# BRRI ANNUAL REPORT
## 2016-2017

**Bangladesh Rice Research Institute**

BRRI ANNUAL REPORT
2016-2017
Bangladesh Rice Research Institute

# BRRI ANNUAL REPORT

**For July 2016-June 2017**

**Bangladesh Rice Research Institute (BRRI)**

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## Contents

# Preface

The present volume of BRRI Annual Report is a summary of research works carried out by 19 research divisions and nine regional stations of the institute during July 2016 to June 2017. This document consists of the significant portions of the research covering eight programme areas.

The programme areas, such as Crop-Soil-Water management, rice farming systems, pest management, socioeconomics and policy, farm mechanization, technology transfer and regional stations representing 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 management technologies were demonstrated in different agro-ecological zones of the country.

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

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

I expect the report will be useful for the scientists, extension agents, policy makers and other partners to be updated on rice research at BRRI.

(Dr Md Shahjahan Kabir)
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* Abroad for higher studies
\+ On deputation outside BRRI
*+ On deputation for higher studies
** Transferred
++ Resigned from BRRI

# Weather information

Weather is an instantaneous state of atmosphere. It influences growth and development as well as pest and diseases. We present here the available weather parameters *viz* maximum and minimum temperature (°C), rainfall (mm), pan evaporation, sunshine hours (hours/day) and solar radiation (Cal/cm$^2$/day) during the experimental year (July 2016-June 2017) as recorded from BRRI headquarters and six regional stations Rangpur, Barisal, Habiganj, Bhanga, Rajshahi and Comilla by Plant Physiology Division.

**Temperature.** The mean (maximum and minimum) temperature was higher in Apri-June for most of the stations during the reporting period. The highest maximum temperature was recorded at Comilla (36.03°C) followed by Barisal (34.77°C), Gazipur (34.57°C), Bhanga (34.31°C Rajshahi (24.14°C) Habiganj (34.10°C) and Rangpur (33.40°C). The mean maximum temperature was quite low during December to January in Rangpur compared to the other stations. However, the mean minimum temperature was the lowest in January for all the stations recorded except Barisal (December) and it was 10.90°C in Rangpur followed by Barisal (11.23°C), Rajshahi (11.31), Bhanga (11.3°C), Comilla (12.29°C), Gazipur (13.52°C) and Habiganj (13.40°C). The mean minimum temperature remained below 20°C from November to March for all the stations data recorded (Fig. 1).

**Rainfall and pan evaporation.** The highest monthly total rainfall (703.00 mm) was recorded in July at Rangpur followed by Habiganj (629 mm), Comilla (563.00 mm), Gazipur (370.00 mm), while it was in August at Barisal (603.60 mm), June at Rajshahi (186.8 mm) and April at Habiganj (539.6 mm). Dry condition prevailed from November to February at all the stations when formal rainfall didn't occur in all the stations except few mm water droplets either mist or dew. Irrespective of station low pan evaporation was observed at cool period of the year that means November to January. The highest evaporation was observed at Gazipur (154.28 mm) in May followed by Rangpur (130 mm) in August, Barisal (118.2 mm) in May, Comilla (104 mm) in April and Habiganj (97.4 mm) in July (Fig. 2)

**Solar radiation and solar hours.** The monthly mean solar radiation was relatively low during the rainy season and also in December to February. The highest mean solar radiation prevailed in November at Comilla, Rangpur and May at Rajshahi, February at Barisal and Habiganj. In all the stations, the mean maximum solar radiation varied from 220 to 439 cal/cm$^2$ per day (Fig. 3).

