMENT

Advanced yield trial (T. Aus)
Fourteen genotypes were evaluated in advanced yield trial (AYT) against the standard checks BR26, BRRI dhan28, BRRI dhan48, BRRI dhan57 and BRRI dhan58 to evaluate to find out suitability at Comilla region. Twenty-four-day-old seedlings were transplanted in a 5.4 m × 8 rows plot following RCB design with three replications using single seedling per hill at a spacing of 20- × 15-cm. Fertilizer doses were 60-15-40-10 kg/ha NPKS with all amounts of P, K and S was applied at the time of final land preparation. N was applied in two splits at 10 and 30 days after transplanting. Crop management such as weeding, disease and insect pests control were done in time. In AYT, genotypes BR7716-49-1-3 and BR7413-14-3-3 gave almost similar yield (4.46-4.48 t/ha) as compared with BR26 and BRRR dhan48 and they showed 102-105 days growth duration. On the other hand genotypes BR7566-39-6-1, BR7417-6-1-2 and BR7708-62-1-1 produced 4.13-4.33 t/ha yield which was higher than BRRI dhan28 and

BRRI dhan57 and showed 101-105 days growth duration. So, considering the yield performance genotypes BR7716-49-1-3, BR7413-14-3-3, BR7566-39-6-1, BR7417-6-1-2 and BR7708-62-1-1 were selected (Table 1).

Rainfed lowland rice (RLR) ecosystem (T. Aman) Hybridization. Ten crosses were made using ten parents for development of improved genotypes with high yield potential along with earliness, photoperiod sensitivity, acceptable grain quality and resistance to diseases and insect pests.

F_1 **confirmation.** Fifteen crosses and their respective parents were grown. All crosses were confirmed and registered in BRRI RS, Comilla cross list with station code BRC431 to BRC445.

Growing of F_2 population. F_2 seeds of eight crosses along with their parents were grown for selection of progenies with emphasis on earliness, plant type, grain type, number of effective tiller and high yield potential than the standard varieties. A total of 362 plant progenies were selected from population of eight crosses.

Pedigree nursery (F_3, F_4 and F_6 generations). Five hundred and twenty-six F_3, 276 F_4 and 102 F_6 progenies were grown for selection of desirable progenies from the segregating populations with emphasis on plant type, earliness, grain type and grain coluor, lodging tolerance and better phenotypic acceptance over the standard varieties. A total of 499, 111 and 14 plant progenies were selected from F_3, F_4 and F_6 generation respectively and seven breeding lines were bulked from F_6 generation.

Table 1. List of selected materials grown in advanced yield trial (AYT), T. Aus 2013-14, BRRI RS, Comilla.

Designation	Growth duration (day)	Yield (t/ha)
BR7708-62-1-1	101	4.13
BR7413-14-3-3	105	4.48
BR7417-6-1-2	102	4.33
BR7566-39-6-1	105	4.15
BR7716-49-1-3	102	4.46
BR26 (ck)	98	4.47
BRRI dhan28 (ck)	93	3.22
BRRI dhan48 (ck)	100	4.47
BRRI dhan57 (ck)	122	2.63
BRRI dhan58 (ck)	105	4.16
5% LSD 34DF	2.49	0.42
CV%	1.5	6.7

DS: 4 May 2013, DT: 28 May 2013.

Observational trial. Three observational trial (OT) containing 38 genotypes were grown along with standard checks viz BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan39, BRRI dhan44, BRRI dhan56, BRRI dhan57, BI dhan2 and Binadhan-7 for selection of genetically fixed lines with uniform plant height, heading, plant type, and grain type along with high yield potential. Each genotype was grown in a 5.4 m × 4 rows plot with a spacing of 20- ×15-cm using single seedling per hill for transplanting. Thirty-day-old seedlings were used for transplanting. Fertilizer doses were 100-20-50 kg/ha NPK with all amounts of P and K applied at the time of final land preparation. N was applied in three splits at 15, 30 and 45 days after transplanting. Gypsum and zinc sulphate @ 100 and 10 kg/ha were applied during land preparation. Other cultural operations were done as and when necessary. Eleven genotypes were selected from OT#1, two genotypes were selected from OT#2 considering field duration ranged from 109-135 and good phenotyping acceptability. All tested entries of OT#3 were damaged due to high infection of RTV (Score 9) and false smut (Score 9).

International Rice Observational Nursery (IRLON). Forty-six genetically diverse test entries along with four international checks and two local checks BRRI dhan49 and BRRI dhan46 were grown for selection of genotypes from the diverse genetic background having earliness, good grain type, compact panicle, lodging resistance, disease and insect resistance and high yield potential at rainfed condition. The experiment was conducted as per International Network for Genetic Evaluation of Rice (INGER) nursery management. Nine genotypes were selected based on better phenotypic performance as compared with standard check, Growth duration of all the entries were ranged from 109-137 days.

Preliminary yield trial (PYT). In total, 19 genotypes were evaluated in PYT (Com) at BRRI RS, Comilla against standard checks BRRI dhan49, BRRI dhan56, BRRI dhan57 and Binadhan-7 for initial yield evaluation and selection of desirable lines. Thirty-day-old seedlings per hill of each genotype were transplanted @ single seedling per hill with a

spacing of 20- ×15-cm. The unit plot size was 5- × 1.6-m. The field layout was RCB design with two replications. Recommended fertilizer doses were applied with a usual split application of urea in three times at 15, 30 and 45 days after transplanting. Other cultural operations were done as and when necessary. In PYT (Com), genotypes IR80431-B-44-4 produced the highest yield (4.28 t/ha) than all the test entries and standard checks and showed six days earlier than BRRI dhan49 and no disease infection was observed. On the other hand, genotypes BRC273-3-4-4-2, BRC273-6-2-1-1, BR7465-3-2-6-3 and BR7155-20-1-3-HR2 showed better yield performance compared to standard checks but these genotypes showed susceptibility to false smut disease except genotype BR7155-20-1-3-HR2. So considering the yield performance and disease reaction, genotypes IR80431-B-44-4, BRC273-3-4-4-2, BRC273-6-2-1-1, BR7465-3-2-6-3 and BR7155-20-1-3-HR2 were selected for further evaluation in SYT during next T. Aman season.

Regional yield trial (RYT). Five RYTs from Plant Breeding Division of BRRI HQ consisting of 23 genotypes were evaluated in RYT#1 (PQR), RYT#2 (RLR), RYT#3 (Collection), RYT#4 (GSR) and RYT#5 (MN) at BRRI RS, Comilla against the standard checks BR11, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan39, BRRI dhan49 and Binadhan-7 for evaluation of specific and general adaptability of the genotypes in on-station condition. Twenty-five to 30-day-old seedlings were transplanted using 2-3 seedlings per hill with the spacing of 20- × 15-cm. The unit plot size was 5- × 3-m. The experiment was laid out in RCB design with three replications. Fertilizer doses were 92 (200 kg urea): 15 (74 kg TSP): 50 (100 kg MP): 12 (67 kg gypsum): 3.6 (10 kg $ZnSO_4$) kg NPKSZn/ha. All amounts of P, K, S and Zn were applied at the time of final land preparation. Nitrogen was applied in three equal splits at 10-15 DAT, maximum tillering and before PI stage. Crop management such as weeding, disease and insect pests control were done in time. In RYT (PQR), genotypes BR7369-52-3-2-1, BR7697-15-4-4-2-2, BR7697-16-2-2-1-1 and BR7697-15-4-4-2-1 gave 4.0-4.3 t/ha yield which was 0.5-0.9 t/ha higher than all the standard checks and they showed 127-133 days growth duration which was 2-3 weeks and one week earlier than the standard check BRRI dhan37 and BRRI dhan34 respectively. Considering the yield potential and earliness above mentioned genotypes were selected. In RYT (RLR) genotypes BR7468-12-1-1-1-1 and BR7638-7-2-5-2 gave the highest yield (4.3 t/ha) as compared with all standard checks BRRI dhan33 and BRRI dhan49. But genotype BR7468-12-1-1-1-1 showed six days earlier and genotype BR7638-7-2-5-2 showed seven days longer than BRRI dhan49. So considering the yield potential genotypes BR7468-12-1-1-1-1 and BR7638-7-2-5-2 were selected. In RYT (Collection) genotypes Sumon Swarna gave highest yield (5.7 t/ha). Genotype WK-1 produced 4.1 t/ha yield which was 0.2-0.3 t/ha less yield than all the standard checks but it showed almost similar growth duration as BRRI dhan39 and 12 days earlier than BR11. Therefore, considering the yield and growth duration genotype Sumon Swarna and WK-1 were selected from RYT (Collection). In RYT (GSR) and RYT (MN) all tested genotypes gave lower yield than standard checks. So, none of genotypes were selected from these two trails.

Proposed variety trial (PVT). Two PVTs consisting of two genotypes were evaluated at Comilla in PVT (RLR) and PVT (GSR) against the standard checks BR11 and BRRI dhan33 for evaluation of promising genotypes by field evaluation committee of NSB team for releasing as a new variety. Twenty-seven-day-old seedlings were transplanted @ 2-3 seedlings per hill with a spacing of 20- × 15-cm. The unit plot size was 6- × 5-m with three replications. Fertilizer doses were 92 (200 kg urea): 15 (75 kg TSP): 50 (100 kg MP): 12 (67 kg gypsum): 3.6 (10 Kg $ZnSO_4$) kg NPKSZn/ha with all amount of P, K, S and Zn were applied at the time of final land preparation. Nitrogen was applied in three equal splits at 15, 30 and 45 days after transplanting (DAT). Crop management such as weeding, disease and insect pests control were done in time. Third top dress of urea was adjusted based on crop performance. In PVT-RLR-T. Aman, proposed genotype BR7611-31-5-3-2 was recommended for releasing as a variety by field evaluation team of NSB for its

higher yield and earliness than the check variety BR11. In PVT-GSR-T. Aman proposed genotype HUA565 and check variety BRRI dhan33 were completely damaged due to RTV (Score 7), sheath blight (score 7) and FSm (Score 3) disease infection and rat attack (Score 9).

Irrigated rice ecosystem (Boro)

Hybridization. Thirteen crosses were made using 23 parents for development of improved rice varieties with high yield potential along with earliness, resistance to diseases and insect pests and suitable for Comilla region.

F_1 **confirmation.** Eighteen crosses and their respective parents were grown. Out of 18 crosses, nine crosses were confirmed and registered in BRRI RS, Comilla cross list with station code BRC447 to BRC455.

Growing of F_2 population. F_2 seeds of nine crosses along with their parents were grown for selection of progenies with desirable plant type and high yield potential. A total of 178 plant progenies were selected from population of nine crosses.

Pedigree nursery (F_3, F_4 and F_5 generations). A total of 703 progenies (466 F_3, 128 F_4 and 109 F_5) were grown for selection of desirable segregates with emphasis on earliness, strong culm, high yield potential and disease and insect resistance at field condition. A total of 950, 182 and 171 plant progenies were selected from F_3, F_4 and F_5 generations respectively.

Observational trial (OT). Four observational trials containing 39 genotypes were grown along with the standard checks viz BR3, BRRI dhan28, BRRI dhan29, BRRI dhan45, BRRI dhan47 and BRRI dhan58 for selecting genetically fixed lines with uniform plant height, heading, plant type, and grain type along with high yield potential. Each genotype was grown in a 5.4 m × 4 rows plot with a spacing of 25- × 15-cm using single seedling for transplanting. Forty-day-old seedlings were used for transplanting. Recommended fertilizer doses were applied with a usual split application of urea in three times at 15, 30 and 45 days after transplanting. Other cultural operations were done as and when necessary. Six, twelve, six and four genotypes were selected from OT#1, OT#2, OT#3

and OT#4 respectively considering growth duration similar to BRRI dhan28 and BRRI dhan29 having good phenotypic acceptability.

International Irrigated Rice Observational Nursery. Thirty-two genetically diverse test entries along with three international checks and one local check BRRI dhan28 were grown for selecting genotypes from the diverse genetic background having earliness, good grain type, compact panicle, lodging resistance, disease and insect resistance and high yield potential. The experiment was conducted as per INGER nursery management. Seventeen were selected based on better phenotypic performance as compared with standard check.

Preliminary yield trial (PYT). In total, 12 genotypes from OT# Comilla were evaluated in PYT#1 at BRRI RS, Comilla against standard checks BR16, BRRI dhan28, BRRI dhan29 and BRRI dhan58 for initial yield evaluation and selection of desirable lines compared to standard checks. Forty-day-old seedlings of each genotype were transplanted @ single seedling with a spacing of 25- × 15-cm. The unit plot size was 5.4 m × 8 rows. The field layout was RCB design with two replications. Recommended fertilizer doses were applied with a usual split application of urea in three times at 15, 30 and 45 days after transplanting. Other cultural operations were done as and when necessary. In PYT BR7781-10-2-3-2, BRC266-1-2-1-6, BRC266-5-1-2-1, BRC266-5-1-2-6, BRC266-5-2-2-2 and BRC266-1-2-1-4 gave satisfactory yield (4.5-5.7 t/ha) as compared with all the standard checks (6.7-3.8 t/ha) and they showed 148-160 days growth duration. So, considering the yield performance these above genotypes could be evaluated in SYT during next Boro 2014-15 seasons.

Secondary yield trial (SYT). Five genotypes from PYT# Comilla were evaluated in SYT at BRRI RS, Comilla against standard checks viz BRRI dhan28, BRRI dhan29, BRRI dhan50 and BRRI dhan58 for confirmation of yield evaluation in a replicated trial and selection of desirable lines compared to standard checks. Forty-day-old seedlings of each genotype were transplanted @ single seedling per hill with a spacing of 25- × 15-cm. The unit plot size was 5.4 m × 8 rows. The

field layout was RCB design with two replications. Recommended fertilizer doses were applied with a usual split application of urea in three times at 15, 30 and 45 day after transplanting. Other cultural operations were done as and when necessary. In SYT genotypes BR7781-10-2-3-2, BR7372-18-3-3 and BRC306-6-2-5-2-1 gave higher yield (5.6-5.7 t/ha) than standard checks BRRI dhan28 and BRRI dhan58 and showed 153-159 days growth duration which was almost similar to growth duration (156-158 days) of BRRI dhan50 and BRRI dhan58. So, considering yield potential genotypes BR7781-10-2-3-2, BR7372-18-3-3 and BRC306-6-2-5-2-1 were selected (Table 2).

Regional yield trial (RYT). Six RYTs from Plant Breeding Division of BRRI HQ consisting of 33 genotypes were evaluated in RYT#1 (FB), RYT#2 (MDR), RYT#3 (PQR), RYT#4 (GSR), RYT#5 (Disease) and RYT#6 (Cold) at BRRI RS, Comilla against the standard checks BRRI dhan28, BRRI dhan29, BRRI dhan50, BRRI dhan55 and BRRI dhan60 for evaluation of specific and general adaptability of the genotypes in on-station condition. Forty-day-old seedlings of each genotype were transplanted @ 2-3 seedlings with a spacing of 25- × 15-cm. The unit plot size was 5.4 m × 12 rows. The field layout was RCB with three replications. Fertilizers @ 120-20-60-20-36 kg NPKSZn/ ha with all amount of P and K were applied at the time of final land preparation. Nitrogen was applied in three equal splits at 10-15 DAT, maximum tillering and before PI stage.

Table 2. Yield and agronomic performance of breeding materials of secondary yield trial (SYT), Boro 2013-14, BRRI RS, Comilla.

Designation	Plant ht (cm)	Growth duration (day)	Panicle/ m^2	Yield (t/ha)
BRC306-6-2-5-2-1	101	158	208	5.8
BR7372-18-3-3	96	153	268	5.7
BR7358-35-3-3	97	157	256	4.9
BR7369-52-3-2-1-1	90	156	284	3.5
BR7781-10-2-3-2	104	159	400	5.6
BRRI dhan28 (ck)	91	149	388	4.8
BRRI dhan29 (ck)	92	167	336	7.3
BRRI dhan50 (ck)	83	158	384	5.9
BRRI dhan58 (ck)	94	156	300	5.3
5% LSD 8DF	7.51	1.90	66.99	1.86
CV%	3.5	0.5	9.2	15.0

DS: 26 Nov 2013, DT: 20 Jau 2014.

gypsum and zinc sulphate @ 20 and 4 kg/ha were applied during land preparation. Crop management such as weeding, controlling disease and insect pests was done in time. In RYT (FB) genotype BR7800-63-1-7-3 gave higher yield (6.2 t/ha) than BRRI dhan28 (5.1) and showed 153 days growth duration, which was almost similar to BRRI dhan50 (150 days). So, considering yield potential, genotype BR7800-63-1-7-3 was selected from RYT (FB). In RYT (MDR) genotypes BR7833-11-1-1-3-4 and BR7881-10-1-5-3-1 were selected for their high yield potential (6.2-6.3 t/ha) as compared with all standard checks. In RYT (PAR) genotype BR7781-10-2-3-2 produced the highest yield (6.4 t/ha) as compared to all genotypes including checks. On the other hand, genotypes BR7358-35-2-1-1 and BR7369-10-5-2-3 produced the higher yield (6.0-6.2 t/ha) than BRRI dhan28. So, genotypes BR7781-10-2-3-2, BR7358-35-2-1-1 and BR7369-10-5-2-3 were selected for high yield potential. In RYT (GSR) genotype HHZ23-DT16-DT1-DT1 and HHZ17-Y16-Y3-Y2 produced the highest yield (6.2-5.6 t/ha) and showed 11-12 days longer as compared with standard check BRRI dhan28. Therefore genotype HHZ23-DT16-DT1-DT1 and HHZ17-Y16-Y3-Y2 were selected for their high yield performance. In RYT (Disease) genotypes BR7986-7-4 and BR7986-2-3 were selected for high yield performance (7.0-6.7) as compared to standard check BRRI dhan28 and BRRI dhan29 with 150 days growth duration, which was 11 days ealier than BRRI dhan29. In RYT (Cold) genotypes BR8245-2-1-4 produced the highest yield (7.1 t/ha) as compared to all genotypes including standard checks having growth duration one week earlier than BRRI dhan29. On the other hand, genotype BR7812-19-1-6-1-P4 gave almost similar yield (6.3 t/ha) as compared with all the checks (6.4-6.5 t/ha) with growth duration two weeks earlier than BRRI dhan29. So, considering the yield potential and earliness genotypes BR7812-19-1-6-1-P4 and BR8245-2-1-4 were selected from RYT (Cold). Table 3 shows some high yielding potential lines.

Proposed variety trial (PVT). One PVT consisting of two genotypes were evaluated in PVT (PQR) and PVT (High zinc) at Comilla

Table 3. Yield and agronomic performance of some high yielding breeding materials selected from of regional yield trial (disease and cold), Boro 2013-14, BRRI RS, Comilla.

Designation	Plant ht (cm)	Growth duration (day)	Panicle/ m²	Sterility (%)	TGW (gm)	Yield (t/ha)	Remark*
Regional yield trial (RYT-Disease), Boro 2013-14, BRRI RS, Comilla[1]							
BR7986-2-3	109	150	312	10.35	26.39	6.7	Ldg-90%, BLB-20% ShR-2%, BS-12%
BR7986-7-4	94	150	341	9.96	23.76	7.0	Ldg-98%, BLB-25%, BS-10%
BRRI dhan28 (ck)	96	144	395	9.89	22.15	5.4	Ldg-95%, BLB-45%, BS-5%
BRRI dhan29 (ck)	99	161	351	13.43	21.91	6.3	
5% LSD 12DF	3.58	1.25	68.53	0.50	0.86	0.64	
CV%	2.0	0.5	10.7	2.0	1.9	5.9	
Regional yield trial (RYT-Cold), Boro 2013-14, BRRI RS, Comilla[2]							
BR8245-2-1-4	100	157	376	17.70	20.3	7.1	Ldg-10%, FSm-15%,
BRRI dhan28 (ck)	94	144	364	17.90	21.3	6.1	Ldg-40%, FSm-2%
BRRI dhan29 (ck)	96	164	376	18.30	21.4	6.5	
BRRI dhan55 (ck)	97	150	305	17.30	28.8	6.4	FSm-5%
5% LSD 14DF	3.59	1.11	61.89	0.67	0.33	0.43	
CV%	2.2	0.4	9.6	2.4	0.8	4.0	

[1]DS: 1 Dec 2013, DT: 1 Feb 2014. [2]DS: 1 Dec 2013, DT: 25 Jan 2014. *Ldg=lodging, BB=bacterial leaf blight, ShR=sheath rot, BS=brown spot, FSm=false smut.

against the standard check BRRI dhan28 for evaluation of promising genotypes by field evaluation committee of NSB team for releasing as a new variety. Forty-four-day-old seedlings were transplanted @ 2/3 seedlings per hill with a spacing of 20- × 20-cm. The field layout was RCB design with three replications. The unit plot size was 5- × 5-m. Fertilizers @ 120 (261 kg urea): 20 (100 kg TSP): 60 (120 kg MP): 20 (111 kg gypsum): 4 (11 kg ZnSO$_4$) kg/ha NPKSZn were applied. All amount of P, K, S and Zn were applied at the time of final land preparation and nitrogen was applied in three equal splits at 15 DAT, maximum tillering and before PI stage. Crop management such as weeding, disease and insect pests control was done in time. NSB team visited and evaluated the experimental plot in several growth stages. In PVT-Boro, proposed genotypes BR7830-16-1-5-3 produced higher yield (8.30 t/ha) than the standard check BRRI dhan28 (8.01 t/ha). On the other hand, proposed genotype Weed Tolerant Rice gave 8.93 t/ha yield which was 0.92 t/ha higher than standard check BRRI dhan28. But these two genotypes showed 10-12 days longer than BRRI dhan28 (141 days). So, considering the high yield potential genotypes BR7830-16-1-5-3 and Weed Tolerant Rice were recommended for releasing as varieties by field evaluation team of NSB. The NSB has sent the result to SCA (HQ) for further processing.

Breeder seed production
For BRRI dhan49, BRRI dhan56 and BRRI dhan57 were grown in 4 ha land for breeder seed production following the standard management practices. In total, 4,500 kg BRRI dhan49, 650 kg BRRI dhan56 and 560 kg BRRI dhan57 breeder seeds were produced. For Boro, BRRI dhan28, BRRI dhan29, BRRI dhan50 and BRRI dhan58 were grown in 5 ha land for breeder seed production following the standard management practices. In total, 8,250 kg BRRI dhan28, 14,250 kg BRRI dhan29, 980 kg BRRI dhan50 and 975 kg BRRI dhan58 breeder seeds were produced and were sent to GRS Division, BRRI HQ, Gazipur.

PEST MANAGEMENT

Survey on the occurrence of diseases in the BRRI RS, Comilla farm during Aman 2013
During Aman season, a survey was conducted to Know the status of rice disease in BRRI RS, Comilla farm for recording the incidence and severity of diseases. All seed production and experimental plots were observed for recording the disease data on variety wise. From each plot, 20 hills were selected randomly for recording the disease incidence and severity on data sheet. Recorded major diseases were false smut, tungro, sheath blight and blast. Among the diseases false

smut was the most prevalent and found in most of the varieties/lines. Incidence and severity of false smut disease was more (30%) in BRRI dhan49 compared to other varieties/ lines. Tungro disease was also found in BRR Idhan56, BRR Idhan57 and BRRI dhan62 with high severity index (DI) ranged from 7-9 as per SES. Incidence of neck blast disease was 7, 10, 2, 7 and 5% in BR5, BRRI dhan34, BRRI dhan37, BRRI dhan38 and IR64 respectively with medium severity index ranged from 3-5. The lower incidence and severity of sheath blight disease was observed in BR10, BR11, BRRI dhan30 and BRRI dhan40. It was ranged from 5-8% incidence and 3-5 DI.

CROP-SOIL-WATER MANAGEMENT

Effect of N rates on the yield of some newly released BRRI varieties in Boro season

The experiment was conducted to determine the N response behaviour of newly released varieties compared to the BRRI modern rice varieties in Boro season at the BRRI RS, Comilla (AEZ-17, land type-MHL). The newly released varieties BRRI dhan59, BRRI dhan60, BRRI dhan61 were tested with BRRI dhan58 (ck) under six N doses (0, 40, 80, 120, 160 and 200 kg N/ha). The experiment was laid out in a split-plot design with three replications. Nitrogen doses were accommodated in the main-plots and the varieties in the sub-plots. Nitrogen was applied in three splits ie 34% at basal, 33% at 25 DAT and the rest 33% at seven days before PI stage. A blanked dose of P, K, S and Zn were applied as soil test based (STB) at the time of final land preparation. Varieties and N level had no significant interaction effect. N level showed significant effect on both grain yield and straw yield (Table 4). The highest grain yield (5.63t/ha) was found at N_{160} level but it was statistically similar with N_{120} (5.36t/ha). N_{200} produced highest straw yield (4.17t/ha) followed by N_{120} and N_{160} and they were statistically similar. Varieties also had significant effect on both grain yield and straw yield. There was no statistical difference among the varieties for grain yield (Table 4). BRRI dhan60 produced maximum straw yield (Table 5).

Table 4. Effects of N rates on grain yield (t/ha) straw yield (t/ha) of some newly released BRRI, Boro varieties at BRRI RS, farm Comilla, 2013-14.

N rate (kg/ha)	Grain yield (t/ha)	Straw yield (t/ha)
N_0	2.65	2.63
N_{40}	3.73	1.8
N_{120}	4.16	2.38
N_{120}	5.36	3.83
N_{160}	5.63	3.71
N_{200}	5.00	4.17
$LSD_{0.05}$	0.3332	0.7776
% CV	9.10	12.42

Table 5. Effect of varieties on grain yield (t/ha) and on straw yield (t/ha) at BRRI RS, farm Comilla, 2013-14.

N rate (kg/ha)	Grain yield (t/ha)	Straw yield (t/ha)
BRRI dhan58	4.64	3.17
BRRI dhan59	4.43	2.50
BRRI dhan60	4.24	4.11
BRRI dhan61	4.38	2.58
$LSD_{0.05}$	0.3332	0.7776
% CV	9.10	12.42

It was observed that 160 kg/ha N level produced the highest grain yield and 200 kg N produced maximum straw yield. Among the varieties BRRI dhan60 produced maximum straw yield.

SOCIO-ECONOMICS AND POLICY

Stability analysis of BRRI developed Aman varieties

Twenty-seven varieties were evaluated to determine the stability index at BRRI RS, Comilla farm. The experiment was laid out in RCB design with three replications. Thirty-day-old seedlings were transplanted with 20- × 20-cm spacing. Each plot size was 6.4- × 2-m. Recommended fertilizer doses were applied with a usual split application of urea three times at 15, 30 and 45 days after transplanting. Among the 27 varieties, five top yielding varieties were BRRI dhan44 (5.07 t/ha), BRRI dhan46 (4.71 t/ha), BRRI dhan41 (4.7 t/ha), BRRI dhan31 (4.58 t/ha) BRRI dhan40 (4.45 t/ha) and the yield was statistically similar at the 5% level of significance. Growth duration of these varieties ranged from 141-151 days. BR3, BR5, BRRI dhan30, BRRI dhan33 and BRRI dhan39 were the low yielding varieties and gave yield

ranged from 1.34-2.42 t/ha. Rest of the varieties gave yield ranged from 2.81- 4.31 t/ha.

Stability analysis of BRRI developed Boro varieties

Twenty-eight varieties were evaluated to determine the stability index at BRRI RS, Comilla farm. The experiment was laid out in RCB design with three replications. Forty-day-old seedlings were transplanted with spacing of 20- × 20-cm. Each plot size was 6.6- × 2-m. Recommended fertilizer doses were applied with a usual split application of urea in three times at 15, 30 and 45 days after transplanting. Considering the yield performance the top five varieties were BRRI dhan29, BRRI dhan60, BRRI dhan58, BRRI dhan55 and BRRI dhan59. These varieties gave yield ranged from 6.56-6.96 t/ha and were statistically similar at the 5% level of significance. Growth duration of these varieties ranged from 144-157 days. BR7 produced the lowest grain yield (3.95 t/ha). Rest of the varieties gave yield ranged from 4.2-5.97 t/ha and showed growth duration ranged from 139-162 days.

BRRI RS, Habiganj

SUMMARY

In T. Aus season, the yield of BR7708-62-1-1 (4.6 t ha^{-1}) was higher than BRRI dhan48 (4.4 t ha^{-1}) with similar growth duration in RYT. Among the somaclonal lines BRRI dhan29-SC3-28-16-10-6-HR3 yielded better with similar growth duration than BRRI dhan48 in RYT. In B. Aman season four tested entries yielded higher than local check HbjAIV (2.75 t ha^{-1}) in OT. In RYT, among the tested entries, BR224-2B-2-5 (2.94 t ha^{-1}), BR5915-B-7 (2.78 t ha^{-1}), and Lal-khama (2.80 t ha^{-1}) yielded higher than HbjAIV (2.75 t ha^{-1}). In a AYT trial, the tested entries BR9892-6-2-2B (155 cm tall and 4.00 t ha^{-1}) and BR9392-6-1-B (137 cm tall and 4.52 t ha^{-1}) showed the highest plant height and better grain yield than the local check Habiganj Aman-1 (154 cm tall and 2.6 t ha^{-1}). These tall improved DWR entries could survive in shallow flooded condition.

In Boro season, BRRI dhan29/BR17 (6.2 t ha^{-1}) and BRRI dhan29/BR18 (6.2 t ha^{-1}) yielded higher than BRRI dhan28 (5.6 t ha^{-1}) with longer growth duration under OT#1. In AYT, all the tested entries yielded higher than BR19 (6.3 t ha^{-1}). In RYT#1, BR7988-10-4-1 (7.4 t ha^{-1}) and BR7800-63-1-7-3 (7.0 t ha^{-1}) yielded higher than BRRI dhan28 (5.4 t ha^{-1}) and BRRI dhan55 (5.5 t ha^{-1}) with similar growth duration. In RYT# 6 BR7813-1-1-3-1 (7.1 t ha^{-1}) and IR2266-42-6-2 (6.9 t ha^{-1}) yielded higher than BRRI dhan29 (6.8 t ha^{-1}) and BRRI dhan55 (6.6 t ha^{-1}) with similar growth duration.

Missing element balanced fertilization with complete treatment gave more than 8 t ha^{-1} grain yield at Habiganj farm. Omission of P and S has no effect on decreasing grain yield over the complete treatment. But omission of N drastically decreased grain yield. Now-a-days K also becomes a great concern for decreasing grain yield in this single cropped area.

The recommended patterns (BRRI dhan46-BRRI dhan29-Fallow) gave 15% higher grain yield and gross margin over existing farmers' patterns. The recommended cropping pattern produced 11.72 t ha^{-1} yield and gross margin of Tk 222,680/ha. It was because of higher yield advantage between recommended and farmers' practice in both T. Aman and Boro seasons of newly released variety BRRI dhan46 which allows accommodating BRRI dhan29 in the pattern instead of BRRI dhan28. In Boro season, normal transplanting gave significantly higher grain yield than the double transplanting and delay planting. Significantly the highest grain yield was obtained from normal planting (T$_1$=8.90 t ha^{-1} and T$_2$=8.80 t ha^{-1}) and the lowest grain yield was observed from delayed transplanting of 75-day-old seedlings (7.59 t ha^{-1}). DT gave significantly higher grain yield (8.32 t ha^{-1}) than the delay planting. Crop duration of delay planting was comparatively higher than the normal and DT.

Total TLS seed production of different popular rice varieties was 35,021 kg during 2013-14. A total of 11,250 kg breeder seed of three popular rice varieties were produced and sent to BRRI breeder seed unit. Seven training programmes and 46 field demonstrations (Boro and Aus) were done in the reporting year.

VARIETAL DEVELOPMENT

Transplant Aus (T. Aus)
Regional yield trial-1 (RYT-1). Seven advanced breeding lines along with BR26 and BRRI dhan48 as check were evaluated. BR7708-62-1-1 (4.6 t ha^{-1}) yielded higher than BRRI dhan48 (4.4 t ha^{-1}) with similar growth duration (Table 1).

Regional yield trial-2 (RYT-2). Seven advanced breeding lines along with BRRI dhan48 as check were evaluated. BRRI dhan29-SC3-28-16-10-6-HR3 yielded better among the somaclone lines with similar growth duration to BRRI dhan48 (Table 2).

Deep water rice (B. Aman)
Observational trial (OT). Seventeen homozygous genotypes were grown in BRRI RS, Habiganj during DWR 2014. Out of 17, BR7730-2B (2.87 t ha^{-1}), BR7731-2B (2.97 t ha^{-1}), BR7735-2B (2.78 t ha^{-1}) yielded higher than local check HbjAIV (2.75 tha^{-1}) (Table 3).

Regional yield trial (RYT). Five advanced genotypes with check HbjAIV and Birpala were evaluated. Among the tested entries BR224-2B-2-

Table 1. Yield and ancillary characters of the advanced breeding lines, RYT, T. Aus 2014.

Designation	Plant ht (cm)	Tiller no. hill[-1]	Panicle no. hill[-1]	Maturity (day)	Yield (t ha^{-1})
BR8113-21-3-1	95	13	11	117	4.4
BR7922-45-2-2-1	104	15	13	110	4.2
IR71866-3R-3-1	102	11	10	106	3.8
BR7708-62-1-1	102	10	9	107	4.6
BR7718-56-3-1	95	14	12	108	3.5
BR7716-49-1-3	102	11	10	109	3.2
BR7718-55-1-3	104	11	10	110	3.3
BR26 (ck)	97	13	11	110	4.0
BRRI dhan48 (ck)	95	13	12	106	4.4
LSD (5%)	3.16	1.15	0.98	1.58	0.16
CV%	1.8	5.4	5.2	0.8	2.4

DS: 18 Apr 2014, DT: 13 May 2014.

Table 2. Yield and ancillary characters of the advanced breeding lines, RYT, T. Aus 2014.

Designation	Plant ht (cm)	Tiller no. hill[-1]	Panicle no. hill[-1]	Maturity (day)	Yield (t ha^{-1})
BRRI dhan29-SC3-28-16-10-8-HR1	104	14	12	110	3.1
BRRI dhan29-SC3-28-16-10-6-HR3	110	9	8	109	3.6
BRRI dhan29-SC3-28-16-10-4-HR5	111	9	8	106	3.2
BRRI dhan29-SC3-28-16-10-6-HR6	110	9	8	107	3.0
Parija	86	14	13	104	2.5
Wk1	106	11	10	111	4.0
Nerica-10	84	11	9	115	2.6
BRRI dhan48 (ck)	101	11	10	109	4.6
LSD (5%)	1.84	0.96	1.87	1.46	0.31
CV(%)	1.0	5.1	1.1	0.8	5.4

DS: 6 May 2014, DT: 27 May 2014.

Table 3. List of the bulked homozygous materials from OT, DWR 2014.

Designation	Yield (t ha^{-1})	Designation	Yield (t ha^{-1})
BR7730-2B	2.87	BR7739-2B	2.24
BR7731-2B	2.97	BR7740-2B	2.10
BR7732-2B	2.13	BR7741-2B	2.43
BR7733-2B	2.65	BR7742-2B	2.11
BR7734-2B	2.34	BR7743-2B	2.17
BR7735-2B	2.78	BR7744-2B	2.13
BR7736-2B	2.58	BR7745-2B	2.01
BR7737-2B	2.71	BR7746-2B	2.10
BR7738-2B	2.48	HbjAIV (local ck)	2.75

DS: 4 Jun 2014.

Table 4. List of the DWR lines with yield (t ha^{-1}) from RYT (Repeated), DWR 2014.

Designation	Yield (t ha^{-1})
BR224-2B-2-5	2.94
BR5915-B-7	2.78
Bazail-65	2.65
Gabura	2.59
Lal-khama	2.80
HbjAIV (local ck)	2.75
Birpala (local ck)	2.40

DS: 4 Jun 2014.

5 (2.94 t ha^{-1}), BR5915-B-7 (2.78 t ha^{-1}), Lal-khama (2.80 t ha^{-1}) yielded higher than HbjAIV (2.75 t ha^{-1}) (Table 4).

Advanced yield trial (AYT). As stem elongation is negatively correlated with higher yield- it is difficult to develop high yielding deep water rice (DWR) varieties. Effort have been taken to select intermediate tall (>140 cm) but lodging resistant DWR varieties for shallow flooded conditions during Aman 2013-14. The tested entries BR9892-6-2-2B (155 cm tall and 4.00 t ha^{-1}) and BR9392-6-1-B (137 cm tall and 4.52 t ha^{-1}) showed the highest plant height and better grain yield than the local check Habiganj Aman-1 (154 cm tall and 2.6 t ha^{-1}). These tall improved DWR entries could survive in shallow flooded condition (Table 5).

IRRIGATED RICE (BORO)

Observational trial-1 (OT-1). Seven advanced breeding lines along with BRRI dhan29 as check were evaluated. None of the tested entries yielded higher than BRRI dhan29 (7.4 t ha^{-1}) (Table 6).

Table 5. Performance of tall deep water Aman lines in 2014.

Designation	Plant ht (cm)	Tiller no. m^2	Panicle length (cm)	Flag leaf lenth (cm)	Maturity (day)	Yield (t ha^{-1})
BR9392-6-2-B	134	280	30	31	115	4.25
BR10238-5-1B	133	289	27	33	130	4.50
BR9892-6-2-2B	155	276	24	32	141	4.00
BR9392-6-1-B	137	302	34	45	143	4.52
BR10230-7-19-B	130	310	33	36	145	4.60
Habiganj Aman-1	154	240	20	23	142	2.60

Table 6. List of the homozygous lines with yield (t ha^{-1}) from OT#2, Boro 2014.

Designation	Plant ht (cm)	Tiller no. hill^{-1}	Panicle no. hill^{-1}	Maturity (day)	Yield (t ha^{-1})
BR8621	103	17	15	163	6.1
BR8622	109	15	14	163	5.5
BR8623	116	16	15	162	5.8
BR8624	108	18	16	161	6.1
BR8625	107	17	16	162	6.0
BR8626	113	18	14	163	5.8
BR8627	95	16	14	162	5.3
BRRI dhan29	95	19	18	166	7.4

DS: 12 Nov 2013, DT: 24 Dec 2013.

Advanced yield trial (AYT). Six advanced breeding lines along with BRRI dhan28 as check was evaluated. Three tested entries, PK8601-10-3 (6.2 t ha^{-1}), PR33993-B-15-2-1-4-5-3-2-2 (6.0 t ha^{-1}), and PR26703-3B-PJ25 (6.1 t ha^{-1}) yielded higher with longer growth duration than BRRI dhan28 (5.8 t ha^{-1}) (Table 7).

RYT#1 (Favourable Boro). Two advanced breeding lines along with BRRI dhan28 and BRRI dhan55 as checks were evaluated. BR7988-10-4-1 (7.4 t ha^{-1}) and BR7800-63-1-7-3 (7.0 t ha^{-1}) yielded higher than BRRI dhan28 (5.4 t ha^{-1}) and BRRI dhan55 (5.6 t ha^{-1}) with similar growth duration (Table 8).

RYT#6 (Cold Boro). Among the five advanced breeding lines- BR7813-1-1-3-1 (7.1 t ha^{-1}) and IR2266-42-6-2 (6.9 t ha^{-1}) yielded higher than BRRI dhan29 (6.8 t ha^{-1}) and BRRI dhan55 (6.6 t ha^{-1}) with similar growth duration (Table 9).

CROP-SOIL-WATER MANAGEMENT

Long-term missing element trial. The experiment was initiated to identify the limiting nutrient, if there is any, in the soils of BRRI RS, Habiganj farm. There was a complete treatment consisting of the application of soil test based (STB) N, P, K and S fertilizer and other treatments 'missing' the nutrient elements such as -N, -P, -K, -S. In Boro season NPKS @ 85-38-50-9 kg ha^{-1} were used. Balanced fertilization with complete treatment significantly increased the grain yield of rice (Tables 10 and 11). The highest rice yield of 8.40 tha^{-1} was obtained with T_1 treatment where complete fertilizer was used followed by T_3 (P omission) and T_5 (K omission). From this result, it was observed that N is the most limiting nutrient followed by K in the BRRI RS, Habiganj farm soil.

Table 7. Yield and ancillary characters of the advanced breeding lines, AYT, Boro 2014.

Designation	Plant ht (cm)	Tiller no. hill^{-1}	Panicle no. hill^{-1}	Maturity (day)	Yield (t ha^{-1})
PK8601-10-3	83	20	18	157	6.2
PR33993-B-15-2-1-4-5-3-2-2	87	18	16	158	6.0
PR26703-3B-PJ25	89	20	18	155	6.1
NSIC RC134	87	17	16	152	5.8
OM4668	90	18	16	153	5.8
PR26703-3B-PJ23	96	17	15	153	5.7
BRRI dhan28 (ck)	92	18	16	155	5.7
LSD (5%)	2.89	1.19	1.21	1.24	0.21
CV (%)	1.8	3.7	4.3	0.5	2.0

DS: 22 Nov 2013, DT: 29 Dec 2013.

Table 8. Yield and ancillary characters of the advanced breeding lines, RYT#1, Boro 2014.

Designation	Plant ht (cm)	Tiller no. hill[-1]	Panicle no. hill[-1]	Maturity (day)	Yield (t ha^{-1})
BR7988-10-4-1	84	20	18	151	7.4
BR7800-63-1-7-3	98	13	12	152	7.0
BRRI dhan28 (ck)	97	17	16	151	5.4
BRRI dhan55 (ck)	88	17	15	153	5.6
LSD (5%)	3.31	0.24	0.01	1.15	0.4
CV (%)	1.8	0.01	0.01	0.4	3.1

DS: 29 Nov 2013, DT: 8 Jan 2014.

Table 9. Yield and ancillary characters of the advanced breeding lines, RYT#6, Boro 2014.

Designation	Plant ht (cm)	Tiller no. hill[-1]	Panicle no. hill[-1]	Maturity (day)	Yield (t ha^{-1})
IR77496-31-2-1-3-1	78	20	16	148	6.3
IR2266-42-6-2	92	16	15	150	6.9
BR-7812-19-1-6-1-P4	95	18	16	149	6.6
BR7813-1-1-3-1	102	20	18	147	7.1
BR8245-2-1-4	99	20	17	158	6.5
BRRI dhan28 (ck)	100	17	15	140	5.4
BRRI dhan29 (ck)	103	17	15	155	6.8
BRRI dhan55 (ck)	93	18	16	150	6.6
LSD (5%)	2.57	0.61	0.01	2.84	0.25
CV(%)	1.5	0.01	0.01	1.1	2.2

DS: 1 Dec 2013, DT: 13 Jan 2014.

Table 10. Treatment details of the long-term missing element experiment, Boro 2014.

Treatment	Nutrient element (kg ha^{-1})
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)
T_8	All missing (-NPKS)

Table 11. Effects of nutrient element omission from the complete treatment on grain yield of BRRI dhan29, Boro 2013-14.

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	8.40	7.55
T_2	4.66	4.45
T_3	8.36	7.33
T_4	7.76	6.73
T_5	8.17	7.25
T_6	4.36	3.77
T_7	4.57	3.95
T_8	4.29	3.18
$LSD_{0.05}$	0.715	0.467
CV (%)	6.5	4.8

RICE FARMING SYSTEMS

Multilocation testing of BRRI dhan46-BRRI dhan29-Fallow cropping pattern. BRRI dhana46 could be transplanted safely up to 25 September with at least 1 t ha^{-1} yield advantage over local varieties/old ones. In Boro season, the performance of BRRI dhan29 in the said pattern is very promising. Therefore, multilocation testing of BRRI dhan46-BRRI dhan29-Fallow cropping pattern was undertaken to increase the system productivity. The recommended patterns gave 15% higher grain yield and gross margin over existing farmers' patterns. The recommended cropping pattern gave of 11.72 t ha^{-1} grain yield and gross margin of Tk 222,680 ha^{-1} (Table 12). It was because of higher yield advantage between recommended and farmers' practice in both the T. Aman and Boro seasons of BRRI dhan46 which allows accommodate BRRI dhan29 in the pattern instead of BRRI dhan28.

Evaluation of double transplanting method at low lying area. Transplanting of T. Aman rice delays very often due to late recession of flood water or delayed harvesting of previous crop or for some other reasons while Boro establishment is delayed mainly for delayed harvesting of previous crop. Due to delayed transplanting, rice yield declined which ultimately reduces the system productivity. Therefore, the present study was undertaken with the objectives to evaluate the performance of double transplanted rice at low lying area. In

Table 12. Grain yield of T. Aman-Boro-Fallow cropping pattern in Habiganj 2013-14.

Management	Cropping pattern	Grain yield of T. Aman (t ha^{-1})	Grain yield of Boro (t/ha)	Total grain yield (t ha^{-1})	Yield increased than FP
Recommended practice	BRRI dhan46-BRRI dhan29-Fallow	4.80	6.92	11.72	15.12
Farmers' practice	BR22-BRRI dhan28-Fallow	4.30	5.88	10.18	

Boro season, normal transplanting gave significantly higher grain yield than the DT and delay planting (Table 13). Significantly the highest grain yield was obtained from normal planting (T$_1$=8.90 t ha^{-1} and T$_2$=8.80 t ha^{-1}) and the lowest grain yield was observed from delayed transplanting of 75 days old seedlings (7.59 t ha^{-1}). DT gave significantly higher grain yield (8.32 t ha^{-1}) than the delay planting. Crop duration of delay planting was higher than the normal and DT. In double transplanted crop the growth duration was one week shorter than delay planting and four days longer than normal transplanting which is an opportunity for Boro rice to escape from early flash flood in *haor* area.

TECHNOLOGY TRANSFER

Seed production and distribution. About 35,021 kg of seeds of different popular varieties were produced and sold to the farmers during 2013-14. About 11,250 kg breeder's seeds of three popular varieties (BR16, BRRI dhan28, BRRI dhan29 and BRRI dhan48) were produced and sent to BRRI breeders seed unit.

Training programme and field demonstration. A number of training programmes and field demonstrations were conducted with the active participation of farmers, SAAOs and other concerned extension personnel from the Department of Agricultural Extension (DAE) (Tables 14 and 15).

Table 13. Yield and yield contributing characters of Boro rice at BRRI RS, Habiganj 2013-14.

Treatment	Panicle (no. /m^2)	Filled grain (no. /pan)	1000-grain wt (g)	Yield (t ha^{-1})	Duration (day)
T$_1$: Normal transplanting (45-day-old seedling) with 20- × 20-cm spacing	366.33	121.83	21.09	8.90a	161
T$_2$: Normal transplanting (45-day-old seedling) with 20- × 10-cm spacing	351.00	116.90	20.78	8.80a	162
T$_3$: Double transplanting (45 days SB + 30 days 1st TP)	350.33	117.90	21.64	8.32b	165
T$_4$: Delay transplanting (75-day-old seedling)	315.67	109.87	21.69	7.59c	173

In a column, means followed by different letters differ significantly at the 5% level by DMRT.

Table 14. Training programme.

Title	No. of training	Fund	Participant (no.)
Farmers' training on modern rice production technologies	1	GOB	40
Modern rice production technologies	6	EQSS	180

Table 15. Field demonstration.

Name	Variety	No. of demonstration	Season
Field demonstration of modern Aus rice variety on farmers field	BRRI dhan48	36	T. Aus 2014
Field demonstration of Modern Boro rice varieties on farmers' field	BRRI dhan28 and BRRI dhan29	10	Boro 2013-14

BRRI RS, Rajshahi

SUMMARY

A rice seed germination technique 'Ankuri' has been developed to help the farmers in low temperature especially in Boro season.

Among four genotypes, BR6855-3B-12 produced the highest yield (2.61 t/ha) followed by BR6848-3B-12 (2.58 t/ha) from regional yield trial of broadcast Aus.

Among nine genotypes, ZHONGU-14 produced the highest yield (4.86 t/ha) followed by IR83142-B-79-B (4.71 t/ha) from regional yield trial (micro-nutrient) of transplant Aus.

Among five genotypes, BR7697-16-2-2-1-1 produced the highest yield 4.51 (t/ha) followed by BR7697-15-4-4-2-2 (4.1 t/ha) in regional yield trial (premium quality rice) of T. Aman.

Among the five collected genotypes, only Sumon Swarna (5.75 t/ha) and Guti Swarna (5.37 t/ha) gave better yield than the check BRRI dhan39 (5.17 t/ha) but lower than BR11 (6.1 t/ha).

Among four tested T. Aman entries only BR7528-2R-19-HR10 produced better yield (5.69 t/ha) than BINA dhan7 (5.18 t/ha) but lower than BRRI dhan49 (6.03 t/ha) in regional yield trial.

All the five tested genotypes produced higher yield (4.30-4.55 t/ha) than BRRI dhan60 (4.15 t/ha) except BR7669-11-1-2-8-2-1 but only two entries out yielded BRRI dhan28 (4.31 t/ha).

Among six genotypes only two entries BR7358-35-2-1-1 and BR7358-35-3-2-1 produced higher yield (5.45 and 5.69 t/ha) than BRRI dhan28 (5.01 t/ha) in premium quality rice.

Among nine GSR materials five entries, HHZ17-DT6-Y1-DT1, HHZ5-SAL10-DT1-DT1, HHZ17-Y16-Y3-Y2, HHZ12-SAL2-Y3-Y2, HHZ23-DT16-DT1-DT1 produced higher yield (4.65-6.25 t/ha) than the check BRRI dhan28 (4.64 t/ha).

All the five tested entries gave higher yield (5.06-6.26 t/ha) than BRRI dhan28 (4.59 t/ha) but only two entries out yielded (5.97-6.26 t/ha) BRRI dhan29 (5.80 t/ha) for disease resistance.

All the five tested entries produced higher yield (3.85-5.52 t/ha) than the check, BRRI dhan28 (3.83 t/ha) and four entries (4.17-5.52 t/ha) than BRRI dhan55 (3.88 t/ha) but three entries out yielded (4.68-5.52 t/ha) BRRI dhan29 (4.62 t/ha) for cold tolerance.

All the 10 tested drought entries produced higher yield than BR11 (3.31 t/ha) and nine entries than BRRI dhan39 (3.47 t/ha) of which HHZ5-DT1-DT1 gave the highest yield (4.53 t/ha).

Among nine RYT test materials two entries, HHZ12-SAL2-Y3-Y2 and HHZ17-DT6-Y1-DT1 gave higher yield (6.34-6.45 t/ha) than the check, BRRI dhan28 (6.15 t/ha) from GSR.

In hybrid trial, A set of 10 genotypes produced >9 t/ha yield of which H949 produced the highest yield (72.79 kg/day). In the B set only three genotypes produced >9 t/ha yield. The genotype H950 produced the highest yield (67.86 kg/day). In the C set four genotypes produced >8 t/ha yield. The genotype H975 produced the highest yield (58.60 kg/day).

The proposed genotype IR82635-B-B-75-2 produced significantly higher yield (3.59 t/ha) than BRRI dhan56 (2.74 t/ha) in different drought prone areas. The proposed genotypes, BR7830-16-1-5-3 and weed tolerant rice produced significantly higher yield (7.30 and 7.83 t/ha) than BRRI dhan28 (5.82 t/ha).

The abundance of green leaf hopper was the highest in the light trap and the peak was in October and November but brown plant hopper in November and December.

The natural enemy earwig population was found the highest followed by carabid beetle and the earwig peak in October whereas carabid beetle showed two peaks, one in December and another in May.

Sheath blight, blast and false smut incidence was more irrespective of variety. Blast incidence was remarkable especially in the aromatic fine grain local variety Chini-atap. Most of the field in Kaliganj of Tanore and Kakonhat areas of Godagari upazila was affected with blast causing 20-90% seed sterility and hence loses the yield.

Rice grain yield was influenced significantly by different conservative tillage options. Permanent bed produced the highest grain yield (5.35 t/ha) but similar with all other treatments except minimum tillage (4.61 t/ha).

TRANSFERABLE TECHNOLOGY

Development of seed germination technique in cold environment

Ankuri. Recently BRRI RS, Rajshshi has developed a sample farmers' friendly seed germination technique called 'Ankuri' by which rice seed germination could be done easily. In this method a frame with a heat insulating cover is prepared. In the frame 25-35°C temperature and high humidity is induced through vapour therapy. Seeds are soaked in a pot for 22-24 hours within the frame. After soaking, water is poured from the pot. All seeds are then filled in a sac and covered with another moist sac or cloth. After 24 hours seeds are sprouted completely and become ready for sowing in the seed bed after another 12 hours.

VARIETAL DEVELOPMENT

Regional yield trial (RYT), B. Aus 2013-14

Four genotypes and a standard check BRRI dhan43 were evaluated under this experiment to evaluate the lines for yield potential and adaptability in Rajshahi region. Dry seeding of the genotypes was done in moist soil in a unit plot size 5.4m × 12 rows with 25 cm row spacing. Genotypes in the field lay out was distributed following RCB design with three replications. Fertilizers PKS and Zn were applied @ 10-30-18-3.6 kg/ha respectively from TSP, MOP, gypsum and zinc sulphate during final land preparation and N @ 60 kg/ha from urea in three splits at 15, 30 and 45 days after seed emergence. Wheat was produced in the previous season in the experimental plot. Hand weeding was done three times but no herbicide applied. Plant protection measures were taken as and when necessary. Data was taken on the date of seeding, flowering and maturity, number of panicles and yield/m^2.

All the tested entries produced higher yield (1.84-2.61 t/ha) than the check BRRI dhan43 (1.64 t/ha) (Table 1). BR6855-3B-12 produced the highest yield (2.61 t/ha) followed by BR6848-3B-12 (2.58 t/ha). The number of panicles was more in BR6848-3B-12 than the check but other entries produced less.

Table 1. Yield contributing parameters and yield of B. Aus lines, 2013.

Designation	Plant ht (cm)	Growth duration (day)	Panicle/ m^2	Yield (t/ha)
BR7699-2B-3-3	69.7	101.67	185	1.84
BR6855-3B-12	90.2	104	201	2.61
BR6855-3B-13	87.9	103.33	216	2.27
BR6848-3B-12	96.1	107.33	276	2.58
BRRI dhan43	92.6	100	240	1.64
5% LSD with 8 DF	6.39	0.81	48.37	0.69

RYT-MN, T. Aus 2013

Nine entries and three checks BR26, BRRIdhan48 and WK1 were evaluated for yield potential and adaptability in Rajshahi region. Twenty-two-day-old seedling was transplanted with 2-3 seedlings/hill. The hill spacing was 25- × 15-cm and unit plot size was 5.4- × 2.0-m. Fertilizers PKS and Zn were applied @ 60-40-40-10 kg/ha respectively from TSP, MOP, gypsum and zinc sulphate during final land preparation and N in two equal splits at 10 and 30 days interval starting after transplanting. Crop management practices such as cultural operations and pest management activities were done in time. Data were recorded on date of seeding, flowering and maturity, plant height, lodging tolerance, phenotypic acceptability and yield.

All the tested entries performed better than the checks BR26, BRRI dhan48 and WK1 (Table 2). ZHONGU-14 produced the highest yield (4.86 t/ha) followed by IR83142-B-79-B (4.71 t/ha).

RYT, T. Aman 2013

Five regional yield trials for premium quality rice

Table 2. Yield and ancillary characters of the genotypes in RYT#1, T. Aus 2013.