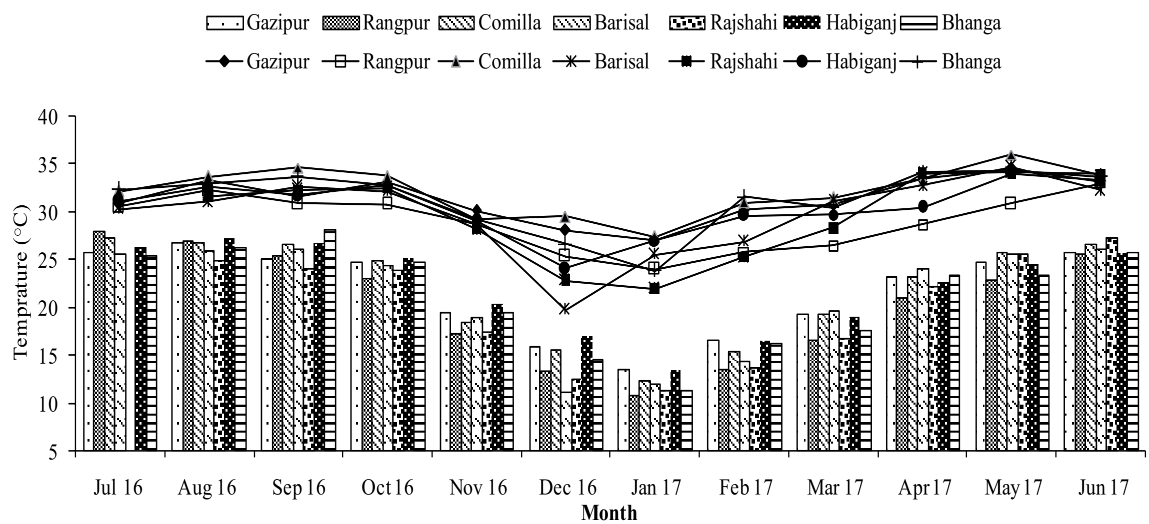



Fig.1. Maximum and minimum temperature of BRRI headquaters in Gazipur and six BRRI RSs during July 2016 to June 2017. Bar and line graph show minimum and maximum temperature respectivly.

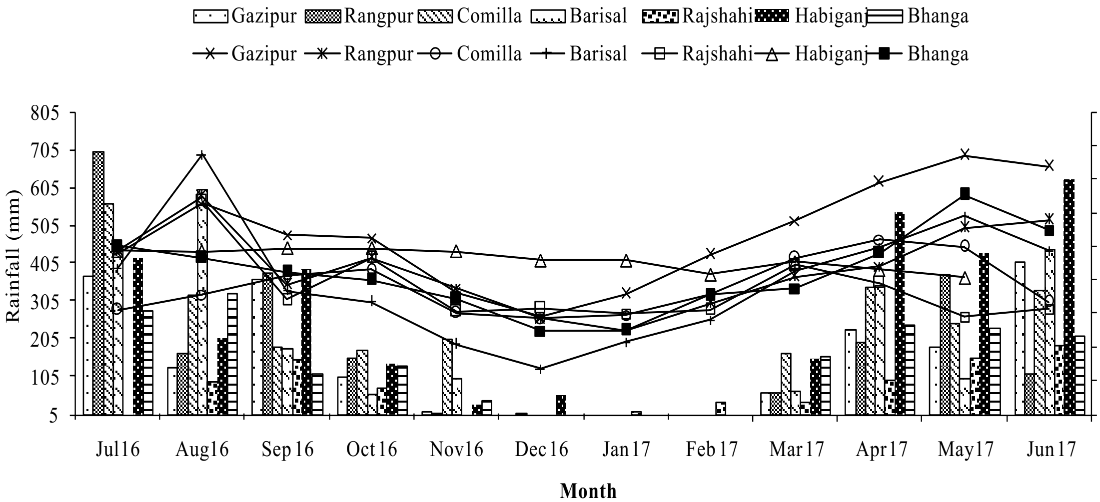



Fig. 2. Rainfall data of BRRI headquaters in Gazipur and six BRRI RSs during the period of July 2016 to June 2017. Bar and line graph show rainfall and evaporation respectivly.