Designation	Plant ht (cm)	Duration (day)	PAcp		Yield (t/ha)
			Vegetative	Maturity	
IR83141-B-17-B	115.3	119	3	3	4.51
IR83142-B-57-B	108.3	121	3	3	3.66
IR43142-B-6—B	115.1	120	3	3	4.47
IR83142-B-79-B	115.8	120	3	3	4.71
IR83142-B-7-B-B	117.2	120	3	3	4.44
SAGC-06	123.6	119	3	3	3.97
ZHONGU-14	98.0	120	3	3	4.26
BR26 (ck)	104.1	116	3	3	3.31
BRRI dhan48 (ck)	101.3	115	3	3	4.24
WK1 (ck)	108.9	118	3	3	3.50

(PQR), rainfed lowland rice (RLR), collection, green super rice (GSR) and micronutrient (MN) were conducted to evaluate specific and general adaptability of the genotypes in on-station condition. Tested genotypes including the standard checks are mentioned in the table in each specific trial. Seventeen- to 21-day-old seedlings were transplanted in 5 m × 15 rows plot with 20- × 15-cm spacing using 2-3 seedlings/hill in RCB design with three replications. Fertilizers PKS and Zn were applied @ 15-50-12-3.6 kg/ha from TSP, MOP, gypsum and zinc sulphate during final land preparation and N @ 92 in three equal splits at 15 days interval starting from 15 days after transplanting (DAT). Data were recorded on date of flowering and maturity, plant height, lodging tolerance, phenotypic acceptability at vegetative and maturity stage and yield/plot.

RYT#1 (PQR). Five genotypes with three checks were evaluated in this trial. All the tested entries produced higher yield than the checks except BR7369-52-3-2-1-1 and BI dhan1 (Table 3). Among them BR7697-16-2-2-1-1 produced the highest yield 4.51 (t/ha) followed by BR7697-15-4-4-2-2 (4.1 t/ha).

RYT#3 (Collection). Five collected genotypes along with two checks, BR11 and BRRI dhan39 were tested. Sumon Swarna (5.75 t/ha) and Guti Swarna (5.37 t/ha) produced better yield (Table 4) than the check BRRI dhan39 (5.17 t/ha) but lower than BR11 (6.1 t/ha). Therefore, Sumon Swarna and Guti Swarna can be cultivated as improved variety.

RYT#4 (GSR). Four genotypes along with the check, BRRI dhan39 were tested. Only IR83142-B-60-B produced better yield (4.70 t/ha) than the check (4.57 t/ha) but was insignificant.

RYT#5 (MN). Four entries along with three checks, BRRI dhan39, BRRI dhan49 and BINA dhan-7 were tested. Only BR7528-2R-19-HR10 gave better yield (5.69 t/ha) than BINA dhan-7 (5.18 t/ha) but lower than BRRI dhan49 (6.03 t/ha).

RYT, Boro 2013-14

Six regional yield trials for favourable Boro (FB), micronutrient-dense rice (MDR), premium quality rice (PQR), green super rice (GSR), disease resistant (DR) and cold tolerant rice were conducted to evaluate specific and general adaptability of the genotypes. The list of tested genotypes including the standard checks is attached in the table in each specific trial. Forty- to 45-day-old seedlings of each genotype were transplanted with 2-3 seedlings/hill in 5.4 m × 12 rows plot with 25- × 15-cm spacing. The field lay out was done following RCB design with three replications. Fertilizers PKS and Zn @ 20-60-20-4 kg/ha from triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied during final land preparation and N @ 120 in three equal splits at 15 days interval starting from 15 days after transplanting (DAT). Data were recorded on flowering and maturity dates, plant height, panicle/hill, spikelet sterility, 1000-grain weight and yield.

RYT#2 (MDR). In this trial five genotypes along with two checks; BRRI dhan28 and BRRI dhan60 were tested. All the entries # higher yield (4.30-4.55 t/ha) than the check BRRI dhan60 (4.15 t/ha) except BR7669-11-1-2-8-2-1 but only two entries out yielded the check BRRI dhan28 (Table 5).

RYT#3 (PQR). Six genotypes along with two checks BRRI dhan28 and BRRI dhan50 were

Table 3. Yield and ancillary characters of the genotypes in RYT#1 (PQR), T. Aman 2013.

Designation	Plant ht (cm)	Duration (day)	Lodging	PAcp		Yield (t/ha)
				Vegetative	Maturity	
BR7697-15-4-4-2-1	134.33	121	33.33	3	3	3.70
BR7697-15-4-4-2-2	136.67	122	20.00	3	3	4.10
BR7697-16-2-2-1-1	136.33	123	10.00	3	3	4.51
BR7369-52-3-2-1-1	133.67	115	16.67	3	3	3.00
BI dhan1	105.67	109	20.00	3	3	3.39
BRRI dhan34 (ck)	158.67	140	100.00	3	3	2.41
BRRI dhan37 (ck)	147.67	149	100.00	3	3	2.04
BRRI dhan39 (ck)	118.00	114	0.00	3	3	3.57

Table 4. Yield and ancillary characters of the genotypes in RYT#3 (Collection), T. Aman 2013.

Designation	Plant ht (cm)	Duration (day)	Lodging tolerance	PAcp		Yield (t/ha)
				Vegetative	Maturity	
Sumon Swarna	132	128	100	3	3	5.75
Guti Swarna	126	129	6.67	3	3	5.37
WK-1	102.67	104	0	3	3	3.10
BR11 (ck)	125.67	128	0	3	3	6.10
BRRI dhan39 (ck)	106	110	0	3	3	5.17

Table 5. Yield and ancillary characters of the genotypes in RYT#2 (MDR), Boro 2013-14.

Designation	Plant ht (cm)	Duration (day)	Panicle/Plant (no.)	PAcp	Yield (t/ha)
BR7881-10-1-5-3-1	74.93	153	10.3	3	4.36
BR7833-11-1-1-3-4	87.13	154	9.2	5	4.30
BR7669-11-1-2-8-2-1	80.50	152	11.8	3	3.46
BR7830-16-1-5-9-9	91.13	155	8.9	3	4.55
BR7833-11-1-1-2-1-2B5	89.33	148	9.3	3	4.42
BRRI dhan28 (ck)	92.13	153	10.5	3	4.31
BRRI dhan60 (ck)	80.93	152	10.9	3	4.15
F value					1.20

evaluated. Only two entries # higher yield (5.45-6.26 t/ha) than BRRI dhan28 (5.01 t/ha) but four entries out yielded BRRI dhan50 (4.62 t/ha) (Table 6).

RYT#4 (GSR). Nine GSR materials were investigated with the check variety BRRI dhan28. Only five entries # higher yield (4.65-6.25 t/ha) than the check (4.64 t/ha) (Table 7).

RYT#5 (DR). Five disease resistant genotypes along with two checks; BRRI dhan28 and BRRI dhan29 were investigated for yield performance. All the tested entries produced higher yield (5.06-6.26 t/ha) than the check, BRRI dhan28 (4.59 t/ha) but only two entries out yielded (5.97-6.26 t/ha) the check, BRRI dhan29 (5.80 t/ha) (Table 8).

RYT#6 (Cold). Five genotypes along with three checks BRRI dhan28, BRRI dhan29 and BRRI dhan55 were observed under standard cultivation technique. All the tested entries produced higher yield (3.85-5.52 t/ha) than the check BRRI dhan28 (3.83 t/ha) and four entries (4.17-5.52 t/ha) than BRRI dhan55 (3.88 t/ha) but three entries out yielded (4.68-5.52 t/ha) BRRI dhan29 (4.62 t/ha) (Table 9).

Preliminary yield trial (PYT-drought and PYT) and secondary yield trial (SYT) of GSR lines, T. Aman 2013 (GSR project)

Three trials of PYT (Drought), PYT and SYT were conducted to evaluate specific and general adaptability of the genotypes during T. Aman at farmers' field, Malumpara, Godagari, Rajshahi. Tested genotypes including the standard checks are mentioned in the table in

Table 6. Yield and ancillary characters of the genotypes in RYT#3 (PQR), Boro 2013-14.

Designation	Plant ht (cm)	Duration (day)	Panicle/Plant (no.)	PAcp	Yield (t/ha)
BR7781-10-2-3-2	98.6	158	9.5	3	4.21 c
BR7376-19-1-6-1	95.6	163	9.8	5	4.71 bc
BR7376-19-2-1-1	97.6	164	9.9	3	5.00 abc
BR7369-10-5-2-3	111.2	165	8.3	3	4.34 c
BR7358-35-2-1-1	82.3	167	11	3	5.45 ab
BR7358-35-3-2-1	82.8	166	12.8	3	5.69 a
BRRI dhan28 (ck)	93.3	148	10.4	3	5.01 abc
BRRI dhan50 (ck)	84.6	159	9.6	3	4.62 bc
F value	-	-	-	-	6.79

Table 7. Yield and ancillary characters of the genotypes in RYT#4 (GSR), Boro 2013-14.

Designation	Plant ht (cm)	Duration (day)	Panicle/Plant (no.)	PAcp	Yield (t/ha)
IR83140-B28-B	84.8	153	9.5	5	3.29 d
IR83142-B-19-B	82.7	155	8.5	3	3.27 d
IR83142-B-60-B	88.9	157	8.7	3	3.54 cd
HHZ5-SAL10-DT1-DT1	94.8	157	8.4	5	4.71 bc
HUANG HUA ZHAN	86.2	159	6.9	3	4.30 cd
HHZ17-DT6-Y1-DT1	87.0	160	9.0	3	4.65 bc
HHZ17-Y16-Y3-Y2	89.7	160	8.4	3	4.72 bc
HHZ23-DT16-DT1-DT1	90.9	162	9.4	3	6.25 a
HHZ12-SAL2-Y3-Y2	97.1	162	9.3	3	5.64 a
BRRI dhan28 (ck)	91.9	153	10.9	3	4.64 bc
F value	-	-	-	-	15.80

Table 8. Yield and ancillary characters of the genotypes in RYT#5 (DR), Boro 2013-14.

Designation	Plant ht (cm)	Duration (day)	Panicle/Plant (no.)	PAcp	Yield (t/ha)
BR7986-2-3	103.1	148	12.7	3	6.26 a
BR7805-5-1-3	96.3	154	14.8	3	5.97 ab
BR7986-7-4	96.5	152	12.2	3	5.77 ab
BR7986-29-4	102.2	148	13.8	3	5.55 ab
BR7806-18-1-2	102.5	150	12.8	3	5.06 ab
BRRI dhan28 (ck)	94.9	148	13.9	3	4.59 b
BRRI dhan29 (ck)	89.6	168	13.2	3	5.80 ab
F value	-	-	-	-	2.75

Table 9. Yield and ancillary characters of the genotypes in RYT#6 (Cold), Boro 2013-14.

Designation	Plant ht (cm)	Duration (day)	Panicle/Plant (no.)	PAcp	Yield (t/ha)
IR77496-31-2-1-3-1	78.0	152	11.0	3	5.52 a
IR2266-42-6-2	90.0	155	9.2	3	4.17 ab
BR7812-19-1-6-1-P4	91.1	150	10.0	3	4.68 ab
BR7813-1-13-1	94.6	147	11.9	3	3.85 b
BR8245-2-1-4	94.8	157	11.4	3	5.26 ab
BRRI dhan28 (ck)	89.7	150	11.2	3	3.83 b
BRRI dhan29 (ck)	86.3	166	10.5	3	4.62 ab
BRRI dhan55 (ck)	88.9	153	8.6	3	3.88 b
F value	-	-	-	-	3.90

each specific trial. Forty-six-day-old seedlings were transplanted in 5 m × 10 rows plot with 25- × 15-cm spacing using 2-3 seedlings/hill in RCB design with three replications. Fertilizers TSP, MOP, gypsum and zinc sulphate were applied @ 100, 120, 110 and 11 kg/ha respectively were applied during final land preparation. Urea @ 210 Kg/ha was applied in three equal splits at 15 days interval starting from 15 days after transplanting. Standard crop management was done within four weeks after transplanting. Then moderate drought was imposed in the experimental plots. Crop management practices such as weeding,

controlling disease and insect pests were done in time. Data were recorded on flowering and maturity dates, seedling height, plant height, lodging tolerance and yield/plot.

PYT (Drought): Ten genotypes and two checks BRR11 and BRRI dhan39 was tested in this experiment. All the tested entries produced higher yield than the checks (Table 10). HHZ5-DT1-DT1 produced the highest yield (4.53 t/ha) followed by HHZ15-DT4-DT1-Y1 (4.31 t/ha).

PYT. Seventeen test materials and three checks BR11 BRRI dhan32 and BRRI dhan39 were evaluated in this trial. Ten entries performed better than the checks (Table 11). HHZ12-Y4-Y1-

Table 10. Growth characters and yield of GSR lines in PYT (Drought) at Godagari, T. Aman 2013.

Designation	Plant ht (cm)	Panicle/ hill (no.)	Growth duration (day)	Yield (t/ha)
HHZ5-DT1-DT1	106.6	9.7	103	4.53
HHZ11-DT7-SAL1-SAL1	98.4	9.9	103	4.11
HHZ15-DT4-DT1-Y1	94.2	7.7	103	4.31
HHZ17-DT6-Y1-DT1	100.6	8.3	103	4.08
HHZ17-Y16-Y3-Y2	95.2	7.9	95	3.54
HUANG HUA ZHAN	95.6	9.3	104	3.39
HHZ23-DT16-DT1-DT1	101.6	9.1	104	3.76
HHZ12-Y12-Y1-DT1	109	8.5	99	4.16
HHZ6-SAL3-Y1-SUB2	103	8.7	106	3.95
HHZ12-SAL2-Y3-Y2	109.2	8.1	101	3.69
BR11 (ck)	117	8.3	120	3.31
BRRI dhan39 (ck)	108.4	8.2	105	3.47
5% LSD with 22DF	6.09	NS	NS	0.25

Table 11. Growth characters and yield of GSR lines in PYT at Godagari, T. Aman 2013.

Designation	Plant ht (cm)	Panicle hill (no.)	Growth duration (day)	Yield (t/ha)
HHZ5-DT20-DT2-DT1	102.4	9.4	101	3.96
HHZ5-DT20-DT3-Y2	101	9.0	103	4.08
HHZ5-SAL10-DT-DT1	104.2	8.8	106	3.63
HHZ5-SAL10-DT3-Y2	105.6	9.4	108	3.69
HHZ5-Y4-SAL1-Y1	108.2	8.1	109	3.46
HHZ12-SAL8-Y1-Y2	113.6	7.9	103	3.61
HHZ12-Y4-Y1-DT1	108	8.7	101	4.21
HHZ15-DT4-DT1-Y1	91.6	8.7	102	4.20
HHZ12-SAL8-Y1-Y2	108.2	7.5	103	3.62
HHZ6-SAL3-Y1-SUB2	100.2	7.9	104	3.84
HHZ15-SAL13-Y1	103.4	7.4	101	4.05
BRRI dhan32 (ck)	131.4	8.0	115	2.96
BRRI dhan39 (ck)	106.4	8.3	106	3.48
BR11 (ck)	116	9.0	125	3.51
5% LSD with 38 DF	6.18	NS	NS	0.17

DT1 and HHZ15-DT4-DT1-Y1gave the highest yield (4.21 and 4.20 t/ha) followed by HHZ5-DT20-DT3-Y2 and HHZ15-SAL13-Y1 (4.08 and 4.05 t/ha).

PYT, SYT and RYT of GSR lines, Boro 2013-14 (GSR project)

Three trials of PYT, SYT and RYT were conducted to evaluate specific and general adaptability of the genotypes during Boro at farmers' field, Malumpara, Godagari, Rajshahi. Tested genotypes including the standard checks are mentioned in the table in each specific trial. Forty-six-day-old seedlings were transplanted in 5 m × 10 rows plot with 25- × 15-cm spacing using 2-3 seedlings/hill in RCB design with three replications. Fertilizers TSP, MOP, gypsum and zinc sulphate were applied

@ 100, 120, 110 and 11 kg/ha respectively were applied during final land preparation. Urea @ 210 kg/ha was applied in three equal splits at 15 days interval starting from 15 days after transplanting. Standard crop management was done until four weeks after transplanting. Then moderate drought was imposed in the experimental plots. Crop management practices such as weeding, controlling disease and insect pests were done in time. Data were recorded on date of flowering and maturity, seedling height, plant height, lodging tolerance and yield/plot.

SYT. Eleven genotypes and check BRRI dhan28 was investigated in this experiment. Three test entries, HHZ15-DT4-DT1-Y1, HHZ15-DT4-DT1-Y1 and HUANG HUA ZHAN gave higher yield (Table 12) than the check BRRI dhan28. But

Table 12. Yield and ancillary characters of GSR lines in SYT, Boro 2013-14.

Designation	Plant ht (cm)	Panicle/ hill (no.)	Growth duration (day)	Yield (t/ha)
RC8	-	-	153	4.14
JH15-1-1-1	95.4	7	158	5.02
D4098	105	7.8	155	5.63
ZX115	87.2	-	145	5.11
HHZ15-DT4-DT1-Y1	-	8.6	154	6.67
HHZ12-Y4-Y1-DT1	94.4	12	156	5.65
HHZ5-DT1-DT1	91.2	10.2	154	5.82
HHZ11-DT7-SAL1-SAL1	87.8		148	4.64
HHZ15-DT4-DT1-Y1	86.8	11.2	155	6.22
HUANG HUA ZHAN	83	9	155	6.04
HHZ6-SAL3-Y1-SUB2	91.8	11.8	156	5.25
BRRI dhan28 (ck)	87.2	-	143	5.93

the growth duration of those three lines were higher than the check.

RYT. Nine test materials and the check BRRI dhan28 were evaluated in this trial. Two test entries HHZ12-SAL2-Y3-Y2 and HHZ17-DT6-Y1-DT1 gave higher yield (6.34-6.45 t/ha) than the check, BRRI dhan28 (6.15 t/ha) (Table 13) and could be selected for future advancement.

Hybrid rice trial for A, B and C set, Boro 2013-14
The trials were conducted with 17 genotypes of A set and 16 genotypes each of B and C set to evaluate specific and general adaptability of the genotypes in on-station condition. Thirty-day-old seedlings were transplanted in 5- × 6-m plot with 20- ×15-cm spacing using single seedlings/hill. The experimental design was RCB with three replications. Fertilizers NPKS and Zn were applied @ 124-26-60-13-3.6 kg/ha from urea. Full doses of TSP, gypsum, zinc sulphate, 1/8th urea 2/3rd MOP were applied during final land preparation. The rest of MOP at 50 DAT and rest of the urea in two

equal splits at 15 and 50 DAT were top dressed. Crop management practices were done as and when necessary. Data were recorded on flowering and maturity dates, plant height, lodging tolerance, phenotypic acceptability and yield/plot.

In the A set 10 genotypes produced >9 t/ha yield. The genotype H949 produced the highest yield (72.79 kg/day) followed by H933 (68.67 kg/ha) (Table 14).

In the B set only three genotypes produced >9 t/ha yield. The genotype H950 produced the highest yield (67.86 kg/day) followed by H959 (61.44 kg/ha) (Table 15).

In the C set four genotypes produced >8 t/ha yield. The genotype H975 produced the highest yield (58.60 kg/day) followed by H978 (55.78 kg/ha) (Table 16).

Proposed variety trial
Drought, T. Aman 2013. Only one proposed line along with the check, BRRI dhan56 were evaluated at farmer's field at Tanore, Godagari, Neamotpur,

Table 13. Yield and ancillary characters of GSR lines in RYT, Boro 2013-14.

Designation	Plant ht (cm)	Panicle/ hill (no.)	Growth duration (day)	Yield (t/ha)
IR 83140-B-28-B	83	8.5	148	5.0
IR 83142-B-19-B	81	9.4	149	6.09
IR 83142-B-60-B	91	8.4	151	5.11
HHZ5-SAL10-DT1-DT1	-	9.6	156	5.75
HUANG HUA ZHAN	82.8	10	157	6.1
HHZ17-DT6-Y1-DT1	82.8	10	158	6.34
HHZ17-Y16-Y3-Y2	86	9.6	158	5.98
HHZ23-DT16-DT1-DT1	83.8	9.6	162	5.87
HHZ12-SAL2-Y3-Y2	96.6	9.2	162	6.45
BRRI dhan28 (ck)	89.4	8.4	146	6.15

Table 14. Yield and ancillary characters of the hybrids for A set Boro, 2013-14.

Designation	Plant ht (cm)	Growth duration (day)	Grain/ Panicle (no.)	Sterility (%)	Yield (t/ha)
H933	110.7	150	135	11.18	10.30
H934	98.5	150	110	23.61	8.75
H935	107.7	158	193	21.22	9.17
H936	113	153	224	25.58	10.18
H937	109	150	156	17.02	7.99
H938	101.3	145	120	22.58	5.75
H939	100.7	164	131	28.02	8.54
H940	105.2	150	100	21.88	9.02
H941	106.3	149	170	17.48	9.21
H942	99	152	148	18.68	9.24
H943	110	163	133	19.39	8.66
H944	112.8	149	154	17.20	9.42
H945	100.3	150	119	21.71	7.98
H946	107.2	150	152	19.58	9.42
H947	101.7	151	103	17.60	9.2
H948	101.5	151	121	22.44	8.71
H949	92	136	170	12.37	9.9

Table 15. Yield and ancillary characters of the hybrids for B set, Boro 2013-14.

Designation	Plant ht (cm)	Growth duration (day)	Grain/ Panicle (no.)	Sterility (%)	Yield (t/ha)
H950	107.5	154	166	9.29	10.45
H951	99	149	130	15.58	8.16
H952	103	149	131	11.49	7.30
H953	99.3	146	128	21.47	5.39
H954	89.3	146	109	18.66	6.99
H955	99.3	145	138	24.18	6.08
H956	96.8	149	132	13.16	7.54
H957	94.8	155	131	14.94	9.4
H958	96.2	149	126	9.35	7.24
H959	94.2	159	202	28.11	9.77
H960	104.2	156	174	28.69	8.83
H961	104.2	150	131	17.61	6.94
H962	94.8	159	110	22.54	8.31
H963	97.5	145	126	9.35	6.45
H964	92.8	144	131	17.09	6.89
H965	90.2	142	114	17.99	4.38

Table 16. Yield and ancillary characters of the hybrids for C set, Boro 2013-14.

Designation	Plant ht (cm)	Growth duration (day)	Grain/ Panicle (no.)	Sterility (%)	Yield (t/ha)
H966	99.7	153	136	17.6	7.54
H967	97.3	150	132	12.6	6.71
H968	93.5	156	139	20.6	7.76
H969	93.3	162	109	19.9	6.59
H970	98.5	160	133	19.9	8.48
H971	97.5	145	131	20.6	6.38
H972	98	150	141	10.2	8.28
H973	102.3	149	115	23.8	6.92

Table 16. Continued.

Designation	Plant ht (cm)	Growth duration (day)	Grain/ Panicle (no.)	Sterility (%)	Yield (t/ha)
H974	95.5	149	137	11	6.83
H975	99.8	145	152	17.8	8.54
H976	102.7	151	126	18.2	7.34
H977	101.5	151	110	14.7	7.38
H978	110.7	154	126	20.8	8.59
H979	91	142	112	26.8	4.96
H980	91.3	141	117	14.6	4.92
H981	100.2	144	121	12.3	6.39

Gomostapur and Pursha to evaluate the performance of the proposed lines for releasing as variety. Twenty-day-old seedlings were transplanted with 2-3 seedlings/hill with 25- × 15-cm spacing in RCB design. Each genotype was transplanted in a unit plot size 5- × 4-m area with three replications. Fertilizers, PKS and Zn were applied @ 15, 50, 12 and 3.6 kg/ha respectively from TSP, MOP, gypsum and zinc sulphate at final land preparation, and N @ 92 kg from urea in three equal splits at 15 days interval starting from 15 DAT. Crop management practices was done as and when necessary. Data on flowering and maturity dates, plant height, lodging tolerance, yield/plot, disease and insect incidence were recorded.

The proposed genotype produced significantly higher yield (Table 17) than the check but overall performance was not good enough except Godagari and Tanore where it produced more than 4 t/ha yield. So the tested genotype may be recommended as variety for drought prone areas.

RLR, T. Aman 2013. Only one proposed line along with the check, BR11 were evaluated at farmer's field at Tanore, Rajshahi to evaluate the performance of the proposed lines for releasing as variety. Twenty-day-old seedlings were transplanted with 2-3 seedlings/hill with 25- × 15-cm spacing in RCB design. Each genotype was transplanted in a unit plot size 5- × 4-m area with three replications. Fertilizers, PKS and Zn were applied @ 15, 50, 12 and 3.6 kg/ha respectively from TSP, MOP, gypsum and zinc sulphate at final land preparation, and N @ 92 Kg from urea in three equal splits at 15 days interval starting from 15 DAT. Crop management practices was done as and when necessary. Data on flowering and maturity dates, plant height, lodging tolerance,

Table 17. Yield performances of proposed genotypes at different locations of Rajshahi region, T. Aman 2013.

Genotype	Tanore		Godagari		Gomostapur		Neamotpur		Pursha	
	Yield (t/ha)	Duration (day)	Yield (t/ha)	Duration (day)	Yield (t/ha)	Duration (day)	Yield (t/ha)	Duration (day)	Yield (t/ha)	Duration (day)
IR82635-B-B-75-2	4.73	114	4.11	113	2.51	107	2.52	113	4.07	111
BRRI dhan56 (ck)	3.82	111	3.20	115	1.48	106	1.91	109	3.31	107

yield/plot, disease and insect incidence were recorded.

The proposed genotype was heavily infested with rice bug and produced lower yield (Table 18) than the check BR11 but was more than 5 t/ha.

GSR lines, T. Aman 2013. Only one line, HUA565 along with the check BRRI dhan33 were evaluated at farmer's field, Godagari, Rajshahi to evaluate the performance of the proposed lines for releasing as variety. Twenty-day-old seedlings were transplanted with 2-3 seedlings/hill with 25- × 15-cm spacing in RCB design. Each genotype was transplanted in a unit plot size 5- × 4-m area with three replications. Fertilizers, PKS and Zn were applied @ 15, 50, 12 and 3.6 kg/ha respectively from TSP, MOP, gypsum and zinc sulphate at the final land preparation, and N @ 92 kg from urea in three equal splits at 15 days interval starting from 15 DAT. Crop management practices was done as and when necessary. Data on flowering and maturity dates, plant height, lodging tolerance, yield/plot, disease and insect incidence were recorded.

Both the genotypes produced significantly higher yield (Table 19) than the check but growth duration was 9-11 days longer. Both the tested genotypes may be recommended as variety.

GSR lines, Boro 2013-14. Two lines along with the check BRRI dhan28 were evaluated at

farmer's field, Godagari, Rajshahi to evaluate the performance of the proposed lines for releasing as variety. Forty-two-day-old seedlings were transplanted with 2-3 seedlings/hill with 25- × 15-cm spacing in RCB design. Each genotype was transplanted in a unit plot size 5- × 4-m area with three replications. Fertilizers, PKS and Zn were applied @ 20, 60, 20 and 4 kg/ha respectively from TSP, MOP, gypsum and zinc sulphate at the final land preparation, and N @ 120 from urea in three equal splits at 15 days interval starting from 15 DAT. Crop management practices were done as and when necessary. Data on flowering and maturity dates, plant height, lodging tolerance, yield/plot, disease and insect incidence were recorded.

Both the genotypes produced significantly higher yield (Table 20) than the check but growth duration was 9-11 days longer. Both the tested genotypes may be recommended as variety.

Observational yield trial of drought stress genotypes

The experiment was conducted on farmers' field at Alimganj, Paba, Rajshahi to select genetically fixed lines with uniform genotypic characters along with grain yield under reproductive stress condition. A total of 145 genotypes including 12 checks (International and local) were tested in the experiment. Twenty-five-day-old seedlings were transplanted on 28 August in 3.75 m × 4 rows plot using single seedling with 25- × 15-cm spacing following augmented RCB design with two replications. Fertilizers, PKS and Zn were applied

Table 18. Yield and growth characters of proposed RLR genotypes.

Designation	Growth duration (day)	Yield (t/ha)	PAcp
BR7611-31-5-3-2	137	5.24	3
BR11 (ck)	133	5.64	3

Table 19. Yield and growth characters of proposed GSR genotypes, T. Aman 2013.

Designation	Growth duration (day)	Plant ht (cm)	Yield (t/ha)	PAcp
HUA565	156	90	7.30	3
BRRI dhan33	149	92	5.82	3

Table 20. Yield and growth characters of proposed GSR genotypes, Boro 2013-14.

Designation	Growth duration (day)	Plant ht (cm)	Yield (t/ha)	PAcp
BR7830-16-1-5-3	156	90	7.30	3
Weed tolerant rice	160	105	7.83	3
BRRI dhan28	149	92	5.82	3

@ 10-41-11-4 kg/ha respectively from TSP, MOP, $ZnSO_4$ and gypsum at the time of final land preparation and N @ 69 kg/ha from urea in three equal splits at 10, 25-30 and 40-45 days after transplanting (DAT). Crop management practices were done as and when necessary. Drought stress was initiated four weeks after transplanting through proper draining of water from the field up to maturity. Same set of the genotypes along with checks were also tested under control condition in the adjacent field. Experimental design, plot size, seedling age, spacing, crop management, fertilizer doses and application of fertilizers were same as stress field condition except standing water was retained in the field from transplanting up to two weeks after flowering.

In T. Aman season, the highest yield (4.0-5.03 t/ha) was found for the genotype IR88836-39-1-2-1 followed by IR88902-36-1-4-4 with 104 and 109 days growth duration respectively in stress conditions whereas the highest yield (3.86-5.85 t/ha) was found for the genotype IR88960-22-1-1-1 followed by IR87761-46-1-1-1 with 117 and 112 days respectively in control conditions.

Advanced yield trial of 100-120 days genotypes
In T. Aman 30 genotypes and three checks, MTU1010 (International), BINA dhan7 and BRRI dhan56 (local) on 30 July 2013 were sown to select desirable genotypes with high yield under drought stress at reproductive stage. Twenty-five-day-old seedlings were transplanted on 24 August 2013 in a 3.75 m × 6 rows plot in T. Aman. Single seedling transplanted in 25- × 15-cm spacing following Alpha Lattice design with two replications. Fertilizers, PKS and Zn were applied @ 10-41-11-4 kg/ha from TSP, MOP, gypsum and zinc sulphate respectively were applied at the time of final land preparation and N @ 69 from urea in three equal splits at 10, 25-30 and 40-45 DAT. Crop management practices was done as and when necessary. Drought stress was initiated four weeks after transplanting through proper draining of water from the field up to maturity. Same set of genotypes along with checks were also tested under control condition in the adjacent field. Experimental design, plot size, seedling age, spacing, crop management, fertilizer doses and application of fertilizers were same as stress field condition except standing water was retained in the field from transplanting up to two weeks after flowering.

Average grain yield in stress and control conditions produced similar results except few genotypes. In stress condition, the highest yield was observed for IR88864-2-1-1-3 (3.81 t/ha) followed by IR10L282 (3.67 t/ha). Whereas in control condition IR10L282 gave the highest yield (4.52 t/ha) followed by IR10L149 (4.23 t/ha). However, considering both conditions IR88966-9-1-1-2 and IR10L282 were considered better yielder.

Participatory variety selection (PVS) under drought stress and control environment
Seventeen advanced rice genotypes and three checks BRRI dhan56, BRRI dhan57 and IR64 were evaluated in participatory variety selection (PVS) to evaluate and select drought tolerant genotypes suitable for northwest Bangladesh. Two field experiments were conducted in drought prone rainfed environments at Alimganj (Paba) and BRRI RS, Rajshahi along with one control experiment in Paba. Twenty-day-old seedlings were transplanted on 3 August with 25- × 15-cm spacing. The unit plot size was 4- × 4-m. Single seedling was transplanted following RCB design with two replications. Fertilizers, PKS and Zn were applied @ 10-41-11-4 kg/ha form TSP, MOP, gypsum and zinc sulphate respectively were applied at the time of final land preparation and N @ 69 Kg/ha at three equal splits at 10, 25-30 and 40-45 DAT. Crop management practices was done as and when necessary. Forty male and 30 female farmers along with researchers, extension and NGO personnel participated in the selection process. They posted their votes for the ranking of the tested genotypes. The genotypes were labelled with codes and a box was hanged on each of them. Three positive and three negative ballot papers were supplied to each participant. At first, the participants moved around the plots and casted their votes considering their own judgments.

The entries, IR83383-B-B-141-2, IR64 (Ck.), and IR82635-B-B-75-2 stood 1st, 2nd and 3rd positions obtaining the preference score 0.103,

0.094 and 0.073 under control condition while IR82635-B-B-75-2, IR83383-B-B-141-2 and IR10L276 stood 1st, 2nd, and 3rd positions obtaining 0.095, 0.087 and 0.083 under drought stress in Paba.

CROP-SOIL-WATER MANAGEMENT

Yield performance of GSR lines

Eight GSR lines and two checks BRRI dhan28 and BRRI dhan58 were tested at BRRI RS, Rajshahi to investigate the lines for grain yield with less urea application. The lines were grown under two different fertilizer treatments; standard fertilization and 20% less to the standard dose. Fifty two day seedlings were transplanted with 20- × 20-cm spacing in a unit plot size 4- × 3-m. Tested genotypes were arranged in the field following RCB design with three replications. Standard fertilization was done with urea, TSP, MOP, gypsum and zinc sulphate @ 260, 100, 120, 88 and 11 kg/ha. All the amount of fertilizers was applied during final land preparation and urea in three equal splits at 15, 30 and 45 DAT. BRRI recommended production procedure was followed for other practices. Including the check BRRI dhan28, all GSR lines produced better yield in standard fertilization than the other. Irrespective of fertilization treatments, all the genotypes gave higher yield. Thus we conclude that tested lines have the ability to produce more yield than the BRRI dhan28 even at low input condition.

PEST MANAGEMENT

Monitoring of pest and natural enemy incidence by using light trap

Rice insect pests and their natural enemies were monitored to study the pests and their natural enemies' incidence pattern in light trap and create a database throughout the year by Pennsylvanian light traps from July 2013 to June 2014 at the BRRI RS, Rajshahi. The traps were operated with 100 WATT white fluorescent tube light from dusk to dawn and the light operated from the nearest electricity sources of the light traps. Insect pests

and natural enemies those were attracted to the light trap slipped into the hole of the trap and caught behind in a pot attached with the hole of the trap. Then the insect pest and natural enemies were collected, sorted, counted and recorded in the data sheet every day.

The abundance of green leaf hopper (GLH), white leafhopper (WLH), brown plant hopper (BPH), white-backed plant hopper (WBPH), yellow stem borer (YSB), pink borer (PB), leaf folder (LF), caseworm (CW), grasshopper (GH), mole cricket (MC), field cricket (FC) and rice bug (RB) were found in the light trap during the reporting period. Among the insect pests, GLH populations found highest followed by WLH and FC. Peak of GLH observed in the month of October to November. Peak of WLH and BPH observed in the month of November and December respectively. Field cricket was found the highest in the month of April to July (Fig. 1).

Among the natural enemies earwig (EW) population was found as the highest followed by carabid beetle (CBB) and dragon fly (Drag. fly). Peak of EW was observed in of October whereas, CBB showed two peak, one in December and another in May (Fig. 2).

Survey and monitoring of rice diseases

Survey and monitoring of rice disease incidence was done to know the status of disease incidence and how farmers' address the disease at field during T. Aman 2013. This was done mainly at Rajshahi area especially Tanore, Godagari and Paba upazilas. Farmer's interview during the visit
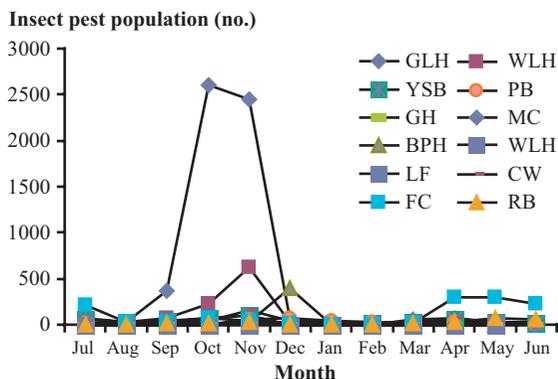

Fig 1. Incidence patterns of major insect pests in light trap, BRRI RS, Rajshahi, July 2013-June 2014.
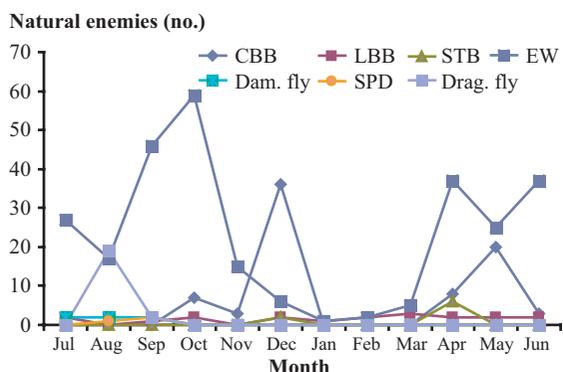
Natural enemies (no.)

Fig. 2. Incidence pattern of natural enemies of rice insect pests in light trap, BRRI RS, Rajshahi, July 2013-June 2014.

was taken to know the knowledge status regarding rice disease.

Sheath blight, blast and false smut incidence was more irrespective of the variety than the other diseases. Guti Swarna, a popular cultivar was found moderately resistant to sheath blight as compared to other varieties observed in the field. Farmers' statement indicated that they are well known to this disease with few control measures like urea management and chemical control. Blast incidence was remarkable in these areas especially in the aromatic fine grain local variety Chini-atap. Most of the field in Kaliganj of Tanore and Kakonhat areas of Godagari upazila was affected with blast causing 20-90% seed sterility and hence loses the yield. In one of the field BRRI dhan34 was affected less probably due to late flowering of the variety. Farmers were not aware of blast disease and its control measures. Again the late planting varieties showed Brown spot incidence and found more prevalent if the crop received drought. BRRI dhan46 was found as a highly susceptible variety to Brown spot disease in this drought stressed area. Survey and monitoring results suggested the need of farmers' skill development on rice disease orientation and management through training programme.

RICE FARMING SYSTEMS

Effect of conservation tillage and residue management on rice productivity

The trial comprising six tillage and three residue management options was conducted to evaluate the suitable conservation tillage options for direct seeded rice and identify the benefits of residue management in BRRI RS, Rajshahi. The tillage options were- i) Zero tillage (ZT), ii) Strip tillage (ST), iii) Minimum tillage (MT) using PTOS, iv) Permanent bed (PB) v) Fresh bed (FB) and vi) Conventional tillage (CT). Residue management options were- i) Zero % previous crop residue incorporation (CR_0), ii) Fifty % previous crop residue incorporation (CR_{50}) and iii) Hundred % previous crop residue incorporation (CR_{100}). The experiment was arranged in split plot with three replications. Except CT, other tillage were considered as conservation tillage. BRRI dhan49 was established in all the conservation tillage treatment except conventional tillage. The land was applied with glyphosate before seeding in all conservation tillage treatments.

Effects on yield components. Results indicates that tillage options caused significant effect on tiller m^{-2}, panicle m^{-2}, panicle length, and grains panicle^{-1}. The highest number of tiller m^{-2} was found in PB, which was statistically similar with rest of the treatments except MT. Similar trend was observed in case of panicle m^{-2}. The panicle length also remained longer in PB followed by CT. The maximum number of grains panicle^{-1} was also found in PB and statistically resembled with CT and FB whereas the lower obtained in ST. Irrespective of tillage treatment, residue management caused little influence on tiller m^{-2} and the maximum was found in CR_{100} followed by CR_{50} and the lower in CR_0 but statistically similar with CR_{50}. Residue management options did not show significant effect on yield parameters except tiller m^{-2}. Although these parameters were not affected significantly, but residue management results followed the increasing trend as $CR_{100}>CR_{50}>CR_0$. The tillage and residue management showed significant interaction on tiller m^{-2}, panicle m^{-2} and grains panicle^{-1}. The tiller and panicle m^{-2} remained higher in CT × CR_{100} and the lower in MT × CR_{100}. The panicle length was not influenced due to the interactions of tillage and residue management and varied from 26.23 to 28.33 cm among the different combinations. Grains panicle^{-1} remained the

highest and lowest in PB × CR_{100} and ST × CR_0 respectively.

Effect on grain and straw yield. Grain yield of rice was affected significantly by the tillage as well as residue management options. Grain yield of rice remained higher in PB which was statistically similar with all other treatments except MT. Irrespective of tillage options, the highest grain yield was found in CR_{100} followed by CR_{50} and those treatments were significantly superior over CR_0. The tillage and residue management also showed significant interaction on rice grain yield and ranged from 4.55 to 5.80 t ha^{-1}. Straw yield of rice was not influenced by the tillage options and ranged from 5.76 to 6.35 t ha^{-1}. The residue management options showed little effect on straw yield but significantly superior for CR_{100}. The tillage and residue management attributed significant interaction on straw yield of rice. The highest straw yield of rice remained in ZT × CR_{100} followed by ST × CR_{50}.

Truthfully levelled and breeder seed production
Two T. Aus, 11 T. Aman and five Boro varieties were cultivated during the reporting year that produced about 12.5 tons truthfully levelled seeds (TLS). The seed was sold to the local farmers for dissemination of good quality seeds.

Five T. Aman and three Boro varieties were cultivated during the reporting year that produced about 28 tons of breeder seed (BS). The seed was sent to the Genetic Resource and Seed Division for dissemination.

BRRI RS, Rangpur

SUMMARY

Twenty crosses were made and five crosses were confirmed. A total of 122 plants were selected from four F_2 populations and 568 plants were selected from observational trial during Boro season.

In T. Aman, BR7468-12-1-1-1-1 gave 0.35 t ha^{-1} yield advantage over BRRI dhan49 with six days longer growth duration. But it showed lodging tolerance.

In T. Aman (GSR), IR83140-B-28-B produced 0.52 t ha^{-1} yield advantage with 12 days shorter growth duration over BRRI dhan39.

In Boro (GSR), HHZ5-SAL10-DT1-DT1 produced 0.81 t ha^{-1} yield advantage over check variety BRRI dhan28.

In Boro (Standard), BR7800-63-1-7-3 produced 1.32 t ha^{-1} yield advantage over BRRI dhan28.

In Boro (MER), BR7830-16-1-5-9-9 and BR7833-11-1-1-3-4 gave 0.73 - 0.82 t ha^{-1} yield advantage over BRRI dhan28.

In Boro (DRR), BR7986-7-4 produced 1.61 t ha^{-1} yield advantage over BRRI dhan28 with 11 days longer growth duration but moderately resistant to BLB and blast disease.

In T. Aman (long term MSW), the genotype IR 09F187 gave the highest yield (3.7 t ha^{-1}) among all tested genotypes and 0.82 t ha^{-1} yield advantage over the check variety (BRRI dhan44).

In Boro, BRRI dhan58 showed better performance in respect of grain yield and it creates farmers interest to cultivate in larger area in this region.

VARIETAL DEVELOPMENT

Modern Boro variety NPT
Hybridization. Sixteen varieties/lines were used in the hybridization block. Single seedling of 40-day-old was transplanted under three planting dates with an interval of seven days to synchronize flowering for cross combinations. The unit plot size was 5.4 m and seedling was planted at a spacing of 20- × 20-cm. Usual method of emasculation and pollination was done and twenty crosses were made (Table 1). Matured F_1 seeds were harvested, sun dried and stored separately in paper bags with proper labeling.

F_1 confirmation. F_1 seeds from eight crosses along with their respective parents were grown in the hybridization block. Single seedling of 40-day-old was transplanted in 3 m single row plots at a spacing of 20- × 20-cm. Five crosses were confirmed (Table 2) as compared to respective parents and objectives. These confirmed crosses will be used to generate F_2 populations.

F_2 population. Four F_2 populations with approximately 2500-3000 progenies for each cross were grown. Single seedling (45-day-old) was transplanted in 5.4 m single row plots with 20- × 20-cm spacing. BRRI dhan28 and BRRI dhan29 were planted as standard check at the end of each cross. A total of 122 plants were selected from four crosses (Table 3) based on specific objective of the cross to initiate pedigree nursery and seeds of the selected plants was preserved with proper labelling.

Observational trial (OT). A total of 400 advanced breeding lines were tested under this experiment. Each entry was grown in 5.4 m × 4 rows plot using single seedling with 25- × 15-cm spacing. Forty-five-day-old seedlings were transplanted. BRRI dhan28, BRRI dhan29 and BRRI hybrid dhan3 were planted as standard check at after every 25 entries. A total of 568 plants were selected from 400 advanced promising genotypes based on cold tolerance at seedling and tillering stage, phenotypic acceptance at vegetative and reproductive stages, earliness, seedling and plant height. Most of the lines showed segregation or not homogeneous. So, individual plant was selected.

Growing and screening of pedigree generations under controlled submergence condition. Eleven F_2, 6 F_3, 3 F_4, 9 F_5, 1 F_6, 1 F_7, 4 BC_1F_2, 1 BC_1F_9, 3 BC_2F_8 populations were grown under controlled submergence condition. Thirty-day-old seedlings were transplanted using single seedling per hill with 25- × 15-cm spacing. Ten days after transplanting the crop was submerged for 16 days. A total of 54 PS from F_2 population,

Table 1. List of crosses to develop standard Boro varieties for northern region, 2013-14.

Designation	# F_1 seed	Objective
Mamun/BRRI dhan29	53	Earliness and high yield
BRRI dhan29/Mamun	04	Earliness and high yield
Mamun/BRRI dhan58	57	Earliness and high yield
BRRI dhan58/Mamun	04	Earliness and high yield
BR7166-5B-5/Mamun	11	Earliness, premium quality and high yield
BR7166-5B-5/Masud	15	Earliness and high yield
BR7166-4B-6/Masud	04	Earliness and High yield
BRRI dhan29/Masud	49	Earliness and high yield
BRRI dhan58/Masud	53	Earliness and high yield
BRRI dhan58/Bashmati Rang	140	Earliness, premium quality and high yield
BR8415-10-1-10-Rang1/BRRI dhan28	17	Earliness, premium quality and high yield
BR8415-10-1-10-Rang1/BRRI dhan58	26	Earliness and high yield
BR7166-5B-5/Bashmati Rang	11	Earliness, premium quality and high yield
BRRI dhan29/Bashmati Rang	18	Earliness, premium quality and high yield
BRRI dhan28/Bashmati Rang	22	Earliness, premium quality and high yield
BR7166-5B-5/Moushumi katari	37	Earliness, premium quality and high yield
BRRI dhan29/Mushumi katari	240	Earliness and high yield
BRRI dhan29/HUA565	115	Earliness and high yield
Mamun/BR8626-21-2-4-Rang3-4	78	Earliness and high yield
Mamun/BRRI dhan28	10	Earliness and high yield

Note: Mamun and Masud are the local rice germplasm which were used as parental line.

Table 2. List of confirmed crosses for standard Boro for northern region, Boro 2013-14.

Designation	Objective
BR7166-5B-5/BRRI dhan29	Earliness and High yield
BR7166-5B-5/BR16	Earliness and High yield
BRRI dhan29/Minikit//Subal lata	Earliness, Premium quality and High yield
RRI dhan29/IR82475B-B-75-1	Earliness and High yield
BRRI dhan29/BR7831-63-4-5-2-2	Earliness and High yield

Table 3. List of selected materials, for standard Boro for northern region, Boro 2013-14.

BR no.	Parentage	Progeny row
BR10405	BRRI dhan29/Pariza	30
BR10406	BRRI dhan29/Minikit	67
BR10407	BR16/IR83140-B-11-B	07
BR10408	BR16/BR7823-53-2-1-1-4	18
Total		122

30 PS from BC_1F_2 population, 46 PS from F_3 generation, 17 PS from F_4 generation, 55 from F_5 generation, 5 PS from F_6 generation, 4 PS from F_7 generation, 14 bulks from BC_2F_8 generation, 5 bulks from BC_1F_9 generations were selected and preserved (Tables 4 and 5).

Mother trial with sub1 and stagnant genotypes under rainfed condition (PVS). Six submergence and medium stagnant water tolerant high yielding genotypes along with two standard check varieties were evaluated under rainfed condition in BRRI farm. The experiment was laid out in RCB design with three replications. Thirty-day-old seedlings were transplanted using 2-3 seedling per hill with 25- × 15-cm spacing. All genotypes showed taller plant height and more or less similar tiller and panicle number. None of the

Table 4. Plants selected from F_2 and BC_1F_2 population, T. Aman 2013, Rangpur.

BR no.	Parentage	Character	No. of plant selected (PS)
	F_2 population		
10192	BR22/BRRI dhan52	Submergence tolerant	5
10194	BRRI dhan46/BRRI dhan51	do	5
10195	BRRI dhan46/BRRI dhan52	do	7
10198	BRRI dhan49/Saita	do	5
10200	BRRI dhan49/Ciherang-Sub1	do	3
10201	BRRI dhan39/KaloJoma	do	10
10202	BRRI dhan49/ KaloJoma	do	6
10204	BRRI dhan39/DG1-349	do	5
10205	BRRI dhan49/DG1-349	do	3
10206	BRRI dhan53/DG1-349	do	2
10208	BRRI dhan53/IR64-Sub1	do	3
Total			54
	BC_1F_2 population		
10197	BRRI dhan49/ Mathia	do	8
10198	BRRI dhan49/Saita	do	8
10199	BRRI dhan49/Damshi	do	6
10203	BRRI dhan53/ KaloJoma	do	8
Total			30
Grand Total			84

Table 5. List of pedigree population selected in T. Aman 2013, BRRI RS, Rangpur

BR no.	Cross	Character	Progeny selected
	F_3		
BR9788	BRRI dhan51/BR11-Saltol-HR1	Sub tol	8
BR9789	BRRI dhan51/BR11-Saltol-HR2	Sub tol, Sal tol	6
BR9790	BRRI dhan52/BR11-Saltol-HR1	Sub tol, Sal tol	9
BR9791	BRRI dhan52/BR11-Saltol-HR2	Sub tol, Sal tol	10
BR9792	BRRI dhan41/ BRRI dhan52	Sub tol	7
BR9793	BRRI dhan32/ BRRI dhan52	Sub tol	6
Total			46
	F_4		
BR9214	BR22/IR85260-66-769-Gaz2	Sub tol	6
BR9215	IR85260-66-769-Gaz2/BRRI dhan51	Sub tol.	5
BR9219	BRRI dhan52/ BRRI dhan51	Sub tol.	6
Total			17
	F_5		
BR9158	BRRI dhan44/BRRI dhan52	Submergence	5
BR9159	BRRI dhan49/BRRI dhan52	Submergence	6
BR9157	BRRI dhan33/BRRI dhan52	Submergence	10
BR9167	BRRI dhan44/Sambha Mahsuri-Sub1	Submergence	6
BR9169	BR10/ IR85260-391-148	Submergence	6
BR9170	BR10/Swarna-Sub1	Submergence	5
BR9173	IR75017-8-LBN-2-1/ IR85260-391-148	Submergence	6
BR9175	BR23/IR85260-391-148	Submergence	6
BR9176	IR68544-25-21-3-1-2/IR85260-391-148	Submergence	5
Total			55
	F_6		
BR8746	BR10/IR81213-246-237	Submergence	5
Total	5		
	F_7		
BR8448	BRRI dhan44/IR81213-246-237	Submergence	4
Total			4
	BC_2F_8		
BR8146	IR75852-208-8-B-B-HR1*2/IR75852-208-8-B-B-HR1	Submergence	6 bulk
BR8155	IR67518-B-1-2-B*2/MT6	Submergence	5 bulk
BR8156	IR67518-B-1-2-B*2/BM9855	Submergence	3 bulk
Total			14 bulk
	BC_1F_9		
RB7932	IR67518-B-1-2-B*2/BR11/	Submergence	5 bulk
Total			5 bulk
Grand total			127 PS +19 bulk

DS: 18 Jun 2013, DT: 21 Jul 2013, D/sub: 4 Aug 2013, D/de-sub: 20 Aug 2013.

tested entry out yielded over the check varieties. The yield and growth duration of all genotypes ranged from 2.54 to 4.81 t ha^{-1} and 128 days to 142 days respectively. The check variety BRRI dhan52 had the highest yield of 4.81 t ha^{-1}. Among the entries, IR09F130 and IR09F181 had the highest yield of 4.34 and 4.30 t ha^{-1} respectively (Table 6).

Mother trial with sub1 and stagnant genotypes under controlled submergence condition (PVS). Six submergence and medium stagnant water tolerant high yielding genotypes along with two standard check varieties were evaluated under controlled submergence condition in BRRI farm. The experiment was laid out in RCB design with three replications. Thirty-day-old seedlings were transplanted using 2-3 seedling per hill with 25- × 15-cm spacing. Check varieties BRRI dhan51 and BRRI dhan52 showed the highest survival percent (94.4%) followed by BR 7937-28-1(88.2%). All entries showed taller plant height. More or less similar tiller and panicle were observed among the entries. The check varieties BRRI dhan51 and BRRI dhan52 had the highest

Table 6. Performance of sub1 and stagnant flood tolerant genotypes in rainfed condition (PVS mother trial), BRRI RS, Rangpur, T. Aman 2013.

Genotype	Plant ht (cm)	Tiller hill^{-1}	Panicle hill^{-1}	Yield (t ha^{-1})	Maturity (day)
BR7937-28-1	133	10.7	9.8	3.85	134
IR09F130	117	10.3	9.3	4.34	128
IR09F181	121	10.9	9.9	4.30	129
IR09F173	124	10.6	9.3	3.85	134
IR09F365	116	10.7	9.2	3.51	134
IR09F119	107	9.1	8.5	2.54	134
BRRI dhan51 (ck)	121	11.6	10.3	4.74	142
BRRI dhan52 (ck)	126	11.4	10.0	4.81	140

DS: 20 Jun 2013, DT: 19 Jul 2013.

yield of 4.65 t ha^{-1} and 4.90 t ha^{-1} respectively. Among the tested entries, IR 09F119 and IR 09F130 had the highest yield of 4.05 t ha^{-1} and 4.10 t ha^{-1} respectively (Table 7) under controlled submergence condition.

PVS function

PVS function was arranged based on PVS mother trial for preference analysis during T. Aman 2013. A total of 37 farmers (male 27 and female 10) were participated in the voting activities. Each farmer cast two positive and two negative votes for the best and worst entries respectively according to their own choice (Table 8).

Preferential analysis

Most preferred. BRRI dhan52 and IR09F130 were chosen by most of the farmers in PVS function due to taller plant height, long and compact panicle, lodging resistant, early maturing.

Least preferred. IR09F173 and BRRI dhan51 got the lowest vote due to shorter plant, fewer tillers, shorter and less compact panicle, high sterility, poor yield and long duration.

On-farm mother trial under participatory variety selection (PVS). There were three on-farm PVS mother trials under Alambiditor, (Gangachara, Rangpur), Sarkerpara, (Nageswari,

Table 7. Performance of Sub1 and stagnant flood tolerant genotypes in submergence condition PVS mother trial, BRRI, Rangpur, T. Aman 2013.

Genotype	Survival (%)	Plant ht (cm)	Tiller hill^{-1}	Panicle hill^{-1}	Grain yield t ha^{-1}	Maturity (day)
BR7937-28-1	88.2	137.9	10.3	9.9	3.95	161
IR09F130	92.3	127.9	10.9	10.6	4.10	162
IR09F181	89.7	120.7	10.3	9.8	3.50	172
IR09F173	90.3	135.1	10.3	9.8	3.80	161
IR09F365	93.8	130.0	10.1	9.4	3.90	162
IR09F119	90.0	125.3	11.3	10.0	4.05	161
BRRI dhan51 (ck)	94.4	116.8	10.0	9.5	4.65	166
BRRI dhan52 (ck)	94.4	128.0	8.1	7.6	4.90	164
LSD$_{0.05}$	9.26	13.68	11.78	11.45	0.78	NS

Table 8. Total positive and negative votes in the PVS function at Alambiditor, Gangachara, mother trial under PVS, BRRI RS, Rangpur, T. Aman 2013.