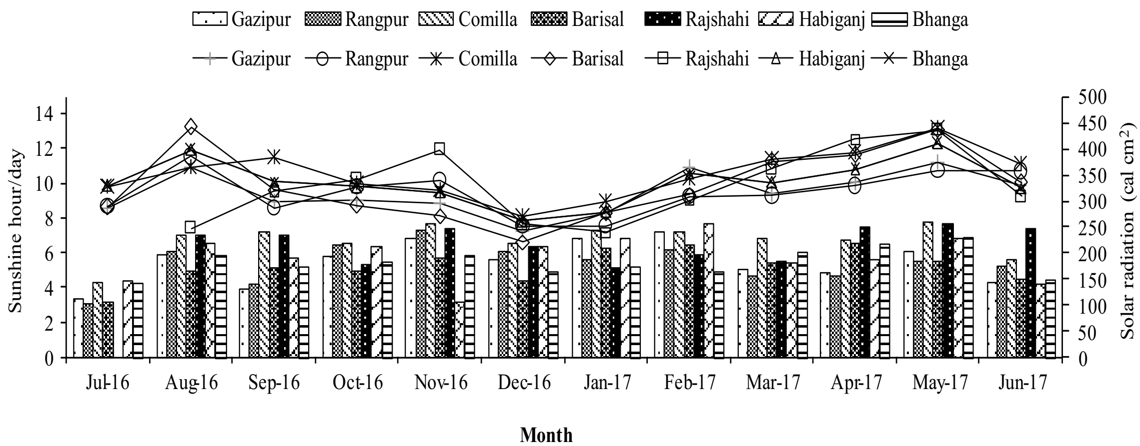



Fig. 3. Sunshine hour and solar radiation of BRRI headquaters in Gazipur and six BRRI RSs during the period of July 2016 to June 2017. Bar and line graph show sunshine hours and solar radiation respectivly.

# Abbreviation and acronyms

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

| | | |
|---|---|---|
| ET | = | evapotranspiration |
| FS | = | foundation seed |
| GABA | = | gamma amino buteric acid |
| GH | = | grasshopper |
| GM | = | gall midge |
| GMB | = | green mirid bug |
| GLH | = | green leafhopper |
| GoB | = | Government of Bangladesh |
| GRS | = | Genetic Resources and Seed |
| GSR | = | green super rice |
| GQN | = | Grain Quality and Nutrition |
| HA | = | Habiganj Aman |
| HAT | = | hours after treatment |
| HB | = | Habiganj Boro |
| ht | = | height |
| IIRON | = | International Irrigated Rice Observational Nursery |
| INGER | = | International Network for Genetic Evaluation of Rice |
| INM | = | integrated nutrient management |
| IPM | = | integrated pest management |
| IPNS | = | integrated plant nutrition system |
| IRRI | = | International Rice Research Institute (Philippines) |
| IRSSTN | = | International Rice Soil Stress Tolerance Nursery |
| IURON | = | International Upland Rice Observational Nursery |
| LCC | = | leaf colour chart |
| LBB | = | lady bird beetle |
| LHC | = | long-horned cricket |
| Lit/ha | = | litre per hectare |
| LR | = | leaf roller |
| LSc | = | leaf scald |
| LSD | = | least significant difference |
| LV | = | local variety |
| LIV | = | local improved variety |
| MAS | = | marker assisted selection |
| ML | = | monogenic line |
| MLT | = | multi-location 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 |
| SPIRA | = | Strengthening Physical Infrastructure and Research Activities |
| SR | = | solar radiation, stem rot |
| STB | = | soil test based |
| STPD | = | staphylinid |
| SYT | = | secondary yield trial |
| | | |
| T. Aman | = | transplanted Aman |
| T. Aus | = | transplanted Aus |
| TGW | = | 1000-grain weight |
| TLS | = | truthfully labelled seed |

| | | |
|---|---|---|
| TOC | = | Training and operation cell |
| TRB | = | Transforming Rice Breeding |
| TSP | = | triple super phosphate |
| USG | = | urea super granule |
| | | |
| WBPH | = | white-backed plant hopper |
| WS | = | wet season |
| WSR | = | wet-seeded rice |
| WTR | = | weed tolerant rice |
| wt | = | weight |
| | | |
| YSB | = | yellow stem borer |