Genotype	Male farmer		Female farmer		Total		Preference index	Yield (t ha^{-1})
	+ ve	-ve	+ ve	-ve	+ ve	-ve		
BR 7937-28-1	12	0	2	2	14	2	0.081	3.95
IR 09F130	15	2	1	0	16	2	0.095	4.10
IR 09F181	2	3	2	0	4	3	0.007	3.50
IR 09F173	0	21	0	2	0	23	-0.155	3.80
IR 09F365	5	8	0	4	5	12	-0.047	3.90
IR 09F119	0	4	1	7	1	11	-0.068	4.05
BRRI dhan51 (ck)	0	16	4	5	4	21	-0.115	4.65
BRRI dhan52 (ck)	20	0	10	0	30	0	0.203	4.90

Kurigram), and Tupamari, (Sadar, Nilphamari) districts. Seeding was done within 22-23 June and 30-day-old seedlings were transplanted from 21 to 25 July. There were flash flood at Gangachara, Rangpur (6 days) and Sadar, Nilphamari (10 days) but continued as stagnation up to 16 days. There was almost no flood at Nageswari, Kurigram. IR 09F365 and BR 7937-28-1 exhibited the lowest growth duration (132 days) followed by IR 09F181 (142 days). The highest grain yield was obtained from BRRI dhan52 (4.54 t ha^{-1}) followed by IR 09F130 (3.98 t ha^{-1}) and IR 09F173 (3.94 t ha^{-1}) At Sadar, Nilphamari BRRI dhan51 could not perform well (2.12 t ha^{-1}) (Table 9). BRRI dhan52 showed better performance in respect of survival percent and grain yield at every location (Table 10).

PVS function. On farm PVS was arranged with the mother trial of Sub1 entries at Alambiditor, Gangachara, Rangpur for preference analysis during T. Aman 2013. A total of 30 farmers (20 male and 10 female) participated in the activities. Each farmer cast two positive and two negative votes for the best and worst entries respectively according to their own choice (Table 11).

Preferential analysis

Most preferred. BRRI dhan52 and IR09F130 were chosen by most of the farmers in PVS function due to taller plant height, long and compact panicle, lodging resistant, early maturing.

Least preferred. IR09F119 and BRRI dhan51 got the lowest vote due to shorter plant, fewer tillers, shorter and less compact panicle, high sterility poor yield and long duration.

Participatory variety selection (PVS) baby trial. BRRI dhan51 and BRRI dhan52 were evaluated in farmers' field in submergence-prone areas. Ten farmers were selected and each farmer was supplied with one kilogram seed. At Gangachara and Aditmari seeds were damaged in seedbed due to early flooding. At Sayedpur, early

Table 9. Performances of Sub1 and stagnant genotypes with on-farm mother trial under PVS, BRRI RS, Rangpur, T. Aman 2013.

Genotype	Plant ht (cm)			Tiller hill^{-1}			Panicle hill^{-1}		
	L1	L2	L3	L1	L2	L3	L1	L2	L3
BR7937-28-1	155.8	135.6	139.7	11.7	8.6	10.8	11.1	8.3	10.8
IR09F130	126.5	130.3	123.6	10.2	10.7	12.7	9.9	9.8	11.9
IR09F181	129.9	129.7	121.7	7.5	7.3	11.0	7.3	7.4	10.4
IR09F173	130.4	128.5	118.2	8.9	9.2	11.1	8.6	8.6	10.5
IR09F365	119.3	118.1	117.3	10.1	12.0	11.1	9.9	10.9	10.5
IR09F119	137.5	127.5	131.1	11.3	7.7	13.3	10.4	7.3	12.6
BRRI dhan51 (ck)	119.5	111.5	102.9	12.6	8.9	14.0	11.9	8.5	13.3
BRRI dhan52 (ck)	136.9	131.9	126.3	9.9	7.9	9.1	9.4	7.4	8.5
LSD$_{0.05}$	2.98	2.77	5.60	1.87	1.52	1.85	1.70	1.36	1.75

L1=Alambiditor, Gangachara, Rangpur, L2=Tupamari, Sadar, Nilphamari, L3=Sarkerpara, Nageswari, Kurigram.

Table 10. Performances of sub1 and stagnant genotypes with on-farm mother trial under PVS, BRRI RS, Rangpur, T. Aman 2013.

Genotype	Survival percent			Grain yield (t/ha)			Day to maturity		
	L1	L2	*L3	L1	L2	L3	L1	L2	L3
BR7937-28-1	96.3	90.8	-	3.91	3.53	4.02	140	146	137
IR09F130	95.7	92.5	-	4.05	3.85	4.04	147	151	133
IR09F181	95.4	90.8	-	3.32	3.34	4.13	144	151	132
IR09F173	96.1	92.1	-	3.80	3.81	4.22	146	150	137
IR09F365	95.1	89.6	-	3.85	2.71	3.48	143	148	133
IR09F119	96.2	91.4	-	4.00	3.70	3.82	144	148	136
BRRI dhan51 (Ck)	97.8	87.3	-	4.60	2.12	4.46	149	153	141
BRRI dhan52 (Ck)	98.4	94.8	-	4.88	4.22	4.52	146	151	138
LSD$_{0.05}$	NS	0.22	-	0.35	0.31	0.35	1.94	NS	NS

L1=Alambiditor, Gangachara, Rangpur, L2=Tupamari, sadar, Nilphamari, L3=Sarkerpara, Nageswari, Kurigram. *No flood occurred.

flood was observed and few farmers got crops. In both the locations farmer's got the yield of BRRI dhan51 and BRRI dhan52 rangeed from 4.10 to 4.70 t ha^{-1}.

Adaptability of some submergence tolerant genotypes under flash flood prone environment. Four field trails in Rangpur region (Rangpur-1, Nilphamari-1, Lalmonirhat-1. Kurigram-1) were conducted under the management practices of researchers. Four genotypes (IR09F224, IR09F198, BRRI dhan51 and BRRI dhan52) were evaluated in farmers' field. The experiment was laid out in RCB design with three replications. About 30-35-day-old seedlings were transplanted using 2-3 seedlings per hill with the spacing of 20- × 20-cm. The unit plot size was 8- × 5-m. Fertilizers were applied @ 150 kg Urea, 112 kg TSP, 75 kg MoP, 50 kg gypsum and eight kg zinc sulphate ha^{-1}. Total amount of K, P, S and Zn and 1/3 urea were applied at the time of final land preparation. Rest of the urea was applied in two splits. Table 12 presents the flooding situation of different locations. The average yield of IR09F224, IR09F198, BRRI dhan51 and BRRI dhan52 were 4.75, 5.04, 5.18 and 6.05 t ha^{-1} respectively (Table 13). Among the varieties BRRI dhan52 was preferred by the farmers for the highest yield and attractive grain type.

Validation and dissemination of modern Boro varieties in Rangpur region. Four varieties were evaluated in farmers' field (Six locations: Rangpur-2, Nilphamari-2, Kurigram-1 and Lalmonirhat-1). The experiment was laid out in RCB design with three replications with 5.4 m × 20 rows plot. Tested entries were: PSBRC82, BRRI dhan28, BRRI dhan55 and BRRI dhan58. Forty-day-old seedlings of each genotype were transplanted using 2-3 seedlings/hill with 25- × 15-cm spacing. Fertilizer doses of urea, TSP, MoP, gypsum, ZnSO$_4$ were 270, 130, 150, 120, 8 kg ha^{-1}. N fertilizer was applied as top dress with three equal splits at 15, 30 and 45 DAT.

The average yield of PSBRC82, BRRI dhan28 BRRI dhan55 and BRRI dhan58 were 6.75, 7.00, 7.05 and 7.00 t ha^{-1} respectively. Among the varieties BRRI dhan28 was preferred by the farmers for their shorter growth duration and better yield. The highest average plant height of BRRI dhan28 was 105 cm (Table 14).

Preliminary yield trial
Evaluation of medium stagnant flood tolerant entries under controlled stagnant and rainfed conditions. Thirteen genotypes of IRRI along with one check variety were evaluated under controlled medium stagnant water depth and under rainfed

Table 11. Total positive and negative votes in the PVS function at Alambiditor, Gangachara, mother trial under PVS, BRRI RS, Rangpur, T. Aman 2013.

Code no.	Genotype	Male farmer		Female farmer		Total		Preference index	Yield (t ha^{-1})
		+ ve	-ve	+ ve	-ve	+ ve	-ve		
PVS 1	BR 7937-28-1	3	1	0	1	3	2	0.008	3.91
PVS 2	IR 09F130	9	0	8	0	17	0	0.142	4.05
PVS 3	IR 09F181	1	5	0	5	1	10	-0.075	3.32
PVS 4	IR 09F173	5	0	2	0	7	0	0.058	3.80
PVS 5	IR 09F365	0	7	3	2	3	9	-0.050	3.85
PVS 6	IR 09F119	2	7	0	8	2	15	-0.108	4.00
PVS 7	BRRI dhan51 (ck)	0	20	0	4	0	24	-0.200	4.60
PVS 8	BRRI dhan52 (ck)	20	0	7	0	27	0	0.225	4.88
Total		40	40	20	20	60	60	-	-

Table 12. Flooding situation at crop growing period of different locations of Rangpur.

Location	Flooding status			Water height
	First flood	2nd flood	3 rd flood	
Gangachara	12-19 August (8 days)	-	-	58 cm
Nilphamari	No flood	-	-	-
Lalmonirhat	No flood	-	-	-
Kurigram	1-4 August (4 days)	-	-	60 cm

Table 13. Average performance (Four trials) of the entries under validation trials in Rangpur region, T. Aman 2013.

Entry	Plant ht (cm)	Duration (day)	Grain yield (t ha^{-1})				
			Rangpur	Kurigram	Nilphamari	Lalmonirhat	Average
IR09F224	123	133	5.18	5.05	3.84	4.94	4.75
IR09F198	128	142	4.85	5.12	4.41	5.80	5.04
BRRI dhan51	101	148	5.20	5.55	3.77	6.21	5.18
BRRI dhan52	123	144	6.67	6.49	4.10	6.94	6.05

Table 14. Performance of four entries in validation trials, (Six locations) in Rangpur region, Boro 2014.

Genotype	Duration (day)	Average plant ht (cm)	Grain yield (t ha^{-1})
PSBRC82	147	93	6.75
BRRI dhan28	145	105	7.00
BRRI dhan55	150	96	7.05
BRRI dhan58	155	99	7.00

conditions. Medium stagnant water stress was applied at 10 DAT. Keeping 20-25 cm standing water at the early vegetative stages with gradual increase of water up to 45 cm at maximum tillering stage and this water level was maintained up to dough stage. Standing water was completely drained out at hard dough stage.

Yield under stagnant condition ranged from 2.45 to 3.70 t ha^{-1} and growth duration ranged from 139 to 175 days and yield under rainfed condition ranged from 3.39 to 4.26 t ha^{-1} and growth duration ranged from 127 to 154 days. Advanced line IR09F191 and IR09F187 gave 0.5 to 0.8 t ha^{-1} higher yield with 19-25 days earlier duration than the check variety BRRI dhan44 (Table 15).

Regional yield trial

A total of 12 regional yield trials were conducted under T. Aus, T. Aman and Boro seasons to develop rice varieties promising for partially irrigated, rainfed lowland (RLR), low inputs (GSR), disease and insect resistant (DRR), new plant type, premium quality (PQR), micronutrient and infiltrated varieties enriched against standard check varieties.

PVT (Dorshona)

A PVT trial was conducted to release standard Boro variety in Dorshona, Rangpur during 2013-14. Two advanced lines were evaluated with standard check BRRI dhan28.

Table 15. Performance of stagnant flood tolerant genotypes in rainfed and controlled stagnant conditions, BRRI RS, Rangpur, T. Aman 2013.

Genotype	Plant ht (cm)		Tiller hill^{-1}		Panicle hill^{-1}		Yield (t ha^{-1})		Duration (day)	
	Rnfd	Ctrl	Rnfd	Ctrl	Rnfd	Ctrl	Rnfd	Ctrl	Rnfd	Ctrl
IR 09F130	126.8	118.1	9.9	8.9	9.3	8.7	4.07	2.45	128	152
IR 09F165	111.7	110.6	8.6	9.6	8.2	9.1	4.14	2.59	128	149
IR 09F175	130.3	120.1	10.4	6.9	9.8	6.6	3.39	3.00	154	171
IR 09F177	123.8	119.9	9.3	11.2	8.9	11.0	4.09	3.00	154	175
IR 09F181	128.5	122.9	7.8	8.8	7.4	8.8	4.15	3.43	129	149
IR 09F186	113.2	111.8	11.3	10.7	10.7	10.3	4.26	2.64	129	144
IR 09F187	121.3	119.6	10.6	11.5	9.2	11.2	*3.49	3.70	127	143
IR 09F188	122.3	132.0	9.6	11.0	8.6	10.7	4.02	2.46	128	151
IR 09F202	120.0	133.2	9.3	8.3	8.6	8.1	3.58	2.61	128	149
IR 09F203	123.1	126.1	9.9	10.5	8.8	10.3	3.53	2.88	134	152
IR 09F220	119.4	119.3	9.8	8.2	8.9	8.0	3.90	3.06	136	148
IR 09F222	116.9	110.8	9.4	9.5	9.1	9.2	3.87	2.86	130	139
IR 09F224	125.3	124.6	7.7	7.2	7.5	6.8	3.93	3.16	127	148
BRRI dhan44 (ck)	136.8	134.9	8.4	7.9	8.1	7.8	5.02	2.88	144	168
LSD $_{0.05}$	9.45	16.41	2.07	2.76	1.88	2.58	0.73	1.09	3.33	0.88

Rnfd=rainfed. Ctrl=control. *Twenty percent were rat damaged. DS: 21 Jun 2013, DT: 20 Jul 2013.

CROP-SOIL-WATER MANAGEMENT

Rice yield maximization through nutrient management in Rangpur region

The experiment was conducted at BRRI RS farm, Rangpur during T. Aman 2013 and Boro 2013-14 seasons. The treatments were- T_1=Soil test based (STB), T_2=STB + Copper and Manganese ((@ 1.25 and 2.5 kg/ha), T_3=2.5 t ha^{-1} decomposed poultry litter (PL), T_4=2.5 t ha^{-1} fresh PL, T_5=USG and T_6=LCC.

Copper and Manganese, which said to reduce percent sterility, were applied at maximum tillering stage of T. Aman rice and at maximum tillering and panicle initiation (PI) stages of Boro rice. Thirty-day-old seedlings of BRRI dhan52 were transplanted on 18 July 2013 during T. Aman season and 45-day-old seedlings of BRRI dhan29 were used in Boro season and were transplanted on 9 January 2014.

T. Aman. Treatment T_2 produced more tillers, panicles and longer panicle than the other treatments during T. Aman. Thousand grain weight was significantly the highest in T_3 treatment, which was followed by T_5 treatment. Significantly the lowest sterility percentage (17.54%) was observed in T_2 treatment and the highest (31.48%) of that was in T_6 treatment, which indicate that application of copper and manganese might reduced the sterility percentage but it didn't reflect on grain yield. Significantly the highest grain yield was observed in T_3 treatment, which was followed by T_1 and the lowest of that was obtained in T_5 treatment.

Tiller production was the highest at 60 DAT and then it decreased with the progress of crop growth. The lowest number of tiller was recorded at maturity. At 60 DAT T_6 produced the highest number of tillers and that trend was maintained up to maturity. Plant dry weight was the highest at 75 DAT and the lowest of that was at 30 DAT. Treatment T_5 produced the highest plant dry matter.

Boro. During Boro season, tiller and panicle production, percent sterility and grain yield were significantly influenced by nutrient management. The highest number of tillers was produced in T_2, followed by T_1 while the lowest of that was in T_6.

The similar trend was observed regarding panicle production. Percent sterility was the lowest in T_2 and the highest of that was in T_6. Higher percent sterility was also recorded in T_3 and T_5. Application of copper and manganese had an influence to reduce percent sterility but grain yield was not increased. Grain yield was the highest in T_1 followed by T_2 and T_3. The lowest grain yield was obtained in T_6 treatment.

Evaluation of BRRI prilled urea applicator

The experiment was conducted at BRRI RS farm, Rangpur. Four N management treatments were tested. These were: T_1=Hand broad casting of prilled urea (recommended rate), T_2=Prilled urea application by applicator (70% of T_1), T_3=USG application by applicator (2.7 g/4 hills) and T_4=Control (-N).

The design of the experiment was RCB with three replications. Fertilizers dose was 220 kg Urea, 100 kg TSP, 115 kg MoP, 75 kg gypsum and 8 kg ZnSO$_4$ ha^{-1}. All fertilizers except urea were applied at final land preparation. Hand broadcasting of prilled urea (T_1) was applied in three equal splits at 15 days after transplanting (DAT), 30 DAT and 45 DAT. Application of prilled urea (T_2) and USG (T_3) were done by applicator at two days after transplanting.

Hand broadcasting of prilled urea (recommended rate) gave the highest tiller per hill (17) followed by T_2 (13). Like tiller number the highest panicles hill^{-1} (16) was found in T_1 followed by T_2 (12). Among the different N management options, 1000-grain weight was found identical. Hand broadcasting of prilled urea (recommended rate) gave the highest grain yield of 5.89 t/ha followed by prilled urea (5.77 t/ha) application by applicator (70% of total urea). The N control treatment gave the lowest yield of 2.87 t/ha in BRRI farm, Rangpur.

Identification of location specific rice cultivation problem and minimizing rice yield gap through BRRI technologies (MRYG Project)

The experiment was conducted during T. Aman 2013 at three upazilas of Dinajpur district and at Parbotipur upazila of Dinajpur district during Boro

2013-14. BRRI dhan49 was grown at Dinajpur sadar and BRRI dhan52 was grown at Fulbari and Parbotipur upazilas within 66 decimal area of each farmer/upazila. During Boro, the tested variety was BRRI dhan58. There were two treatments or practices such as BRRI recommended practice and farmers' practice. Seeds were sown between 19-22 June during T. Aman 2013.

In T. Aman, BRRI dhan49 yielded 5.82 t/ha at Dinajpur sadar upazila using BRRI recommended practices. Whereas, BRRI dhan49 gave 5.74 t/ha using farmers' practices. BRRI dhan52 yielded 5.76 and 4.67 t ha^{-1} using BRRI recommended practices at Fulbari and Parbotipur upazila respectively. On the other hand, BRRI dhan52 obtained 5.62 and 4.38 t ha^{-1} yield using farmers practices at Fulbari and Parbotipur upazilas. Yield of farmers' practices was comparatively low because they used old seedlings, imbalanced fertilizer, wider spacing and were reluctant to follow recommended pest management techniques at the right time. BRRI recommended practice increased grain yield 3.5% over farmers' practices.

In Boro, BRRI dhan58 yielded 8.16 t ha^{-1} using BRRI recommended practices, whereas BRRI dhan58 gave 7.71 t ha^{-1} using farmers' practices. Yield of farmers' practices was comparatively low because they used imbalanced fertilizer and reluctant to follow recommended pest management techniques timely. BRRI recommended practice increased average grain yield by 5.83% over farmers practices. Farmers were very much interested to grow this variety in next Boro season due to its high yield potential, phenotypic acceptance at flowering and maturity stage, growth duration, disease and insect pest reaction, usually where they cultivated BRRI dhan29.

TECHNOLOGY TRANSFER

Expansion and dissemination of submergence tolerant varieties in submergence prone areas. Seeds of BRRI dhan51 and BRRI dhan52 were distributed in farmers' fields in submergence-prone areas of Rangpur and Lalmonirhat districts through GO and NGO. Each farmer was supplied 1 kg seed of each variety together with a Bangla leaflet on cultivation technique. Farmers got better yield from both the varieties that ranged from 4 to 5 t ha^{-1}.

On-station seed production activity for dissemination of submergence tolerant varieties in submergence prone areas. Seeds of BRRI dhan51 and BRRI dhan52 were transplanted in on-station for distributing farmers field of submergence prone areas through GO and NGO in next season. About 110 kg of BRRI dhan51 and 100 kg of BRRI dhan52 seeds were harvested.

Demonstration of modern T. Aus varieties in Rangpur region 2013. A varietal trial in six farmers' field at six locations of Rangpur region (Rangpur-2, Nilphamari-2, Lalmonirhat-1. Kurigram-1) was conducted in Aus season using four genotypes (BRRI dhan28, BRRI dhan48, BRRI dhan55 and Pariza). The experiment was laid out in RCB design with three replications. Around 20-25-day-old seedlings were transplanted using 2-3 seedlings hill^{-1} with 20- × 15-cm spacing. The unit plot size was 8- × 5-m. Fertilizers were applied @ 128 kg urea, 53 kg TSP, 61 kg MoP, 37 kg gypsum and 8 kg zinc sulphate ha^{-1}. Total amount of K, P, S and Zn and 1/3 urea was applied at the time of final land preparation. Rest of the urea was applied in two splits.

Average grain yield of BRRI dhan28, BRRI dhan48, BRRI dhan55 and Pariza were 3.97, 4.21 3.77 and 2.9 t ha^{-1} respectively. Among the varieties BRRI dhan48 was preferred by the farmers due to better yield.

Short duration Aman rice varieties for increasing cropping intensity in Rangpur region. A varietal trial in four farmers' field in Rangpur region (Rangpur-2, Nilphamari-1, Lalmonirhat-1.) was conducted using four genotypes (BRRI dhan62, BRRI dhan56, BRRI dhan33 and IR82475). The experiment was laid out in RCB design with three replications. Fertilizers were applied @ 164 kg urea, 90 kg TSP, 60 kg MoP, 52 kg gypsum and 8 kg zinc sulphate ha^{-1}.

BRRI dhan56 produced the highest number of panicle plant^{-1} (11) and the lowest panicle plant^{-1}

(9) was produced by BRRI dhan33 and IR82475. The grains panicle^{-1} of BRRI dhan62, BRRI dhan56, BRRI dhan33 and IR82475 were 99, 113, 100 and 114 respectively. The highest grain yield (5.40 t ha^{-1}) was observed by IR82475 followed by BRRI dhan56 (4.65 t ha^{-1}). Almost similar grain yield (3.70 t ha^{-1}) was found in BRRI dhan62 and BRRI dhan33. BRRI dhan62 was early maturing (103 days) than the other varieties (112-115 days).

Demonstration of DSR techniques using short duration varieties during T. Aman (IAPP). A total of 10 demonstration trials were conducted in six upazilas of four districts during Aman 2013 with dry DSR using BRRI dhan33 and BRRI dhan56. Sowing was completed from 12-20 July. Forty kg ha^{-1} seed was used. Urea 170-TSP 56-MOP 80-gypsum 60-ZnSO$_4$-7.5 kg ha^{-1} fertilizers were applied. Herbicide glyphosate @ 3.0 L ha^{-1} was applied at 5-7 days before sowing. Pendimethylene @ 1.5 L ha^{-1} was applied at 2-3 days after sowing. Urea was applied as 1/3 basal and the rest 1/3 was top dressed at 20 and 40 DAS.

The highest grain yield was found in BRRI dhan56 followed by BRRI dhan33. With BRRI dhan56, the highest grain yield was found in Nilphamari sadar followed by Aditmari, Lalmonirhat, Mithapukur, Rangpur and Kurigram sadar. In case of BRRI dhan33, the highest grain yield was found in Mithapukur, Rangpur followed by Aditmarti, Lalmonirhat and Jaldhaka, Nilphamari. The farmer's reaction about BRRI dhan56 was highly positive and they did not like BRRI dhan33 due to high BPH infestation.

Demonstration of submergence tolerant varieties in T. Aman 2013. A total of four demonstration trials were conducted in three upazilas of Kurigram district during Aman 2013 with submergence tolerant varieties (BRRI dhan51 and BRRI dhan52). Urea 195-TSP 52-MoP 82-gypsum 60-ZnSO$_4$ 7.5 kg/ha was applied. All fertilizers were applied as basal except urea; 1/3 urea top dress was done at 15-20 DAT, 1/3 at 30-35 DAT and 1/3 at 50 DAT.

There is no flood at Nagessori and Ulipur during crop growth period, but at Fulbari, there was flash flood from 20 September to 24 September. In submergence tolerant variety trials, the highest grain yield was found in BRRI dhan52 followed by BRRI dhan51. In case of BRRI dhan52, the highest grain yield was found in Nageshory Kurigram followed by Ulipur and Foubari Kurigram. In case of BRRI dhan51, the highest grain yield was found in Nageshory, Kurigram followed by Fulbari and Ulipur, Kurigram. Farmers preferred BRRI dhan52 and they did not like BRRI dhan51 due to shorter plant height and poor phenotypic acceptance.

Varietal trials of newly released BRRI varieties in Boro 2013-14. A varietal trial was conducted in farmers' plot during Boro 2013-14 under IAPP project. Two popular (BRRI dhan28 and BRRI dhan29) and two newly released varieties (BRRI dhan58 and BRRI dhan59) were used in this trial. The demonstration trail was conducted in ten farmers' fields of different upazila under Rangpur, Nilfamari, Lalmonirhat and Kurigram districts. Urea 280-TSP 80-MoP 90-gypsum 70-ZnSO$_4$ 7.5 kg ha^{-1} were applied. All fertilizers except urea were applied as basal during final land preparation. Urea was applied in three equal splits as top dress (at 20, 40 and 60 DAT). Each farmer was treated as a replication. Pre-emergence herbicide Pretilachlor was applied @ 1 L ha^{-1} at 5-6 DAT. Carbofuran 5G was applied at 30-35 DAT @ 10 kg ha^{-1}. The short duration variety BRRI dhan59 gave higher grain yield than BRRI dhan28. The long duration variety BRRI dhan29 gave higher grain yield than BRRI dhan58. BRRI dhan28 and BRRI dhan59 gave the highest grain yield in Kurigram district followed by Nilghamari, Lalmonirhat and Rangpur district. BRRI dhan29 and BRRI dhan58 gave the highest grain yield in Nilphamari followed by Kurigram, Lalmonirhat and Rangpur district. The farmer's reaction on BRRI dhan58 and BRRI dhan59 was positive but it was negative on BRRI dhan58 due to neck blast in some areas.

Enhancing Quality Seed Supply Project (EQSSP)
BRRI regional station, Rangpur conducted 10 varietal demonstrations with BRRI dhan58 at 10 upazilas of four districts (Dinajpur-3, Nilphamari-1, Kurigram-2 and Rangpur-4) during the Boro season 2013-14. The variety demonstrations were within 33 decimal area of each farmer's plot.

BRRI recommended management practices were followed. In addition, daylong 10 farmers' training and 10 field days were conducted at 10 upazilas.

About 300 farmers (Male-250 and female-50) participated and gathered knowledge on modern rice cultivation techniques from those training programmes. At the time of field day in all locations, Farmers' showed positive response and expressed their interest to grow this variety in upcoming Boro season. Yield of BRRI dhan58 ranged from 6.7 to 9.0 t ha^{-1} which was higher than the mega variety BRRI dhan28 (6.0-7.0 t ha^{-1}) but similar to BRRI dhan29 with 7-10 days earlier.

Seed production and dissemination

A total of 5,301 kg TLS and 1,600 kg breeder seed was produced during Aman and 6,405 kg TLS and 4,290 kg breeder seed was produced during Boro season. A total of 3,151 kg TLS in Aman and 4,343 kg in Boro was sold among different organizations and farmers in this region.

BRRI RS, Satkhira

SUMMARY

Six regional yield trials (RYT) were conducted in BRRI RS farm, Satkhira during Boro season 2013-14. In RYT-cold, IR77496-31-2-1-3-1 showed the highest yield (7.71 t ha^{-1}) among the tested eight genotypes, but there was no statistical difference with other entries. In the RYT-GSR, HUANGHUA ZHAN yielded the highest (7.99 t ha^{-1}) which was statistically different with IR8140-B28-B but statistically similar with other eight entries. In eight entries of RYT-PQR, BR7376-19-1-6-1 showed the highest yield (6.81 t ha^{-1}) and BR7376-19-2-1-1 showed the lowest yield (5.48 t ha^{-1}). In the trial of RYT-MDR, the entry BR7830-16-1-5-9-9 was significantly higher yielder (8.04 t ha^{-1}) than the tested entries except BR7833-11-1-1-3-4 and standard check BRRI dhan28. Among six entries of RYT-DR, the highest yielder was BR7986-29-4 (8.11 t ha^{-1}). The yields of the entries were very close. In case of RYT-FB, BRRI dhan28 yielded the highest (7.14 t ha^{-1}) and BRRI dhan55 the lowest (6.05 t ha^{-1}), but there was no statistical difference among the entries.

Three PVS trial was conducted during Boro 2013-14. In all the cases, the best yield performance was found in BRRI dhan47 (6.69 t ha^{-1}).

Proposed variety trial (PVT) were conducted during Boro 2013-14 in eight locations under different upazilas of Khulna and Satkhira district. BR7100-R-6-6-1(V1) genotype yielded higher than IR78794-B-Sat29-1(V2) and standard check BRRI dhan47 irrespective of location except Batiaghata, Khulna. In Batiaghata the salinity was 18.5 dS/m at maturity and IR78794-B-Sat29-1 yielded the highest (3.90 t ha^{-1}) among the tested genotypes.

In cropping pattern trial, BRRI dhan47 yielded the highest (8.90 t/ha) though it showed no statistically significant difference with the other varieties. The lowest yield (7.61 t ha^{-1}) was found in BRRI dhan55.

In long-term missing element trial at on station, omission of N from complete treatment (NPKSZn) gave significantly lower yield. Omission of P, K, S and Zn also reduced the yield slightly. Therefore, to get desired yield, balance fertilization of NPKSZn emphasizing on N is necessary.

In the stability analysis of BRRI released Boro varieties, the highest yield was obtained from BR6 and the lowest from BR12, but all the varieties yielded more than 4 t ha^{-1} where most of the varieties yielded more than 5 t ha^{-1}.

A total of 11 tons breeder seed was produced in Boro 2013-14 where BRRI dhan28, BRRI dhan29 and BRRI dhan58 had 5, 2 and 4 tons respectively.

A total of 16 tons TLS was produced in Boro and Aus 2013-14. TLS of BRRI dhan28, BRRI dhan47, BRRI dhan48, BRRI dhan55, BRRI dhan58 and BRRI dhan61 were 1.95, 0.62, 5.58, 2.10, 1.91 and 4 tons respectively.

A total of 5.87 tons quality seeds of BRRI dhan48 were produced in Aus 2014 under SPDP in the farmers' field funded by EQSS project. The farmers retained about three tons seeds for next season and 451 farmers were motivated to grow this variety for the next year.

Twenty farmer's training programmes on rice production technology were conducted to train up $(30 \times 20) = 600$ participants of Satkhira and Khulna district. Ten field days were arranged at different upazilas of Khulna and Satkhira districts, BRRI RS, Satkhira farm as well. One regional workshop was arranged to highlight the research activities, progress of BRRI regional station, Satkhira and removal of unsettlers under Binerpota farm.

VARIETAL DEVELOPMENT

Regional yield trial for Boro Season

Six RYT were conducted at BRRI RS farm, Satkhira in Boro 2013-14 following RCB design with three replications using 2-3 forty-five-day-old seedlings hill^{-1}. The unit plot size was 5.4- $\times$ 3-m with spacing of 25- $\times$ 20-cm. Fertilizer rate was 260, 100, 120, 110, 10 kg urea, TSP, MoP, gypsum and zinc sulfate per hectare respectively. Urea was applied in three splits of 100, 80 and 80 kg at 15 days after transplanting (DAT), 30 DAT and 5 days before P1 stages. Other fertilizers were

applied at final land preparation. The recommended cultural practices were followed.

RYT-COLD. Among the eight entries, IR77496-31-2-1-3-1 produced the highest yield (7.71 t ha^{-1}) followed by IR2266-42-6-2 (7.34 t ha^{-1}) with similar growth duration of BRRI dhan28 but there was no statistical difference with other entries including BRRI dhan28 and BRRI dhan55 (Table 1). On the contrary, BRRI dhan29 produced the lowest grain yield (6.57 t ha^{-1}). Yield performance and adaptability of IR77496-31-2-1-3-1 and IR2266-42-6-2 genotypes are better than BRRI dhan28 and BRRI dhan55.

RYT-GSR. HUANGHUA ZHAN yielded the highest (7.99 t ha^{-1}) followed by HHZ5-SAL10-DT1-DT1 with more or less similar growth duration compared to BRRI dhan28 (Table 1). HUANGHUA ZHAN could be selected for further progress.

RYT-PQR. Among eight entries, BR7376-19-1-6-1 yielded the highest (6.81 t ha^{-1}) followed by BR7358-35-3-2-1 (6.75 t ha^{-1}) where as the other entries yielded less than the check varieties BRRI dhan28 and BRRI dhan50 (Table 1). Both BR7376-19-1-6-1 and BR7358-35-3-2-1 showed higher growth duration compared to BRRI dhan28 but more or less similar to BRRI dhan50 and these entries could be selected as better genotypes.

RYT-MDR. BR7830-16-1-5-9-9 yielded significantly higher (8.04 t ha^{-1}) than the tested entries except BR7833-11-1-1-3-4 and BRRI dhan28 (Table 1) Considering all attributes, BR7830-16-1-5-9-9 and BR7833-11-1-1-3-4 could be selected for variety release process.

RYT-DR. Among the tested entries the highest yielder was BR7986-29-4 (8.11 t ha^{-1}) with growth duration similar to BRRI dhan28 (Table 1). Regardless disease reaction (since disease resistance was not measured), BR7986-29-4 could be a better genotype.

RYT-FB. BRRI dhan28 yielded the highest (7.14 t ha^{-1}) among the tested entries, which is statistically similar with other entries but different with BRRI dhan55 (Table 1). The tested genotypes may not be suitable for this region.

Participatory variety selection (PVS) for Boro season
Twelve most promising genotypes suitable for saline prone area were selected for this trial. The trial was conducted at BRRI Binerpota farm and farmer's field in the salt affected areas in Ashasuni and debhata of Satkhira district. Forty-five-day-old seedlings were transplanted using 2-3 seedlings per hill with 25- × 15-cm spacing. The unit plot size was 5.4- × 2.5-m with two replications. Fertilizer dose was applied at a rate of 120-60-40 kg N-P-K ha^{-1}

Table 1. Yield and yield contributing characters with growth duration of different entries (RYT-COLD, RYT-GSR, RYT-PQR, RYT-MDR, RYT-DR and RYT-FB) during Boro 2014.

Designation	Plant ht (cm)	PACP	Tiller hill^{-1}	Panicle hill^{-1}	Yield (t ha^{-1})	Growth duration (day)
			RYT-COLD[a]			
IR77496-31-2-1-3-1	88.2	3	19	14	7.71	133
IR2266-42-6-2	106.8	7	15	13	7.34	136
BR7812-19-1-6-1-P4	95.2	5	19	14	6.75	133
BR7813-1-1-1-3-1	104.2	5	20	13	6.97	130
BR8245-2-1-4	109.8	4	17	12	6.64	144
BRRI Dhan28	99.8	4	21	14	6.82	132
BRRI Dhan29	104.2	4	19	13	6.57	144
BRRI Dhan55	95.6	4	19	11	6.87	135
CV%	1.99	-	-	12.2	7.58	-
LSD (0.05)	3.49	-	-	2.78	0.93	-
			RYT-GSR[b]			
IR8140-B28-B	93.03	6	15	12	6.41	131
IR83142-B-19-B	95.36	4	14	12	6.66	132
IR83142-B-60-B	97.20	4	14	12	6.89	133
HHZ5-SAL10-DT1-DT1	107.56	5	14	12	7.89	130
HUANGHUA ZHAN	93.73	2	13	12	7.99	137
HHZ17-DT6-Y1-DT1	96.83	4	16	11	7.12	137
HHZ17-Y16-Y3-Y2	103.83	4	13	12	7.24	144

Table 1. Continued.

Designation	Plant ht (cm)	PACP	Tiller hill⁻¹	Panicle hill⁻¹	Yield (t ha⁻¹)	Growth duration (day)
HHZ23-DT16-DT1-DT1	98.96	3	17	11	7.63	144
HHZ12-SAL2-Y3-Y2	106.53	5	15	11	7.62	139
BRRI Dhan28 (ck)	96.53	5	15	12	7.81	132
CV%	1.22	-	-	10.89	11.16	-
LSD (0.05)	2.07	-	-	2.18	1.40	-
RYT-PQR[c]						
BR7781-10-2-3-2	104.85	5	18	13	6.47	132
BR7376-19-1-6-1	109.80	6	13	12	6.81	143
BR7376-19-2-1-1	115.71	5	15	12	5.48	143
BR7369-10-5-2-3	90.40	5	15	13	6.47	135
BR7358-35-2-1-1	88.85	4	16	13	6.08	135
BR7358-35-3-2-1	100.55	5	16	14	6.75	139
BRRI Dhan28 (ck)	84.90	5	14	12	6.60	130
BRRI Dhan50 (ck)	91.58	4	16	12	6.50	137
CV%	1.21	-	-	7.68	8.76	-
LSD (0.05)	2.08	-	-	1.70	0.98	-
RYT-MDR[d]						
BR7881-10-1-5-3-1	87.46	5	15	13	6.23	135
BR7833-11-1-1-3-4	91.66	3	16	14	7.43	132
BR7669-11-1-2-8-2	92.50	3	16	12	6.95	133
BR7830-16-1-5-9-9	88.83	3	14	11	8.04	135
BR7833-11-1-1-2-1-2B5	100.13	5	15	12	6.03	129
BRRI dhan28 (ck)	112.00	4	15	12	7.44	131
BRRI dhan60 (ck)	93.40	5	17	12	6.78	132
CV	1.67	-	-	9.97	7.02	
LSD	2.87	-	-	2.19	0.87	
RYT-DR[e]						
BR7986-2-3	109.40	5	15	12	7.54	134
BR7986-7-4	114.86	4	16	13	7.91	134
BR7986-29-4	109.86	3	16	14	8.11	133
BR7806-18-1-2	113.80	5	16	13	7.74	137
BRRI dhan28 (ck)	110.86	5	17	13	7.25	133
BRRI dhan29 (ck)	110.80	5	16	13	7.70	147
CV%	2.32	-	-	11.32	5.08	-
LSD (0.05)	4.71	-	-	2.69	0.71	-
RYT-FB[f]						
BR7988-10-4-1	94.93	4	15	12	6.23	132
BR7800-63-1-7-3	105.43	3	13	10	6.97	132
BRRI dhan28(ck)	103.40	3	16	12	7.14	134
BRRI dhan55(ck)	95.80	5	13	11	6.07	137
CV (%)	3.79	-	-	10.83	7.95	
LSD (0.05)	7.56	-	-	2.45	1.05	

[a]DS : 14 Dec 2013, DT : 20 Jan 2014. [b]DS : 14 Dec 2013, DT : 21 Jan 2014. [c]DS : 14 Dec 2013, DT : 22 Jan 2014. [d]DS : 14 Dec 2013, DT : 22 Jan 2014. [e]DS : 14 Dec 2013, DT : 22 Jan 2014. [f]DS : 14 Dec 2013, DT : 22 Jan 2014.

respectively. Gypsum and $ZnSO_4$ was applied at a rate of 100 and 10 kg ha⁻¹ respectively. N was applied in three splits. Total amount of P, K, gypsum and $ZnSO_4$ was applied at final land preparation. Other cultural management was done as and when necessary. Around 110 farmers participated in PVS activities. The crop was harvested and selected by active participation of farmers.

PVS at BRRI RS farm, Satkhira. The average best yield (6.69 t ha⁻¹) performance was found in BRRI dhan47 followed by IR78767-B-SDO1-3-AJY2 at BRRI Binerpota farm (Table 2). The field was in the non-saline area.

PVS at Ashashuni, Satkhira. The best yield (5.36 t ha⁻¹) performance was found in IR83484-3-B-7-1-1-1 followed by standard check BRRI

Table 2. Yield performance of PVS genotypes at BRRI RS farm, Nawapara Ashasuni and Kulia Debhata, Satkhira, Boro 2013-14.

Genotype	Growth duration (day)	Plant ht (cm)	Tiller hill[-1]	Yield (t ha^{-1})
BRRI RS farm, Satkhira[a]				
IR77660-B-9-1-3-2-1-17-4-1	142	100	15	5.55
IR77674-3B-8-2-2-8-2-AJY6	143	114	10	5.81
IR78767-B-SDO1-3-AJY2	140	117	13	6.02
IR83484-3-B-7-1-1-1	146	116	11	5.41
IR86385-117-3-1-B	140	94	13	5.45
IR86385-184-1-1-B	144	109	12	5.26
IR83415-B-SDO3-3-AJY4	139	101	12	5.42
IR86385-117-1-1-B	143	104	11	4.91
IR83440-4-B-11-2-1-1-AJY1-B	141	104	8	4.72
IR84649-308-7-1-B-AJY1-B	140	101	13	5.39
BRRI dhan47 (ck)	145	107	11	6.69
BRRI dhan61 (ck)	145	93.5	17	5.92
Nawapara Ashasuni[b]				
IR77660-B-9-1-3-2-1-17-4-1	141	70	11	4.62
IR77674-3B-8-2-2-8-2-AJY6	143	81	9	0.00
IR78767-B-SDO1-3-AJY2	146	72	11	4.75
IR83484-3-B-7-1-1-1	145	85	11	5.36
IR86385-117-3-1-B	144	73	11	4.53
IR86385-184-1-1-B	146	87	8	3.88
IR83415-B-SDO3-3-AJY4	144	80	9	3.27
IR86385-117-1-1-B	147	84	10	3.85
IR83440-4-B-11-2-1-1-AJY1-B	146	80	9	3.77
IR84649-308-7-1-B-AJY1-B	145	83	9	3.86
BRRI dhan47 (ck)	146	93	9	5.17
BRRI dhan61 (ck)	147	82	10	4.87
Kulia Debhata[c]				
IR77660-B-9-1-3-2-1-17-4-1	137	90	12	7.72
IR77674-3B-8-2-2-8-2-AJY6	138	95	11	7.24
IR78767-B-SDO1-3-AJY2	136	101	12	7.82
IR83484-3-B-7-1-1-1	142	105	14	7.14
IR86385-117-3-1-B	142	90	12	6.97
IR86385-184-1-1-B	142	91	13	6.24
IR83415-B-SDO3-3-AJY4	140	92	10	5.96
IR86385-117-1-1-B	141	81	14	6.85
IR83440-4-B-11-2-1-1-AJY1-B	140	96	14	7.29
IR84649-308-7-1-B-AJY1-B	141	92	12	6.91
BRRI dhan47 (ck)	145	99	9	8.05
BRRI dhan61 (ck)	144	81	12	8.30

[a]DS: 12 Dec 2013; DT: 19 Jan 2014. [b]DS : 7 Dec 2013, DT : 12 Jan 2014. [c]DS : 7 Dec 2013, DT : 8 Jan 2014.

dhan47 (Table 2). The salinity varied between 04.00 and 10.50 dS/m (Table 3). The salinity was high at the beginning and at the end of the season. This change in salinity might be due to the amount and frequency of rainfall in this area.

PVS at Debhata, Satkhira. At Kulia of Debhata upazila, BRRI dhan61 yielded the highest followed by BRRI dhan47 and IR78767-B-SDO1-3-AJY2 (Table 2). The farmer's preference and the yield performance of the genotypes have been correlated with some exceptions. Water salinity of the experimental plots was stable over the growing period and was found from 2.80 dS/m to 3.30 dS/m (Table 3).

Proposed variety trial (PVT) in Boro Season
Field evaluation of two genotypes has been completed during Boro 2014 in PVT trials at seven locations. Forty-five-day-old seedlings were transplanted using 2-3 seedlings hill[-1] with 25- × 15-cm spacing. The unit plot size was 5.4- × 3-m with three replications. Fertilizer dose was applied at a rate of 120-60-40 kg N-P-K ha^{-1} respectively. Gypsum and $ZnSO_4$ was applied at a rate of 100

Table 3. Salinity (dS/m) data of PVS at Ashashuni and Debhata during Boro 2014.

Date	EC (dS/m)	
	Ashashuni	Kulia, Debhata
12 Aug 14	10.50	3.20
25 Aug 14	6.50	3.30
9 Sep 14	7.50	2.80
23 Sep 14	4.00	2.06
13 Oct 14	7.90	3.30
21 Oct 14	9.05	3.00
25 Oct 14	9.45	3.10

and 10 kg ha^{-1} respectively. N was applied in three splits. Total amount of P, K, gypsum and $ZnSO_4$ was applied at the final land preparation. Other cultural managements were done as and when necessary.

BR7100-R-6-6-1 yielded higher than IR78794-B-Sat29-1 and standard check BRRI dhan47 irrespective of location except Batiaghata, Khulna. In Batiaghata, IR78794-B-Sat29-1 yielded the highest (3.90 t ha^{-1}) though the salinity was 18.5 dS/m at maturity (Table 4). Table 5 presents salinity status in PVT fields during the growing season.

RICE FARMING SYSTEMS

Evaluation of T. Aman and Boro varieties against salinity in Boro-Fallow-T. Aman cropping pattern

This experiment was conducted during T. Aman and Boro 2013-14 season at Binerpota farm. Four Boro varieties were tested in Boro-Fallow-T. Aman cropping pattern following RCB design with three replications. T. Aman was lost due to heavy rainfall and water logging. Management practices were done as per BRRI recommendation.

In Boro season, BRRI dhan47 yielded the highest (8.90 t ha^{-1}) though it was not statistically significant with other varieties and salinity was less than 3 dS/m (2.95 dS/m) throughout the year. The lowest yield (7.61 t ha^{-1}) was found in BRRI dhan55 (Table 6).

CROP-SOIL-WATER MANAGEMENT

Long-term missing element trial at Satkhira
The experiment was started on a permanent layout

Table 4. Yield performance of PVT genotypes at different upazilas of Khulna and Satkhira districts, Boro 2014.

Variety/Line	Maturity (day)	Growth duration (day)	Yield (t ha^{-1})	Salinity (dS m^{-1}) at days to maturity
BRRI RS farm, Satkhira				
BR7100-R-6-6-1	21 Apr 14	142	7.48	2.95
IR78794-B-Sat29-1	18 Apr 14	139	7.25	
BRRI dhan47	23 Apr 14	143	7.44	
Ashasuni, Satkhira				
BR7100-R-6-6-1	23 Apr 14	143	6.94	5.66
IR78794-B-Sat29-1	20 Apr 14	140	6.51	
BRRI dhan47	23 Apr 14	143	6.40	
Tala, Satkhira				
BR7100-R-6-6-1	26 Apr 14	146	7.27	3.80
IR78794-B-Sat29-1	23 Apr 14	143	6.62	
BRRI dhan47	25 Apr 14	145	7.16	
Debhata, Satkhira				
BR7100-R-6-6-1	23 Apr 14	143	5.97	4.58
IR78794-B-Sat29-1	20 Apr 14	140	5.62	
BRRI dhan47	22 Apr 14	142	5.79	
Dacope, Khulna				
BR7100-R-6-6-1	20 Apr 14	140	5.29	9.90
IR78794-B-Sat29-1	15 Apr 14	135	4.32	
BRRI dhan47	19 Apr 14	139	4.32	
Batiaghata, Khulna				
BR7100-R-6-6-1	20 Apr 14	140	3.81	18.50
IR78794-B-Sat29-1	19 Apr 14	139	3.90	
BRRI dhan47	24 Apr 14	144	3.28	

Table 4. Continued.

Variety/Line	Maturity (day)	Growth duration (day)	Yield (t ha^{-1})	Salinity (dS m^{-1}) at days to maturity
		Paikgacha, Khulna		
BR7100-R-6-6-1	21 Apr 14	141	5.57	3.20
IR78794-B-Sat29-1	18 Apr 14	138	4.95	
BRRI dhan47	21 Apr 14	141	4.81	
		Sadar, Satkhira		
BR7100-R-6-6-1	24 Apr 14	125	5.35	-
IR78794-B-Sat29-1	28 Apr 14	129	6.08	
BR28	21 Apr 14	122	6.11	

DS: 30 Nov 2013.

Table 5. Salinity (dS/m) data of PVT at different locations during Boro-2014.

Location	1 Feb	15 Feb	1 Mar	15 Mar	1 Apr	15 Apr	24 Apr
Dacope	2.80	3.00	3.24	5.40	6.07	8.90	9.90
Batiaghata	8.58	8.59	8.95	9.32	11.64	15.00	18.50
Paikgacha	0.80	0.92	1.78	1.92	2.30	3.20	-
Debhata	3.25	2.80	3.19	3.15	3.90	4.58	-
Tala	2.23	2.45	3.35	3.05	3.40	3.80	-
Ashasuni	4.18	4.50	4.67	4.90	5.85	5.66	-
BRRI Farm	2.05	2.15	2.24	2.20	2.80	2.95	-

Table 6. Yield performance of different Boro varieties against salinity in Boro-Fallow-T. Aman cropping pattern.

Variety	Yield (t ha^{-1})	Panicle m^{-2}	Plant ht (cm)
BRRI dhan47	8.90	318	107
BRRI dhan55	7.61	342	101.33
BINA dhan10	8.70	394	117.66
BRRI dhan28	7.90	381	105.66
CV%	8.67	1.58	4.02
LSD (5%)	1.44	11.29	8.66

Table 7. Effect of long-term missing element on the grain and straw yield of BRRI dhan47 in Boro 2014 at BRRI RS farm, Satkhira.

Treatment	Grain yield (t ha^{-1})	Straw yield (t/ha)	Grain yield decrease due to missing nutrient from NPKSZn
NPKSZn	6.52	6.34	-
-N	2.81	2.93	3.41
-P	5.98	6.29	0.54
-K	6.05	5.89	0.47
-S	5.86	6.14	0.66
-Zn	5.88	6.02	0.64
LSD (5%)	0.41	0.55	-
CV%	4.1	5.4	-

Initial Soil: Silty-clay-loam, pH: 7.7 (1:2.5), Org. C: 1.26%, Total N: 0.13%, Avail. P: 11.6 ppm, Exch. K: 0.32 meq/100 g soil, Avail. S: 40 ppm.

at BRRI RS farm, Satkhira from T. Aman, 2010 viewing missing element approach using six treatments in RCB design with three replications. In Boro 2014, NPKSZn at a rate of 100-15-60-10-1 kg ha^{-1} respectively were used. Urea was applied in three equal splits (1/3 at final land preparation, 1/3 at active tillering stage and 1/3 at 5-7 days before PI stage). Rest of the fertilizers were applied at final land preparation. The unit plot size was 6- × 5-m. Forty-day-old seedlings with 2-3 seedlings hill^{-1} were transplanted.

In Boro 2014, the complete treatment (NPKSZn) produced the highest grain yield (6.34 t ha^{-1}), while the missing of N produced the lowest yield (2.81 t ha^{-1}) which was significantly lower from P, K, S and Zn omitted plots (Table 7). Omission of P, K, S and Zn also reduced the yield slightly. More or less similar trend was also observed in case of straw yield. Therefore, for obtaining desired yield, balance fertilization of NPKSZn is necessary.

SOCIO-ECONOMIC AND POLICY

Stability analysis of BRRI varieties at BRRI RS, Satkhira

Twenty-eight BRRI developed modern varieties were tested at BRRI farm, Satkhira in Boro 2014 to evaluate its yield and other characters. Forty-day-old seedlings were transplanted in 5.4- × 3-m plot following RCB design with three replications

using 2-3 seedling hill^{-1} with 20- × 20-cm spacing. Fertilizer and cultural practices were followed as per BRRI recommendation.

The highest grain yield was recorded for BR6 (7.98 t ha^{-1}) followed by BRRI dhan55 (7.85 t ha^{-1}) and BRRI dhan47 (7.68 t ha^{-1}). The lowest yield was obtained from BR12 (4.15 t ha^{-1}) followed by BR16 (4.26 t ha^{-1}) and BRRI dhan19 (Table 8). At the end of maturity stage BRRI dhan27, BR7 and BRRI dhan28 showed 100%, 46% and 12% lodging respectively.

TECHNOLOGY TRANSFER

Breeder seed production programme
All the breeder seeds were grown using nucleus stock seeds. Fertilizers were applied at a rate of 120-80-80 kg NPK ha^{-1} respectively and gypsum 100 kg ha^{-1} was applied at the time of land preparation. Necessary control measures were taken against disease, weed and insects pest infestation. Rouging was done when necessary with proper record keeping. Urea was applied as top-dress in four splits depending on the crop conditions. After harvest, the seeds of each variety were threshed, dried, cleaned individually and all of the breeder seed was sent to GRS Division, BRRI, Gazipur. The harvested seed then offered as a lot of getting the laboratory certificate from SCA for breeder seed with tag.

A total of 11 tons breeder seed was produced where BRRI dhan28, BRRI dhan29 and BRRI dhan58 were 5, 2 and 4 tons respectively in Boro 2014 at BRRI RS, Satkhira and total seed was sent to GRS Division, BRRI, Gazipur.

Truthfully labelled seed (TLS) production programme
Seedlings were grown in modern seed beds and seedlings were grown up maintaining all recommendation of BRRI. Seedlings of recommended age were transplanted using 2-3 seedling hill^{-1} at a spacing of 20- × 20-cm. Fertilizer was applied according to BRRI recommendations. Necessary control measures were taken against disease, weed and insects pest infestation. Rouging was done when necessary. After harvest, the seeds of each variety were threshed, dried and cleaned individually.

Seed production and dissemination programme (SPDP)
For rapid dissemination of BRRI varieties among the farmers, BRRI RS, Satkhira conducted SPDP last year. During the reporting period, the SPDP has been conducted in different locations in Jessore region in Aus season under different funding sources (EQSS and GOB). In Aus season, twelve SPDPs were conducted. Plot sizes of demonstrations were one bigha for each farmer. Progressive farmers were selected in collaboration

Table 8. Yield performance of BRRI varieties at BRRI RS, Satkhira during Boro 2014.

Variety	Yield t ha^{-1}	Maturity (day)	Variety	Yield t ha^{-1}	Maturity (day)
BR1	6.63	28 Apr 2014	BR26	6.50	28 Apr 2014
BR2	6.47	3 May 2014	BRRI dhan27	6.43	4 May 2014
BR3	6.36	12 May 2014	BRRI dhan28	7.67	23 Apr 2014
BR6	7.98	25 Apr 2014	BRRI dhan29	6.74	7 May 2014
BR7	5.86	9 May 2014	BRRI dhan35	7.32	2 May 2014
BR8	5.92	7 May 2014	BRRI dhan36	7.11	25 Apr 2014
BR9	6.88	7 May 2014	BRRI dhan45	7.31	20 Apr 2014
BR12	4.15	12 May 2014	BRRI dhan47	7.68	26 Apr 2014
BR14	6.43	30 Apr 2014	BRRI dhan50	6.71	2 May 2014
BR15	5.94	5 May 2014	BRRI dhan55	7.85	30 Apr 2014
BR16	4.26	12 May 2014	BRRI dhan58	6.99	29 Apr 2014
BR17	4.61	30 Apr 2014	BRRI dhan59	6.86	23 Apr 2014
BR18	4.54	7 May 2014	BRRI dhan60	7.37	25 Apr 2014
BR19	4.41	7 May 2014	BRRI dhan61	6.85	30 Apr 2014
CV%	11.89	-	-	11.89	
LSD (0.05)	1.25	-	-	1.25	

with DAE. Grain yield, amount of seeds produced, retained seeds by the farmers from the demonstrated plots, number of interested farmers those were impressed and motivated by the variety were recorded.