# Plant Breeding Division

SUMMARY

For developing improved rice varieties under different ecosystems, 453 crosses were made and 419 crosses were confirmed as true $F_1$. From segregating generations' ($F_2$-$F_7$), 11,665 superior genotypes were selected and 1,60,075 progenies were advanced through field RGA nurseries (FRGA) in the reporting period. Also, 985 fixed lines were isolated from advanced segregating generations. A total of 437 genotypes from observational yield trial and 290 advanced breeding lines were selected from yield trials. Fifty-nine germplasms from different biotic and abiotic screening nurseries were selected to use in the breeding programme.

Three promising genotypes viz IR77092-B-2R-B-10 having dual tolerance (salinity + submergence) ability for saline prone environment, BR9159-8-5-40-14-57 for submergence and BR7697-15-4-4-2-2 as aromatic rice were evaluated during T. Aman 2016-17 by National Seed Board of Bangladesh (NSB) field evaluation team and have been released as BRRI dhan78, BRRI dhan79 and BRRI dhan80 respectively. BRRI dhan78 showed 6-8 dS/m water salinity tolerance in whole life cycle and 14 days complete submergence at different coastal regions of Bangladesh in the proposed variety trial (PVT). It produced 4.4 t/ha grain yield with 135 days growth duration. BRRI dhan79 produced 5.37 t/ha grain yield, which was significantly higher than the grain yield of BRRI dhan49 (4.12 t/ha). The growth duration of the variety was around five days earlier than BRRI dhan52. Though under 16 days of controlled complete submergence pressure the line produced similar grain yield compared to BRRI dhan52 but under 25 days of submergence pressure at BRRI HQ, Gazipur, the line produced 2.3 t/ha more yield than BRRI dhan52 and 3.1 t/ha more grain yield than BRRI dhan49. BRRI dhan80 is designated as jasmine type premium quality rice and produced higher yield (4.0-4.5 t/ha) than the check variety BRRI dhan37 in a PVT during T. Aman 2016-17. In a proposed variety trial, BR7358-5-3-2-1-HR2 (Com) was tested and showed 0.2-0.3 t/ha higher yield than BRRI dhan28 and similar growth duration to BRRI dhan28 that was recommended by the National Technical Committee as BRRI dhan81. Another genotype BR7831-59-1-1-4-5-9-P1 was evaluated by NSB team in Boro 2016-17 and showed 0.5 t/ha higher yield than the check variety BRRI dhan28 with similar growth duration to the check.

VARIETY DEVELOPMENT

**Upland rice (Aus).** Upland rice (Aus) is synonymous to direct seeded rice (DSR-Aus) or broadcast aus rice in Bangladesh that is important for growing short duration varieties (90-100 days) to increase cropping intensity for boosting rice production. The main emphasis was given to develop varieties with combination of multiple traits such as quick seedling emergence and vigorous growth, short growth duration (90-95 days), tolerance to lodging, drought and pre-harvest sprouting; medium bold to medium slender grains and good eating quality. In total, 29 crosses were made using 24 parents, 18 crosses were confirmed as true hybrid; 434 progenies and 25 fixed lines were selected from pedigree nurseries. Fourteen entries were selected from observational yield trial (OYT). Thirteen advanced lines were selected from preliminary yield trial (PYT#1 and PYT#2). Nine genotypes were selected from secondary yield trial (SYT) for further evaluation. In regional yield trial (RYT), three promising lines were selected. One genotype, BR6848-3B-12 was selected from ALART and recommended for proposed variety trial.