In total 31 SPDP was conducted in the farmer's field of different upazilas in Jessore and Khulna region. Among them 12 were conducted in Aus season (10 were funded by EQSS project and two by GOB) and 19 in Boro season. Total produced seed in Aus season was 7,050 kg from where 3,259 kg was retained as seed by the farmers for further use and for distribution to other interested farmers. On the other hand, 7,060 kg BRRI dhan28, 1,525 kg BRRI dhan47, 1,680 kg BRRI dhan55 and 5,215 kg BRRI dhan61 was produced in Boro season. A total of 651 farmers were motivated to cultivate BRRI varieties in the next year.

BRRI RS, Sonagazi

SUMMARY

During the reporting period 56 entries were evaluated in replicated trials of which 25 entries appeared promising for further evaluation. In proposed variety trial (PVT), the line OM1490 yielded higher and has been released as BRRI dhan65 for the broadcast Aus season. However, proposed entries BR7100-R-6-6, BR7830-16-1-5-3 and weed tolerant rice yielded higher than their respective checks and have been released as BRRI dhan67, BRRI dhan68 and BRRI dhan69 respectively for the Boro season.

The rates and application times of K fertilizer had no effect on grain yield of BRRI dhan28 in saline charland ecosystem. In Sonagazi regions, BR11 and BRRI dhan58 performed better in T. Aman and Boro seasons respectively. During the reporting period, the station produced 22 tons seeds of recently developed BRRI varieties and also arranged twenty farmers' training programmes.

VARIETAL DEVELOPMENT

Regional yield trial during Aus 2013-14 season
Advanced lines BR6848-3B-12, BR7699-2B-3-3, BR6855-3B-12 and BR6855-3B-135 performed better for RYT broadcast Aus against check of BRRI dhan43 while entries BR7718-54-1-3, BR7708-62-1-1, BR566-32-6-1 and BR741-6-1-2 yielded higher for RYT transplanted Aus than their respective checks and were selected for further trial.

Regional yield trial during T. Aman 2013-14 season
Nineteen breeding lines were evaluated in four different RYT at BRRI RS farm, Sonagazi against standard check BRRI dhan34, BRRI dhan37, BRRI dhan39, BRRI dhan33, BRRI dhan49, and BR11. Of them three breeding lines produced higher yield for RYT-PQR, two entries gave higher yield for RYT-collection and four entries showed higher yield for RYT-GSR than their respective checks (Table 1) and were selected for further evaluation.

Table 1. Yield and ancillary characters of RYT, BRRI, Sonagazi, T. Aman 2013-14.

Designation	Duration (day)	Plant ht (cm)	Yield (t/ha)
RYT-PQR			
BR7697-15-4-4-2-1	140	76.6	6.01
BR7697-15-4-4-2-2	140	99.73	5.57
BR7697-16-2-2-1-1	143	97.53	5.44
BR7369-52-3-2-1-1	142	102.40	3.85
BI dhan1	142	84.4	2.91
BRRI dhan34 (ck)	140	105	3.25
BRRI dhan37 (ck)	140	115	3.66
BRRI dhan39 (ck)	120	90.91	4.77
RYT-collection			
Sumon Swarna	144	97.46	7.55
Guti Swarna	145	88.7	6.77
Bikalpa Swarna	121	94.93	5.18
Subal Lata	120	94.1	3.11
WK-1	121	92.4	4.32
BR11 (ck)	145	95.2	6.37
BRRI dhan39 (ck)	122	93.6	5.21
RYT-GSR			
IR83140-B-28-B	123	92.6	5.72
IR83142-B-19-B	122	96.5	5.08
IR83142-B-60-B	128	95.6	5.87
HHZ5-SAL10-DT1-DT1	128	97.2	5.40
BRRI dhan39	122	94.2	4.73

DS: 10 July 2013; DT: 6 Aug 2013.

Regional yield trial (RYT) during Boro 2013-14 season
Twenty-two breeding lines were evaluated in four different RYT at BRRI RS farm, Sonagazi along with standard checks of BRRI dhan28, BRRI dhan29, BRRI dhan50 and BRRI dhan55. Among them two entries produced higher yield for RYT-GSR, two entries gave higher yield for RYT-FB and also two entries yielded higher for RYT-cold than their respective checks (Table 2) and were selected for further evaluation.

PVT (Broadcast Aus)
One proposed genotype for new variety was evaluated in two farmers' field of Feni sadar and Sitakunda, Chittagong against standard check of BRRI dhan43. OM1490 yielded higher in both the locations than the check with the shorter plant height and similar growth duration and was selected to release as a broadcast Aus variety.

PVT (Favourable Boro)
Two proposed genotypes for new variety were

Table 2. Yield and ancillary characters of RYT, BRRI, Sonagazi, Boro 2013-14.

Designation	Duration (day)	Plant ht (cm)	Yield (t/ha)
RYT-GSR			
IR83140-B28-B	143	93	5.90
IR83142-B-19-B	144	90	6.49
IR83142-B-60-B	144	89.87	6.53
HHZ5-SAL10-DT1-DT1	146	93.03	6.76
HUANG HUA ZHAN	146	85.13	6.45
HHZ17-DT6-Y1-DT1	146	87.87	6.50
HHZ17-Y16-Y3-Y2	146	93.06	6.43
HHZ23-DT16-DT1-DT1	148	91.33	5.69
HHZ12-SAL2-Y3-Y2	146	97.43	6.90
BRRI dhan28 (ck)	144	95.50	6.64
RYT-FB			
BR7988-10-4-1	145	91.43	6.73
BR7800-63-1-7-3	146	96.93	6.96
BRRI dhan28 (ck)	142	95.80	6.53
BRRI dhan55 (ck)	150	94.73	6.15
RYT-cold			
IR77496-31-2-1-3-1	144	89.06	6.02
IR2266-42-6-2	145	88.60	5.45
BR7812-19-1-6-1-P4	145	97.13	6.45
BR7813-1-1-3-1	142	97.20	5.33
BR8245-2-1-4	153	102.00	5.80
BRRI dhan28 (ck)	144	96.46	5.88
BRRI dhan29 (ck)	160	99.80	5.48
BRRI dhan55 (ck)	147	93.53	5.62

DS: 3 Dec 2013; DT: 13 Jan 2014.

evaluated in farmer's field of Sonagazi, Feni along with check of BRRI dhan28. Proposed lines of BR7830-16-1-5-3 and weed tolerant rice gave the higher yield than the standard check and were selected for release as favourable Boro varieties.

PVT (Salt tolerance)
Two salt tolerant genotypes for new variety were evaluated in farmer's field of Sonagazi, Feni along with the check BRRI dhan47. Salt tolerant lines BR7100-R-6-6 and IR78794-B-Sat29-1 gave the higher yield than the standard check with similar growth duration and were selected to release as salt tolerant Boro varieties.

Effect of different rates and application times of K fertilizer on the growth and yield of BRRI dhan28 in saline charland ecosystem
The experiment was initiated at the BRRI RS farm, Sonagazi during Boro 2013-14 season viewing to identify the proper rates and application times of K

fertilizer on the yield of BRRI dhan28 under saline charland ecosystem. A total of 13 different K fertilizer combinations were imposed in this experiment. All the treatments received recommended doses of NPS and Zn fertilizer. Results revealed that the rates and application times of K fertilizer had no effect on yield of BRRI dhan28 in saline charland ecosystem.

Stability analysis of BRRI released variety
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 RCB design were followed. Crop management practices were adopted as per BRRI recommendation. In T. Aman season BR 11 produced the highest yield of 4.9 t/ha while in Boro season BRRI dhan58 produced the highest yield of 7.52 t/ha.

Minimizing rice yield gap through BRRI technologies
The study was conducted during T. Aman 2013-14 season at Sadar, Raipur and Ramgoti upazillas of Laximupur district. BRRI recommended rice cultivation practices along with farmer's practices were imposed in this experiment. The average grain yield increased upto 11% over farmer's practices in Laxmipur district. Lower yield under farmer's practices were identified as use of over aged seedling, imbalanced fertilizer application as well as weed, insect and disease management was not done in time and properly.

Farmers' training
Farmers' training is an important tool to train up farmers on updated information of rice. BRRI RS, Sonagazi arranged 20 training programmes at different upazilas of Feni district in collaboration with DAE and BADC of which 600 farmers were participated. Most of the farmers were very much impressed by taking this rice production training.

Breeder seed and TLS production
Nucleus seed stock was collected from GRS Division of BRRI. Single seedling was transplanted per hill. For breeder seed production all official

formalities with SCA and BRRI authority were performed through proper channel. Breeder seed was produced in T. Aman and Boro seasons but TLS seed was produced in Aus and T. Aman seasons. Considering three seasons (Aus, T. Aman and Boro) the amount of produced breeder seed and TLS was 14.60 and 7.50 tons respectively.

BRRI RS, Kushtia

SUMMARY

Nine materials were tested in T. Aus season 2013. The yield of the tested lines ranged from 3.4 to 4.6 t/ha. The highest and the lowest yield was observed in the line BR7718-56-3-1 and BR7708-62-1-1 respectively. The range of the growth duration was 105-113 days where the growth duration of the check varieties was BR26 (115 days) and BRRI dhan48 (110 days).

In PVT, drought, T. Aman 2013, yield of the line IR82635-B-B-75-2 was slightly higher than the check variety BRRI dhan56. Other characters (growth duration, plant height, panicles/m^2 and 1000 grain weight were similar to the check variety BRRI dhan56.

In PVT, RLR, T. Aman 2013, yield of the proposed line BR7611-31-5-3-2 (4.3 t/ha) was lower than the check variety BR11 (5.0 t/ha). Growth duration of the proposed line BR7611-31-5-3-2 was similar to that of the check variety BR11.

Proposed variety trial (PVT) was conducted in T. Aman 2013 with green super rice (GSR) material. Yield (5.0 t/ha) and growth duration (112 days) of the proposed material HUA565 was similar to the check variety BRRI dhan33. Number of panicles/m^2 (323.3) of the proposed material was higher than the check variety BRRI dhan33 (249.0) and this character might be contributed to the yield.

The yield of the tested lines ranged from 4.3 to 4.9 t/ha and it was similar to the check variety BRRI dhan39 (4.6 t/ha) in the RYT, GSR, T. Aman 2013. The highest yield was observed in the line IR83140-B28-B (4.9 t/h). Growth duration of the test entries was 5-7 days earlier than the check variety except the material HHZ5-SAL10-DT1-DT1.

The yield of the tested lines ranged from 4.5 to 5.1 t/ha in the trial of premium quality rice (PQR), T. Aman 2013. The highest yield was observed in the line BR7697-16-2-2-1-1 (5.1 t/ha) and it was about 1.5 t/h higher than the standard check BRRI dhan39 (3.6 t/ha). Growth duration of the tested lines was slightly earlier than the check varieties (BRRI dhan34 and BRRI dhan37) but about 11-13 days later than the check variety BRRI dhan39.

In the trial of RYT, RLR, T. Aman 2013, the yield of the tested lines ranged from 3.7 to 4.7 t/ha. BR7468-12-1-1-1-1, BR7472-16-2-1-2-1 and BR7638-7-2-5-2 produced similar yield to the check varieties BRRI dhan33 (4.4 t/ha) and BRRI dhan49 (4.6 t/ha). Growth duration of the lines BR7468-12-1-1-1-1 and BR7472-16-2-1-2-1 was seven days earlier than the standard check BRRI dhan49 (128 days).

In regional yield trial (RYT), micronutrient rice (MN), T. Aman 2013, the highest yield was observed in the tested line BR8417-2-1-2 (5.2 t/ha) and this was followed by BR7528-2R-19-HR10 (5.0 t/h). The line BR7528-2R-19-HR10 gave 0.5 t/h higher yield than the check variety BINA dhan7. Growth duration of the line BR8417-2-1-2 was similar to BRRI dhan39 (115 days) and the line BR7528-2R-19-HR10 (125 days) was similar to BRRI dhan49.

Among the five exotic materials Bikalpa Swarna, Subal Lata and WK-1 gave higher yield (4.9-5.4 t/ha) with lower growth duration (97-104 days) in RYT collection, T. Aman 2013. Growth duration of these three materials was 3-5 weeks earlier than the standard checks BRRI dhan39 (124 days) and BR11 (138 days) respectively. From the trial Bikalpa Swarna, Subal Lata and WK-1 can be selected for further evaluation.

The proposed lines, weed tolerant rice and BR7830-16-1-5-3 respectively gave 0.7-0.8 t/ha higher yield than the check variety BRRI dhan28 (5.8 t/ha) in the trial PVT, Boro 2013-14. Growth duration of the proposed lines was 5-8 days later than the standard check variety BRRI dhan28 (150 days).

The highest yield was observed in the line HHZ17-DT6-YI-DTI (6.1 t/h) and this was followed by IR83142-B-19-B (6.1 t/h) in RYT, GSR, Boro 2013-14. Growth duration of the tested entries was 6-16 days longer than the check variety BRRI dhan28 (151 days).

Six materials were tested in RYT, PQR, Boro 2013-14. The highest yield was observed in the line BR7781-10-2-3-1 (5.7 t/ha) and it was 0.6-0.7 t/ha higher than the standard checks BRRI dhan50 and BRRI dhan28 respectively. Growth duration of these lines was 9-15 days later than BRRI dhan28 (150 days).

The yield of the tested lines ranged from 5.2-6.7 t/ha in the trial of RYT, micronutrient rice (MN), Boro, 2013-14. The highest yield was observed in the line BR7830-16-1-5-9-9 (6.7 t/ha) with the similar growth duration of BRRI dhan60 (157 days). Growth duration of the test entries was 4-7 days later than the check variety BRRI dhan28 (150 days).

Two materials were evaluated under RYT, favourable Boro 2013-14. The yield of the line BR7988-10-4-1 was similar to the check BRRI dhan28 (5.9 t/ha) and the line BR7800-63-1-7-3 was similar to the check BRRI dhan55 (6.7 t/ha). Growth duration and plant height of these lines were similar to the standard checks BRRI dhan28 (154 days) and BRI dhan55 (156 days).

Four rice lines was tested under disease resistant rice (DR), Boro, 2013-14. The highest yield was observed in the line BR7986-7-4 (6.4 t/ha) and it was 0.6 t/ha higher than the standard check BRRI dhan28 and similar to BRRI dhan29. Growth duration of the tested entries was 3-8 days longer than the check BRRI dhan28 (152 days) but 5-10 days earlier than the standard check BRRI dhan29 (165 days).

The yield of the tested lines ranged from 4.9 to 6.0 t/ha in RYT, cold tolerance rice, Boro, 2013-14. The highest yield was observed in the line BR8245-2-1-4 (6.0 t/ha) and it was followed by IR77496-31-2-1-3-1 (6.0 t/ha) and BR7812-19-1-6-1-P4 (5.9 t/ha). Growth duration of IR77496-31-2-1-3-1 was similar to BRRI dhan55 (159 days); BR8245-2-1-4 and BR7812-19-1-6-1-P4 were similar to BRRI dhan29 (165 days). These materials might be selected for further evaluation.

The early establishment of T. Aman through supplemental irrigation effectively mitigated the terminal drought occurred at reproductive and ripening phases during T. Aman 2013. Both short and long duration T. Aman varieties suffered less drought and showed good yield performance if they were transplanted before 24 July. So transplanting before 24 July would be medium risk period of drought and after that it would be high risk period.

Fifteen centimeter levee height management around the rice field reserved total rain water in the field in 2013 and water level fluctuation was low compared to farmers practice. It ensured more moisture and reduced need of supplemental irrigation as well. It also makes sure better yield and reduces production cost.

AWD practice with poly pipe to convey water saved 34.88 and 63.12% water in field 1 and 2 respectively over farmers practice (continuous standing water with earthen canal). Loss of water increased with increasing distance from irrigation source to field. AWD with poly pipe saved time of irrigation and power consumption of the pump. In AWD practice 12 and 11% yield increased over farmers practice in field 1 and 2 respectively.

Rice leaf folder larval parasitism rate was the highest 27.27% by single species of parasitoid *Elasmus* sp. during the observation period september-october at farmer's field.

Yield and growth duration of 27 BRRI varieties were studied in T. Aman 2013. Among the 27 varieties 20 were found to give higher yields than the standard yield determined for them. The other varieties yielded similar or lower than the standard yield. Growth duration of some of the tested varieties decreased (up to 14 days as in the case of BR3), whereas in some varities it increased (up to 6 days as in the case of BR23). On the other hand, eight were found to give higher yields and the other varieties yielded lower than the standard yield among the 28 varieties in Boro 2013-14. Growth duration of some of the test varieties decreased (up to 18 days as in the case of BR17), whereas in some varities it increased (up to 27 days as in case of BRRI dhan27 in this season).

Yield performance of BRRI developed T. Aman and Boro varieties were evaluated Kushtia sadar and Kumarkhali upazila. In T. Aman the highest yield was found in BRRI hybrid dhan4 and the lowest in case of BRRI dhan34. In Boro the highest and the lowest yield was found for BRRI hybrid dhan3 and BRRI dhan50. Farmers showed positive reaction on BRRI developed new varieties.

BRRI recommended practices gave higher yield over farmer's practices in all of the three locations (Shailkupa, Jhenidah sadar and Kotchandpur) during T. Aman under yield gap minimization project of rice (MRYG). In the Boro season, demonstration was established in only

Shailkupa location and found similar result. Overall, yield was increased by 7.8% in the T. Aman and 19.3% in the Boro season.

In total, 33 farmers' training was conducted and about 1000 farmers participated in the training programmes. Eighteen demonstration plots and 14 field day programmes were organized to demonstrate BRRI developed technologies. Agricultural Fair was arranged by DAE, Kushtia and BRRI regional station took part in that fair.

VARIETAL DEVELOPMENT

Regional yield trial, T. Aus 2013
Nine materials were tested at Boria, Kushtia in T. Aus season 2013. The materials were BR7708-62-1-1, BR7716-4-1-1, BR7718-56-3-1, BR7577-9-1-2, BR7417-6-1-2, BR7566-39-6-1, BR7708-24-2-1, BR7716-49-1-3 and BR7718-55-1-3. BR26 and BRRI dhan48 were used as standard checks. The yield of the tested lines ranged from 3.4 to 4.6 t/ha. The highest and the lowest yield was observed in the line BR7708-62-1-1 and BR7718-56-3-1 respectively. The range of the growth duration was 105-113 days where the growth duration of the check varieties was BR26 (115 days) and BRRI dhan48 (110 days) (Table 1).

Proposed variety trial, Drought, T. Aman 2013
The PVT was done with IR82635-B-B-75-2 and

BRRI dhan56 (Std. check) at Boria, Kushtia in T. Aman season 2013. Yield of the line IR82635-B-B-75-2 was slightly higher than the check variety BRRI dhan56. Other characters (growth duration, plant height, panicles/m² and TGW was similar to the check variety BRRI dhan56 (Table 2). Therefore, the material (IR82635-B-B-75-2) can be proposed as a variety in drought prone situation.

PVT, rainfed low land rice (RLR), T. Aman 2013
The PVT was done in rainfed low land ecosystem with BR7611-31-5-3-2 and BRRI dhan11 (Std. check) at Boria, Kushtia in T. Aman season 2013. Yield (4.3 t/ha) of the proposed line BR7611-31-5-3-2 was lower than the check variety BR11 (5.0 t/ha). Growth duration of the proposed line BR7611-31-5-3-2 was similar to that of the check variety BR11. Plant height was 14.4 cm longer than the check variety but lodging was not occurred (Table 3). TGW (28.7 gm) was higher than the check variety BR11 (25.2 gm). Therefore, this proposed line might be suitable in Barisal region as the people of that region preper coarse grain.

PVT, green super rice (GSR), T. Aman 2013
Green super rice line HUA565 was tested with BRRI dhan33 as check at Boria, Kushtia in T. Aman season 2013. Yield (5.0 t/ha) and growth duration (112 days) of the proposed material

Table 1. Performance of some BRRI developed RYT lines, T. Aus 2013.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m²)	TGW (g)	Yield (t/ha)
BR7708-62-1-1	112	96.8	128	21.7	4.6
BR7716-4-1-1	113	86.6	145	22.0	3.7
BR7718-56-3-1	109	97.0	174	23.4	3.4
BR7577-9-1-2	110	87.6	132	21.9	4.4
BR7417-6-1-2	105	107.2	138	23.9	4.3
BR7566-39-6-1	109	94.6	144	23.5	4.3
BR7708-24-2-1	108	87.7	122	23.1	3.7
BR7716-49-1-3	109	110.3	154	21.0	4.1
BR7718-55-1-3	112	100.0	135	20.0	4.0
BR 26 (ck)	115	116.2	133	21.4	4.4
BRRI dhan48 (ck)	110	103.3	136	23.2	4.7

DS: 7 Apr 2013, DT: 30 Apr 2013. TGW=Thousand grain weight.

Table 2. Performance of some PVT lines, Drought, T. Aman 2013.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m²)	TGW (g)	Yield (t/ha)
IR82635-B-B-75-2	108	115.1	242.7	23.6	4.1
BRRI dhan56 (ck)	107	112.8	221.3	22.9	3.8

DS: 14 Jul 2013, DT: 5 Aug 2013.

Table 3. Performance of some PVT lines, RLR, T. Aman 2013.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m²)	TGW (g)	Yield (t/ha)
BR7611-31-5-3-2	131	127.4	247.0	28.7	4.3
BR11 (ck)	130	112.7	279.3	25.2	5.0

DS: 14 Jul 2013, DT: 6 Aug 2013.

HUA565 was similar to the check variety BRRI dhan33 (Table 4). Number of panicles/m^2 (323.3) of the proposed material was higher than the check variety BRRI dhan33 (249.0) and this character might be contributed to the yield. Considering the above yield and yield contributing characters the material (HUA565) can be proposed as a variety.

RYT, GSR, T. Aman 2013

Four materials were tested at Boria, Kushtia in T. Aman season 2013. The materials were IR83140-B-28-B, IR83142-B-19-B, IR83142-B-60-B and HHZ5-SAL10-DT1-DT1. BRRI dhan39 was used as standard check. The yield of the tested lines ranged from 4.3 to 4.9 t/ha and it was similar to the check variety BRRI dhan39 (4.6 t/ha). Growth duration of the test entries was 5-7 days earlier than the check variety except the material HHZ5-SAL10-DT1-DT1. All of the entries showed similar plant height to that of the check variety (Table 5).

RYT, premium quality rice, T. Aman 2013

Four materials were tested at Baradi, Kushtia in T. Aman season 2013. The materials were BR7697-15-4-4-2-1, BR7697-15-4-4-2-2, BR7697-16-2-2-1-1 and BR7369-52-3-2-1-1. BRRI dhan34, BRRI dhan37 and BRRI dhan38 were used as standard checks. The yield of the tested lines ranged from 4.5 to 5.1 t/ha. The highest yield was observed in the line BR7697-16-2-2-1-1 (5.1 t/ha) and it was about 1.5 t/ha higher than the standard check BRRI dhan39 (3.6 t/ha). Growth duration of the tested entries was slightly earlier than the check varieties (BRRI dhan34 and BRRI dhan37) but about 11-13 days later than the check variety BRRI dhan39. All of the entries showed shorter plant height than the check varieties (BRRI dhan34 and BRRI dhan37) but taller than the check variety BRRI dhan39 (Table 6).

RYT, RLR, T. Aman 2013

Five entries were tested at Boria, Kushtia in T. Aman 2013. The materials were BR7468-12-1-1-1-1, BR7472-16-2-1-2-1, BR7966-16-2-2, BR7966-25-2-1 and BR7638-7-2-5-2. BRRI dhan33 and BRRI dhan49 were used as standard checks. The yield of the tested lines ranged from 3.7 to 4.7 t/ha. BR7468-12-1-1-1-1, BR7472-16-2-1-2-1 and BR7638-7-2-5-2 gave similar yield to the check varieties BRRI dhan33 (4.4 t/ha) and BRRI dhan49 (4.6 t/ha). Growth duration of the lines BR7468-12-1-1-1-1 and BR7472-16-2-1-2-1 was seven days earlier than the standard check BRRI dhan49 (128 days). Plant height of these two lines was slightly higher than the standard checks and lodging tendency was not occurred. TGW was similar to the check variety BRRI dhan49 (19.4 gm) (Table 7).

RYT, micronutrient rice (MN), T. Aman 2013

Three materials were tested at Baradi, Kushtia in T. Aman 2013. The materials were BR8417-2-1-2, BR7528-2R-19-HR10 and AL-29. BRRI dhan39,

Table 4. Performance of some PVT lines, GSR, T. Aman 2013.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m^2)	TGW (g)	Yield (t/ha)
HUA565	112	110.9	323.3	22.1	5.0
BRRI dhan33 (ck)	112	116.4	249.0	23.1	5.3

DS: 14 Jul 2013, DT: 6 Aug 2013.

Table 5. Performance of some GSR lines, RLR, T. Aman 2013.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m^2)	TGW (g)	Yield (t/ha)
IR83140-B-28-B	109	103.6	247.7	26.6	4.9
IR83142-B-19-B	109	100.6	268.7	26.3	4.5
IR83142-B-60-B	111	108.4	282.3	26.9	4.5
HHZ5-SAL10-DT1-DT1	118	104.6	272.0	26.1	4.3
BRRI dhan39 (ck)	116	104.0	213.7	22.6	4.6

DS: 14 Jul 2013, DT: 4 Aug 2013.

Table 6. Performance of some premium quality rice (PQR) T. Aman 2013.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m^2)	TGW (g)	Yield (t/ha)
BR7697-15-4-4-2-1	133	121.6	214.3	24.8	4.5
BR7697-15-4-4-2-2	135	117.8	236.3	25.0	4.8
BR7697-16-2-2-1-1	134	120.0	228.7	26.7	5.1
BR7369-52-3-2-1-1	133	117.3	201.0	27.5	4.6
BRRI dhan34 (ck)	139	116.0	274.0	10.4	3.4
BRRI dhan37 (ck)	137	123.0	273.3	15.1	3.5
BRRI dhan39 (ck)	122	101.0	211.3	23.0	3.6

DS: 14 Jul 2013, DT: 14 Aug 2013.

Table 7. Performance of some rainfed low land rice (RLR) lines, T. Aman 2013.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m²)	TGW (g)	Yield (t/ha)
BR7468-12-1-1-1-1	121	110.8	211.3	20.4	4.5
BR7472-16-2-1-2-1	121	109.0	229.3	20.5	4.6
BR7966-16-2-2	118	124.0	188.0	26.0	3.9
BR7966-25-2-1	116	108.4	195.3	20.6	3.7
BR7638-7-2-5-2	130	117.2	192.7	23.2	4.7
BRRI dhan33 (ck)	112	103.0	209.0	23.5	4.4
BRRI dhan49 (ck)	128	102.4	277.7	19.4	4.6

DS: 14 Jul 2013, DT: 6 Aug 2013.

BRRI dhan49 and Binadhan-7 were used as standard checks. Among the three lines the highest yield was observed in the tested line BR8417-2-1-2 (5.2 t/ha) and this was followed by BR7528-2R-19-HR10 (5.0 t/h). The line BR7528-2R-19-HR10 gave 0.5 t/h higher yield than the check variety BINA dhan7. Growth duration of the line BR8417-2-1-2 was similar to BRRI dhan39 (115 days) and the line BR7528-2R-19-HR10 was similar to BRRI dhan49 (125 days) (Table 8). The highest number of panicles/m² was observed in the tested line BR8417-2-1-2 (245.7) (Table 8). Therefore, these two lines might be considered for further evaluation.