**Transplant Aus rice.** The project aimed to develop short duration (105-110 days), high yield potential genotypes having tolerance to lodging and heat (high temperature) at reproductive phase, pre-harvest sprouting and good grain quality. In total 36 crosses were made using 26 parents and 2,998 $F_1$ seeds were obtained; 18 crosses were confirmed as true hybrid; 525 progenies and 20 fixed lines were selected from pedigree nurseries. Thirty entries were selected from observational yield trial (OYT) and 25 advanced lines were selected from PYT on the basis of homogeneity in respect to plant height, phenotypic acceptability at vegetative and maturity stages. BRRI dhan62 was evaluated in RYT with the check BR26 and BRRI dhan48 for observing the performance of BRRI dhan62 in T. Aus season. BRRI dhan62 produced similar yield with same growth duration to the check BR26 and gave lower yield than the check BRRI dhan48. NERICA10 pure line (Nerica10-7-PL2-B) was recommended by advanced line adaptive research trial (ALART) and proposed variety trial (PVT) will be conducted with it in T. Aus 2017 to release as a new variety.

**Improvement of rice for shallow flooded and deep water environment.** Twenty-two single crosses were made involving 24 parents and 1026 $F_1$ seeds were produced. Six crosses were selected and confirmed as true $F_1$s. Totally 4,620 individuals of $F_2$, $F_5$, $F_7$ and $F_8$ population were advanced through FRGA. From one OYT and one MYT conducted under rainfed condition, two genotypes were selected based on grain yield and growth duration.

**Rainfed lowland rice (RLR).** In total 14 crosses were made, 41 crosses were confirmed and 504 plants were selected from 22 $F_2$ populations. From pedigree nursery 775 segregating progenies and 37 fixed lines were isolated. From observational yield trial (OYT), 63 genotypes were selected, nine genotypes were selected for PYT from IRLON, six genotypes were selected from PYT, 20 genotypes were selected from SYT, eight lines were selected from RYT and two advanced line was selected from ALART. Under TRB project, 14 crosses were made and in OYT, 16 genotypes performed better than check varieties. In PYT, 16 genotypes were selected for RYT trial.

**Salt tolerant rice.** The general objective of this project is to develop high yielding rice varieties tolerant to salt stress as salinity is one of the major constraints for the rainfed lowland and Boro rice ecosystem in southern coastal zone of Bangladesh.

In T. Aman season, 50 crosses were made. A total of 50 $F_1$s for Aman season were confirmed and selected. The field rapid generation advance (FRGA) method was tested at BRRI farm, Gazipur and pedigree nursery yield trials were conducted in Khulna and Satkhira during both T. Aman and Boro seasons. Figures 1 and 2 show the water salinity levels of different experimental locations. Nineteen $F_2$ populations were grown in hotspot (Satkhira) and 260 progenies were selected. In total 363 progenies and 87 fixed lines were selected from pedigree nurseries ($F_3$-$F_6$). Seven genotypes (out of 30 genotypes) were selected from OYT. Nineteen entries (out of 49 genotypes) were selected from STBN, OYT. Five entries (out of 12 genotypes) were selected from PYT. Four entries (out of eight genotypes) were selected from SYT.

In PVS preference analysis IR85926-11-3-1-AJY1-B (4.7 t/ha) and IR78761-B-SATB1-68-6 (5.2 t/ha) were the most preferred genotype. *Saltol* and *Sub*1 QTLs were pyramided into BRRI dhan49 through marker assisted selection. Three S*altol* linked markers (G11, RM493 and RM7075) were used as foreground markers. Recovery of recurrent parent genome in the BRRI dhan49-*Saltol* (BR10050-32-181-32-263) line was 98.2% using 64 background markers (Fig. 3). IR77092-B-2R-B-10 having dual tolerance (salinity + submergence) ability for saline prone environment was recommended by NSB team and has been released as BRRI dhan78 that showed 6-8 dS/m water salinity tolerance in whole life cycle and 14 days complete submergence at different coastal regions of Bangladesh (Tables 1 and 2).

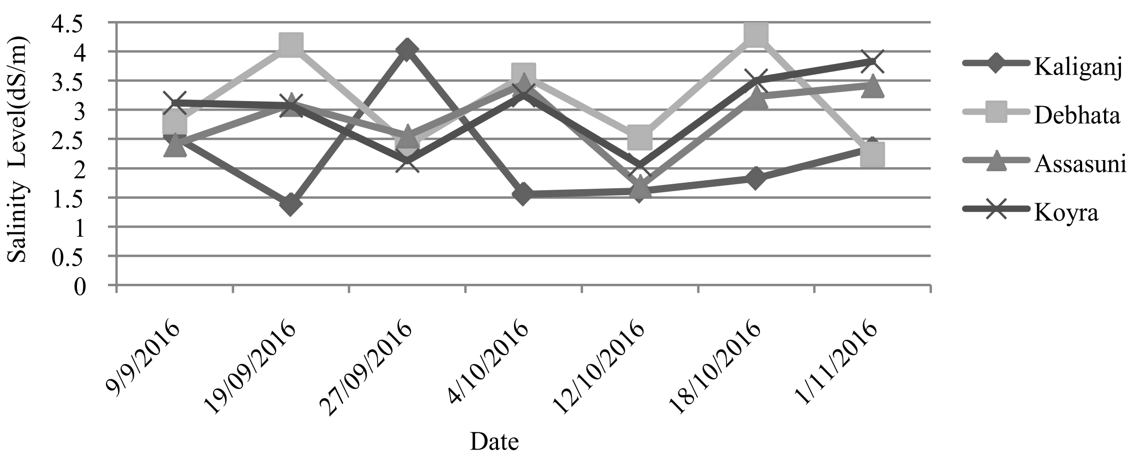



Fig. 1. Water salinity levels of different experimental location in Satkhira, T. Aman 2016-17.

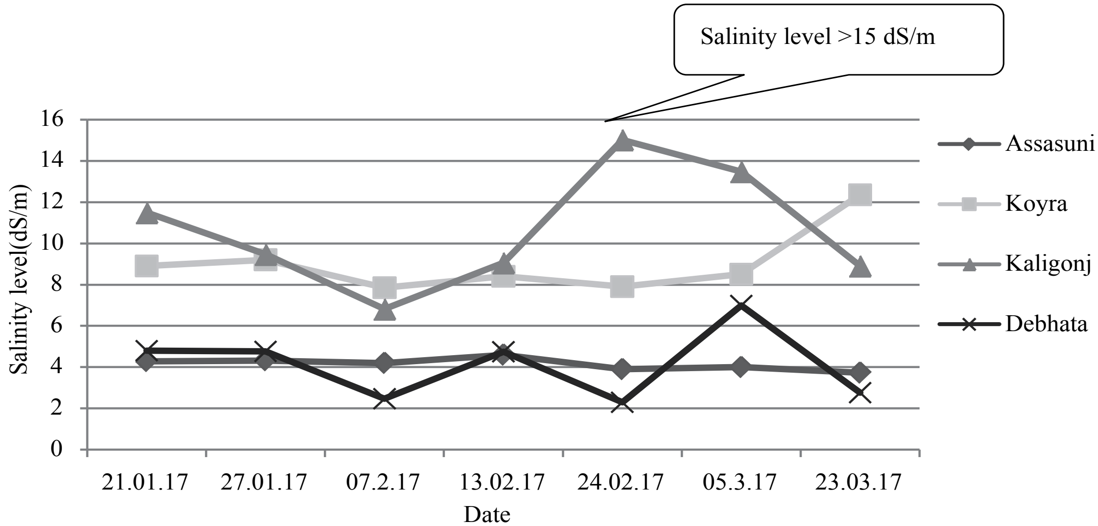



Fig. 2. Water salinity levels of different experimental location in Satkhira, Boro 2016-17.