RYT, collection, T. Aman 2013

Five materials were tested at farmers field Boria, Kushtia in T. Aman 2013 to observe the performance of some collected exotic materials. The materials were Sumon Swarna, Guti Swarna, Bikalpa Swarna, Subal Lata and WK-1. BR11 and BRRI dhan39 were used as standard checks. Among the five exotic materials Bikalpa Swarna, Subal Lata and WK-1 gave higher yield (4.9-5.4 t/ha) with lower growth duration (97-104 days)

Table 8. Performance of some RYT (MN) T. Aman 2013.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m²)	TGW (g)	Yield (t/ha)
BR8417-2-1-2	115	109.2	245.7	22.1	5.2
BR7528-2R-19-HR10	124	123.4	189.3	29.4	5.0
AL-29	120	102.1	220.7	19.3	4.1
BRRI dhan39 (ck)	115	107.2	209.3	23.4	4.1
BRRI dhan49 (ck)	125	98.4	225.3	19.1	4.3
BINA dhan7 (ck)	107	108.9	320.7	22.6	4.5

DS: 16 Jul 2013, D/T: 4 Aug 2013.

(Table 9). Growth duration of these three materials was 3-5 weeks earlier than the standard checks BRRI dhan39 (124 days) and BR11 (138 days). Highest number of panicles/m² with shorter plant height, lowest TGW and higher yield (4.9 t/ha) was observed in the material Subal Lata. Bikalpa Swarna and WK-1 had higher number of panicles with low TGW. Therefore, Bikalpa Swarna, Subal Lata and WK-1 can be selected for further evaluation.

PVT, Boro 2013-14

Two favourable Boro lines namely, BR7830-16-1-5-3, weed tolerant rice with BRRI dhan28 as check were tested at Kushtia in Boro 2013-14. Fifty-five-day-old rice seedlings were planted. The proposed line, BR7830-16-1-5-3 gave the highest (6.6 t/h) yield (Table 10) and it was followed by weed tolerant rice (6.5 t/ha). Weed tolerant rice and BR7830-16-1-5-3 respectively gave 0.7-0.8 t/ha higher yield than the check variety BRRI dhan28 (5.8 t/ha). Growth duration of the proposed lines was 5-8 days longer than the standard check BRRI dhan28 (150 days). Therefore, these two lines can be proposed release as a variety.

Table 9. Performance of some RYT (Collection) T. Aman 2013.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m²)	TGW (g)	Yield (t/ha)
Sumon Swarna	129	132.8	224.3	19.9	4.3
Guti Swarna	128	132.8	292.7	20.3	4.2
Bikalpa Swarna	104	128.2	264.0	20.2	5.4
Subal Lata	97	105.4	315.7	15.6	4.9
WK-1	103	115.2	267.3	23.7	5.3
BR11 (ck)	138	111.2	261.0	25.2	5.4
BRRI dhan39 (ck)	124	102.6	202.0	24.1	5.1

DS: 16 Jul 2013, DT: 3 Aug 2013.

Table 10. Performance of proposed variety trial (PVT), Boro 2013-14.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m²)	TGW (g)	Yield (t/ha)
BR7830-16-1-5-3	155	93.2	298.0	24.9	6.6
Weed tolerant rice	158	98.9	233.3	23.7	6.5
BRRI dhan28 (ck)	150	98.7	305.3	21.7	5.8

DS: 8 Dec 2013, DT: 1 Feb 2014.

RYT, GSR, Boro 2013-14

Nine materials were tested at Baradi farm, Kushtia in Boro 2013-14. The materials were IR83140-B-28-B, IR83142-B-19-B, IR83142-B-60-B, HHZ5-SAL10-DT1-DT1, HUANG-HUA-ZHAN, HHZ17-DT6-YI-DTI, HHZ17-YI6-Y3-Y2, IR83142-B-19-B and HHZ12-SAL2-Y3-Y2. BRRI dhan28 was used as standard check. Sixty-six-day-old seedlings were planted in 5.4- × 3.0-m unit plots with 25 cm x 15 cm spacing. The yield of the tested entries ranged from 5.2 to 6.1 t/ha (Table 11). The highest yield was observed in the line HHZ17-DT6-YI-DTI (6.1 t/ha) followed by IR83142-B-19-B (6.1 t/ha). These materials had similar plant height with similar TGW to the check variety and higher number of panicles/m^2. Growth duration of the tested entries was 6-16 days longer than the check variety BRRI dhan28 (151 days). Both HHZ5-SAL10-DT1-DT1 and HUANG-HUA-ZHAN showed higher yield (5.8 t/ha) with higher number of panicles/m^2 (Table 11). Therefore, HHZ17-DT6-YI-DTI, IR83142-B-19-B, HHZ5-SAL10-DT1-DT1 and HUANG-HUA-ZHAN might be selected for further evaluation.

RYT, PQR, Boro 2013-14

Six materials were tested at Baradi farm, Kushtia in Boro 2013-14. The materials were BR7781-10-2-3-1, BR7376-19-1-6-1, BR7376-19-2-1-1, BR7369-10-5-2-3, BR7358-35-2-1-1 and BR7358-35-3-2-1. BRRI dhan28 and BRRI dhan50 were used as standard checks. Sixty-five-day-old rice seedlings were planted. The yield of the tested lines ranged from 4.7 to 5.7 t/ha. The highest yield

was observed in the line BR7781-10-2-3-1 (5.7 t/ha) and it was 0.6-0.7 t/ha higher than the standard checks, BRRI dhan50 and BRRI dhan28 respectively. Yield of BR7376-19-2-1-1, BR7358-35-2-1-1 and BR7358-35-3-2-1 was similar to the yield of the checks BRRI dhan50 and BRRI dhan28. Growth duration of these lines was 9-15 days longer than BRRI dhan28 (150 days) (Table 12). Higher number of panicles/m^2 was observed in these lines. Therefore, these materials can be selected for further evaluation.

RYT, MN, Boro 2013-14

Five materials were tested at Baradi farm, Kushtia in Boro, 2013-14. The materials were BR7881-10-1-5-3-1, BR7833-11-1-1-3-4, BR7669-11-1-2-8-2-1, BR7830-16-1-5-9-9 and BR7833-11-1-1-2-1-2B5. BRRI dhan28 and BRRI dhan60 were used as standard checks. Sixty-four-day-old rice seedlings were planted. The yield of the test lines ranged from 5.2-6.7 t/ha. The highest yield was observed in the line BR7830-16-1-5-9-9 (6.7 t/ha) with the similar growth duration of BRRI dhan60 (157 days). Growth duration of the test entries was 4-7 days longer than the check variety BRRI dhan28 (150 days). All of the entries showed shorter plant height than that of the check variety BRRI dhan28 except BR7830-16-1-5-9-9 (100.2 cm) (Table 13). TGW was higher than the standard check BRRI dhan28.

RYT, favourable Boro 2013-14

Two materials were tested at Baradi farm, Kushtia in Boro 2013-14. The materials were BR7988-10-4-1 and BR7800-63-1-7-3. BRRI dhan28 and

Table 11. Performance of some GSR lines, Boro 2013-14.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m^2)	TGW (g)	Yield (t/ha)
IR83140-B-28-B	157	88.8	315.7	27.9	5.2
IR83142-B-19-B	158	85.9	363.3	27.7	5.5
IR83142-B-60-B	160	91.3	325.7	25.6	5.6
HHZ5-SAL10-DT1-DT1	164	96.8	264.3	25.2	5.8
HUANG-HUA-ZHAN	164	81.4	291.0	20.7	5.8
HHZ17-DT6-YI-DTI	164	91.3	293.0	21.3	6.1
HHZ17-YI6-Y3-Y2	167	92.2	296.7	21.4	5.7
IR83142-B-19-B	167	93.5	290.3	22.1	6.1
HHZ12-SAL2-Y3-Y2	163	98.9	294.3	21.8	5.6
BRRI dhan28 (ck)	151	93.6	345.0	22.6	5.2

DS: 8 Dec 2013, DT: 12 Feb 2014.

Table 12. Performance of some premium quality rice (PQR) lines, Boro 2013-14.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m^2)	TGW (g)	Yield (t/ha)
BR7781-10-2-3-1	159	101.2	358.0	17.2	5.7
BR7376-19-1-6-1	163	99.8	320.7	21.8	4.9
BR7376-19-2-1-1	165	105.2	308.3	24.7	5.2
BR7369-10-5-2-3	161	121.4	234.3	23.8	4.7
BR7358-35-2-1-1	161	85.2	361.0	20.1	5.3
BR7358-35-3-2-1	163	82.3	372.7	19.4	5.1
BRRI dhan28 (ck)	150	97.5	335.3	22.5	5.0
BRRI dhan50 (ck)	155	88.4	323.0	19.1	5.1

DS: 8 Dec 2013, DT: 11 Feb 2014.

Table 13. Performance of some MN lines, Boro 2013-14.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m²)	TGW (g)	Yield (t/ha)
BR7881-10-1-5-3-1	155	83.9	263.0	30.5	5.2
BR7833-11-1-1-3-4	156	93.8	273.7	29.8	6.1
BR7669-11-1-2-8-2-1	156	90.3	379.7	26.1	5.8
BR7830-16-1-5-9-9	157	100.2	290.0	27.3	6.7
BR7833-11-1-1-2-1-2B5	154	94.3	337.7	21.0	5.3
BRRI dhan28 (ck)	150	96.1	377.7	22.7	5.6
BRRI dhan60 (ck)	157	91.6	351.3	26.1	5.5

DS: 7 Dec 2013, DT: 9 Feb 2014.

BRRI dhan55 were used as standard checks. Sixty-three-day-old rice seedlings were planted. The yield of the line BR7988-10-4-1 was similar to the check BRRI dhan28 (5.9 t/ha) and the line BR7800-63-1-7-3 was similar to the check BRRI dhan55 (6.7 t/ha). Growth duration and plant height of these lines were similar to the standard checks BRRI dhan28 (154 days) and BRRI dhan55 (156 days). The highest number of panicles (402.3) with lowest TGW was observed in the line BR7988-10-4-1 (Table 14).

RYT, disease resistant rice, Boro 2013-14

Four materials were tested at Baradi farm, Kushtia in Boro 2013-14. The materials were BR7986-2-3, BR7986-7-4, BR7986-29-4 and BR7806-18-1-2. BRRI dhan28 and BRRI dhan29 were used as standard checks. Sixty-five-day-old rice seedlings were planted. The yield of the tested lines ranged from 5.1 to 6.4 t/ha. The highest yield was observed in the line BR7986-7-4 (6.4 t/ha) and it was 0.6 t/ha higher than the standard check BRRI dhan28 and similar to BRRI dhan29. Growth duration of the tested entries was 3-8 days longer than the check BRRI dhan28 (152 days) but 5-10 days earlier than the standard check BRRI dhan29 (165 days). Plant height of the lines was similar to

Table 14. Performance of some favourable Boro rice lines 2013-14.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m²)	TGW (g)	Yield (t/ha)
BR7988-10-4-1	157	92.3	402.3	19.6	5.8
BR7800-63-1-7-3	160	96.9	288.7	24.1	6.4
BRRI dhan28 (ck)	154	97.5	404.3	22.0	5.9
BRRI dhan55 (ck)	156	95.7	312.7	25.9	6.7

DS: 7 Dec 2013, DT: 8 Feb 2014.

the check BRRI dhan29 (95.9 cm) (Table 15). Another line, BR7986-29-4 gave similar yield (5.9 t/ha) and growth duration (155 days) with BRRI dhan28. Therefore, these materials BR7986-7-4, BR7986-29-4 can be proceeded for further evaluation.

RYT, cold tolerant rice, Boro 2013-14

Five materials were tested at Baradi farm, Kushtia in Boro 2013-14. The materials were IR77496-31-2-1-3-1, IR2266-42-6-2, BR7812-19-1-6-1-P4, BR7813-1-1-3-1 and BR8245-2-1-4. BRRI dhan28, BRRI dhan29 and BRRI dhan55 were used as standard checks. Sixty-eight-day-old rice seedlings were planted. The yield of the tested lines ranged from 4.9 to 6.0 t/ha (Table 16). The highest yield was observed in the line BR8245-2-1-4 (6.0 t/ha) and IR77496-31-2-1-3-1 (6.0 t/ha) followed by BR7812-19-1-6-1-P4 (5.9 t/ha). Growth duration of IR77496-31-2-1-3-1 was similar to BRRI dhan55 (159 days). On the other hand, growth duration of BR8245-2-1-4 and BR7812-19-1-6-1-P4 was similar to BRRI dhan29 (165 days). Most of the entries showed about 100 cm plant height (Table 16). Among the tested

Table 15. Performance of some disease resistant rice, Boro 2013-14.

Designation	Duration (day)	Plant ht (cm)	Panicle (no./m²)	TGW (g)	Yield (t/ha)
BR7986-2-3	157	95.8	296.7	23.4	5.1
BR7986-7-4	160	92.6	218.0	16.9	6.4
BR7986-29-4	155	92.7	229.0	24.5	5.9
BR7806-18-1-2	158	96.6	231.0	26.3	5.6
BRRI dhan28 (ck)	152	88.2	275.7	21.1	5.8
BRRI dhan29 (ck)	165	95.9	269.7	21.4	6.5

DS: 7 Dec 2013, DT: 10 Feb 2014.

Table 16. Performance of some cold tolerant rice lines, Boro, 2013-14.

Designation	Growth duration (day)	Plant ht (cm)	Panicle (no./m²)	TGW (g)	Yield (t/ha)
IR77496-31-2-1-3-1	160	81.6	340.7	23.2	6.0
IR2266-42-6-2	163	93.4	290.7	26.1	4.9
BR7812-19-1-6-1-P4	162	100.2	305.3	24.5	5.9
BR7813-1-1-3-1	158	94.8	360.7	26.5	5.7
BR8245-2-1-4	164	98.1	340.7	21.0	6.0
BRRI dhan28 (ck)	155	91.5	333.7	21.6	4.9
BRRI dhan29 (ck)	165	98.8	312.7	21.2	6.1
BRRI dhan55 (ck)	159	93.1	291.0	26.4	6.1

DS: 7 Dec 2013, DT: 13 Feb 2014.

entries, higher number of panicles with low TGW was observed in the line BR8245-2-1-4, IR77496-31-2-1-3-1. These materials will be selected for further evaluation.

CROP-SOIL-WATER MANAGEMENT

Terminal drought mitigation adopting transplanting dates in T. Aman 2013

A long duration variety (BR11) and a short duration variety (BRRI dhan33) were tested during T. Aman season to determine effect of drought for different transplanting dates and its severity and probability at different growth stages of rice plant. There were six treatments with three replications in the experiment and the treatments were transplanting at 10 July (T_1), transplanting at 17 July (T_2), transplanting at 24 July (T_3), transplanting at 31 July (T_4), transplanting at 7 August (T_5) and transplanting at 14 August (T_6). A USWB Class A evaporation pan and a rain gauge were installed near the experimental field to determine rainfall and evaporation amounts during the rice growing season. Data were recorded at 09:00h daily to determine seepage and percolation, rainfall and evaporation from the experimental field. Drought amount (water deficit in soil) was calculated using a model (developed by Dr Towfiqul Islam).

Figure 1 shows the annual rainfall amount from 2002 to 2013 was analyzed. In 2013, total annual rainfall was 1060 mm, which is considerably less than average annual rainfall (1385 mm) in this region. Figure 2 presents the monthly rainfall over the year. From the drought pattern of the previous year in case of BRRI dhan33 drought in reproductive and ripening phases increased with delay transplanting (Fig. 3). In 2013, drought in reproductive phase for transplanting after 24 July rapidly increased (Fig. 4) but ripening phase faced fewer droughts due to sufficient rainfall in October. When short duration variety transplanted before 31 July it can escape terminal drought. For long duration variety, drought amount increased with late transplanting. Figure 5 presents terminal drought over transplanting dates for different growth phases in the previous years and figure 6 presents that of 2013. Drought in vegetative phase shows a decreasing trends over transplanting dates and reproductive phase has a rising trends after transplanting on 24 July and ripening phase has almost similar trend. In 2013, reproductive phase shows decreasing trend on delay transplanting. But in ripening phase severe drought occurred in case of transplanting after 24 July.

BRRI dhan33 yielded the highest (5.1 t/ha) when it was transplanted on 24 July and the lowest yield was found 4.5 t/ha in case of transplanting on 14 August. For BR11, the highest yield was found for July 24 transplanting (5.9 t/ha) and lowest yield was observed in case of 14 August (5.1 t/ha). Yield decreased for both short and long duration
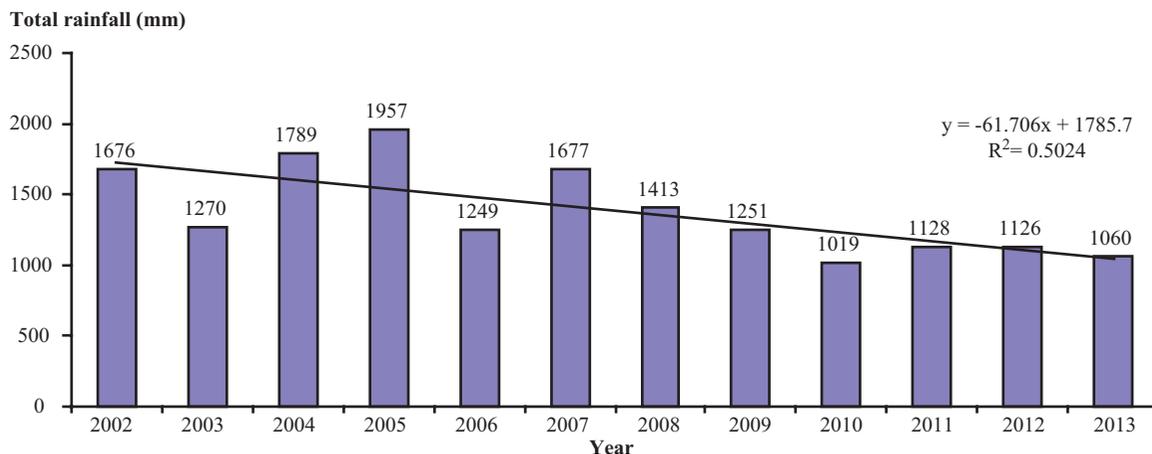
Total rainfall (mm)

Fig. 1. Annual rainfall (2002-2013).

The chart shows annual rainfall values: 2002: 1676, 2003: 1270, 2004: 1789, 2005: 1957, 2006: 1249, 2007: 1677, 2008: 1413, 2009: 1251, 2010: 1019, 2011: 1128, 2012: 1126, 2013: 1060. Trend line equation: $y = -61.706x + 1785.7$, $R^2 = 0.5024$.
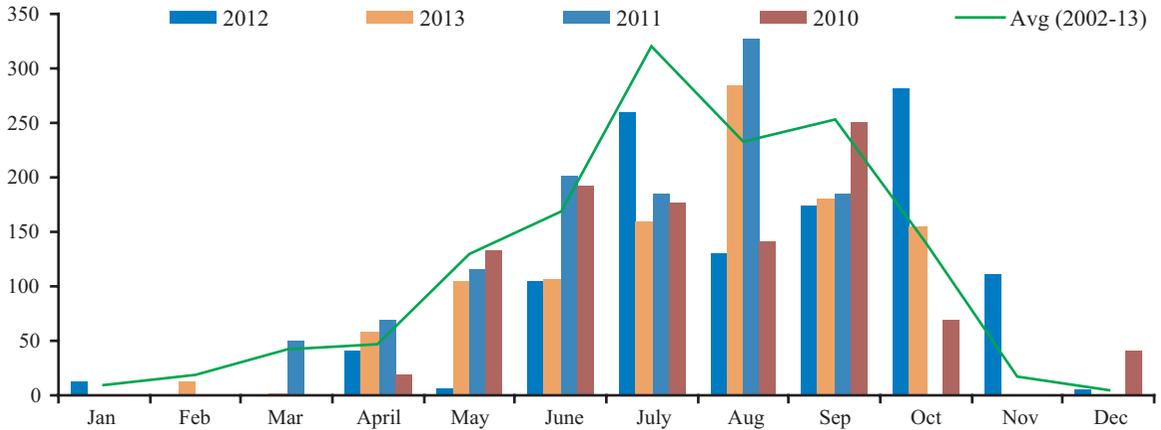
Rainfall (mm)

Fig. 2. Monthly rainfall pattern.
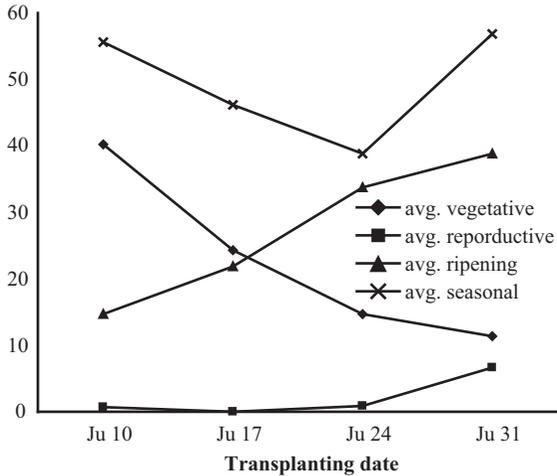
Fig. 3. Average drought pattern(2009-13) for BRRI dhan33.
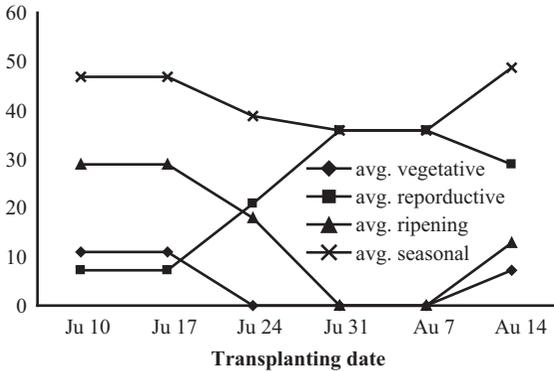
Fig. 4. Drought pattern in 2013 for BRRI dhan33.
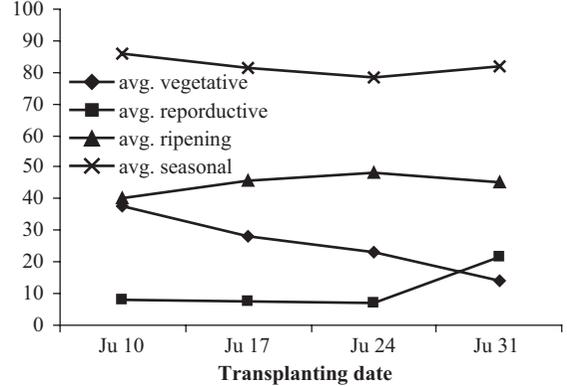

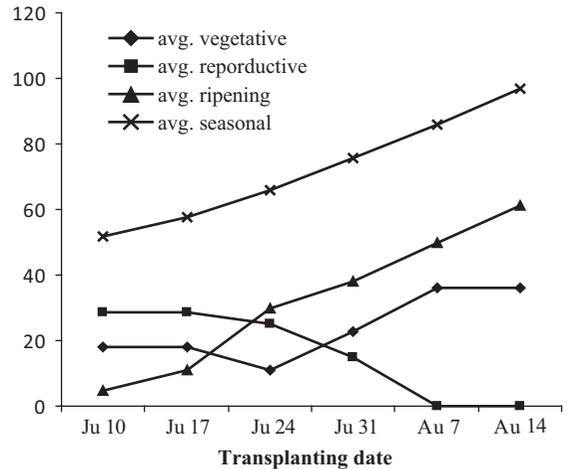Fig. 5. Average drought pattern (2009-13) for BR11.

Fig. 6. Drought pattern in 2013 for BR11.

variety after transplanting on 24 July. Short duration variety faced fewer droughts due to its shorter growth duration. But both short and long duration variety faced fewer droughts when they transplanted before 24 July. So transplanting before 24 July would be medium risk period of drought and after that it would be high risk period.

PEST MANAGEMENT

Parasitism of rice leaf folder

Natural enemies efficiency against rice leaf folder was monitored. For this, rice leaves with the symptoms of leaf folder infestation were collected from three locations of Kushtia sadar upazila during T. Aman season 2013. The leaves were kept individually in test tubes. The open ends of the test tubes were closed by cotton wads with a few drops of water inside the tube kept the leaves moistened .Thus the leaf folder larvae were reared for 20-25 days until completion of the parasite emergence. A total of 256 larvae of rice leaf folder were collected from Kushtia sadar upazila in fourteen occasions. Only one type of parasitoid species (Elasmus sp.) emerged from the reared leaf folder larvae in nine occasions. Out of 11 larvae collected three were parasitized indicating 27.27% of larval parasitism. In some other occasions parasitism ranged from 9 to 16.16%.

SOCIO-ECONOMICS AND POLICY

Stability analysis of BRRI varieties

Objective of the study was to maintain season, year and location-wise data base on the yield performance of BRRI varieties. Experiments were conducted at the Baradi farm of BWDB, Kushtia both in T. Aman 2013 and in Boro 2013-14 seasons. Twenty-seven BRRI developed rice varieties were considered in T. Aman 2013 and 28 BRRI varieties in Boro 2013-14. Among the tested varieties highest yield was obtained with the BR4 (5.5 t/ha) and the lowest with the BR5 (3.7 t/ha). Of the 27 varieties, 20 were found to give higher yields than the standard yield determined for them. The other varieties yielded similar or lower than

the standard yield. The highest increase in yield was obtained with BRRI dhan38 (increase by 0.9 t/ha), whereas the highest reduction was found in case of BR23 (0.8 t/ha reduction). Growth duration of some of the test varieties decreased (up to 14 days as in the case of BR3), whereas in some varities it increased (up to 6 days as in the case of BR23). Lodging at different magnitudes (30%-60%) was observed in case of five test varieties viz BR5, BR25, BRRI dhan32, BRRI dhan34, BRRI dhan37 and BRRI dhan38.

Among the tested varieties the highest yield was obtained with the BR3 (7.4 t/ha) and the lowest was with the BR17 (3.4 t/ha). Of the 28 varieties, eight were found to give higher yields than the standard yield determined for them. The other varieties yielded lower than the standard yield. The highest increase in yield was obtained with BR26 (increase by 2.5 t/ha), whereas the highest reduction was found in case of BR17 (2.6 t/ha reduction). Growth duration of some of the test varieties decreased (up to 18 days as in the case of BR17), whereas in some varieties it increased (up to 27 days as in case of BRRI dhan27). Lodging tendency was not found in the BRRI varieties during Boro season.

TECHNOLOGY TRANSFER

Performance evaluation of BRRI developed Aman and Boro varieties

The activity was conducted at Tarapur, Kumarkhali, Kushtia and Boria sadar, Kushtia to demonstrate BRRI developed high yielding Aman and Boro varieties and evaluate their yield performance. Eleven BRRI developed high yielding Aman varieties BR10, BR11, BRRI dhan33, BRRI dhan34, BRRI dhan39, BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan56, BRRI dhan57 and BRRI hybrid dhan4 were transplanted in Boria, Kushtia. On the other hand eight varieties BRRI dhan28, BRRI dhan29, BRRI dhan50, BRRI dhan55, BRRI dhan58, BRRI dhan59, BRRI dhan60 and BRRI hybrid dhan3 was transplanted in Boro 2013-14 at Tarapur, Kumarkhali. Among the eleven varieties in T. Aman 2013, the highest yield was found in BRRI

hybrid dhan4 and it was 6.41 t/ha and the lowest yield was 3.44 t/ha in case of BRRI dhan34. The highest growth duration was 146 days and the lowest was 105 days in BRRI dhan34 and BRRI dhan57 respectively. In Boro 2013-14, among the eight varieties the highest yield was found 8.17 t/ha in BRRI hybrid dhan3 and the lowest was 5.78 t/ha in case of BRRI dhan50. The highest and the lowest growth duration was 162 days and 147 days in BRRI dhan29 and BRRI dhan28 respectively. Farmers showed positive reaction on BRRI developed new varieties.