In Boro season, 100 crosses were made. Ninety F1s were confirmed and registered in the BRRI cross list. Twenty-five F2 populations were selected and bulked crosswise. Four hundred two progenies and 88 fixed lines were selected from pedigree nurseries (F3-F6). Twenty-one entries (out of 56 genotypes) were selected from OYT. Ten entries (out of 49 genotypes) were selected from STBN, OYT. Ten entries (out of 24 genotypes) were selected from PYT#1 and PYT#2. Three entries (out of 13 genotypes) were selected from SYT. Two entries (out of 12 genotypes) were selected from AYT#2.

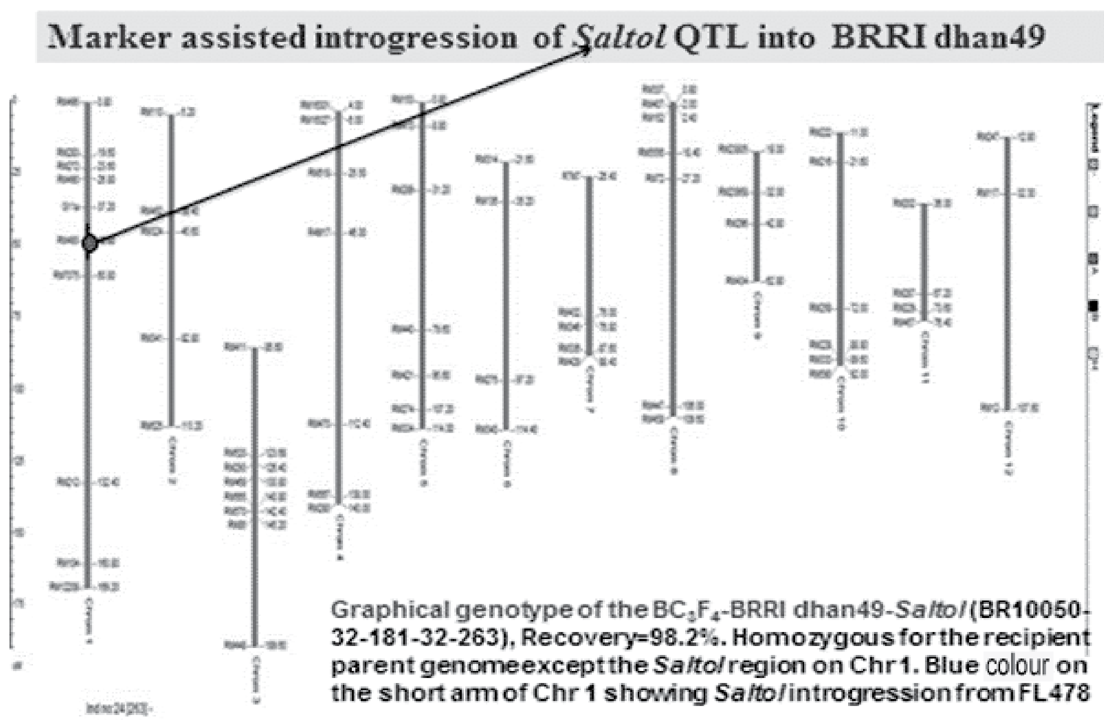



Fig. 3. Marker Assisted introgression of *Saltol* QTL into BRRI dhan49.

In PVS preference analysis, IR86385-117-1-1-B (6.4 t/ha) was the most preferred genotype by the farmers.

### Establishment of new field rapid generation advance (FRGA) method at BRRI

The pedigree breeding method was used by BRRI since its inception in 1970. BRRI has developed raised bed based FRGA technique for managing bigger breeding population (3000-4000 progenies per cross) and rapid cycle breeding, which is different from IRRI FRGA system. Breeding populations are grown using FRGA followed by single seed descent (SSD) method to transmit the desirable variations/traits from $F_2$ to $F_{5}:_{6}$ generation (Fig. 4). In IRRI, FRGA was setup through inserting the seedling trays and maintained 104 progenies per tray. Thus FRGA method that established at BRRI is effective for rapid advancing of larger breeding populations in industrial scale to achieve the target genetic gain (M A Rahman, BRRI).

### Newly developed methods of FRGA

Segregating populations were grown in the field in raised beds (9 m × 1.25 m) with very close spacing (5 cm × 5 cm) and low fertilizer (a quarter of recommended dose) to shorten growth duration (Fig. 4). The duration from $F_2$ to $F_5$, which generally takes about four years was shortened to two years. In the 1st year (season 1), a cross between variety A and variety B was performed. Genuine $F_1$ plants were confirmed by observing phenotypic characters, bulked and grown in the RGA nursery. Around 3000-4000 randomly selected $F_2$ seeds were sown in raised bed at high density. Raising healthy seedlings was achieved by using a lower seed rate (50 g/m$^2$) than the usual practice. Older seedlings (21-day-old, salinity programme; 36-day-old, insect resistance programme) were transplanted after pre-screening. Growth duration became seven days shorter when older seedlings (36 days) were transplanted than 21-day-old seedlings in the FRGA field. Because seedlings remain in the seedbed more than five weeks with closer spacing and higher temperature (microclimatic variation) that may trigger early flowering compared to younger (21-days-hold) seedling. A spacing of 5 cm × 5 cm was used to accommodate a high density of seedlings compared to the traditional pedigree method. Therefore, we accommodated 12 times more plants in the same area using FRGA compared to the conventional pedigree method. We grew over 4,000,000 plants per hectare, whereas in the pedigree method we can grow only >300,000 plants (20 cm × 15 cm spacing) per hectare. Using FRGA, fertilizers were not applied by top dressing during the cultivation, which reduced input costs for every generation. Although the plants showed nitrogen deficiency symptoms, sufficient panicles from each plant were produced. For the line stage testing (LST), single rows were grown from single panicles in $F_6$/$F_7$ generation.

Two types of water controlling practices were followed: (1) minimum irrigation as required; or (2) standing water. For the first method, it was important not to over-stressing plants. The water

**Table 1. Yield and agronomic performance of BRRI dhan78 in the proposed variety trial (PVT), T. Aman 2015-16.**

| Designation | Seedling height (cm) | Plant height (cm) | Growth duration (day) | Grain yield (t/ha) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | Mean |
| BRRI dhan78 (IR77092-2R-B-10) | 53 | 119.5 | 135 | 4.42 | 4.61 | 4.59 | 4.13 | 4.05 | 5.36 | 4.42 | 6.89 | 4.46 | 4.77 |
| BRRI dhan41 (ck) | 40 | 121.0 | 144 | 3.9 | 4.99 | 4.71 | 3.34 | 3.69 | 4.16 | 4.01 | 5.31 | 5.43 | 4.34 |

Seeding date: 15 July 2015. L1: Assasuni (Satkhira), L2: Tarali (Khulna), L3: Dumuria (Khulna), L4: Rampal (Bagerhat), L5: Paikgacha (Khulna), L6: Debhata (Satkhira), L7: Subarnachar (Noakhali), L8: Kolapara (Patuakhali), L9: Saronkhola (Bagerhat).

**Table 2. Grain characteristics of the proposed variety.**

| Designation | Milling yield (%) | Head rice yield (%) | Decorticated grain | | | | ER* | 1000 grain wt (g) | Protein (%) | Amylose (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length (mm) | Breadth (mm) | L-B Ratio | Size and shape | | | | |
| BRRI dhan78 (IR77092-2R-B-10) | 69.4 | 65.3 | 5.6 | 2.0 | 2.80 | MS | 1.4 | 26.6 | 8.0 | 25.2 |
| BRRI dhan41 (ck) | 70.0 | 66.0 | 6.1 | 2.2 | 2.77 | MS | 1.3 | 26.4 | 7.0 | 25.0 |

* ER: Elongation ratio. MS= Medium slender.

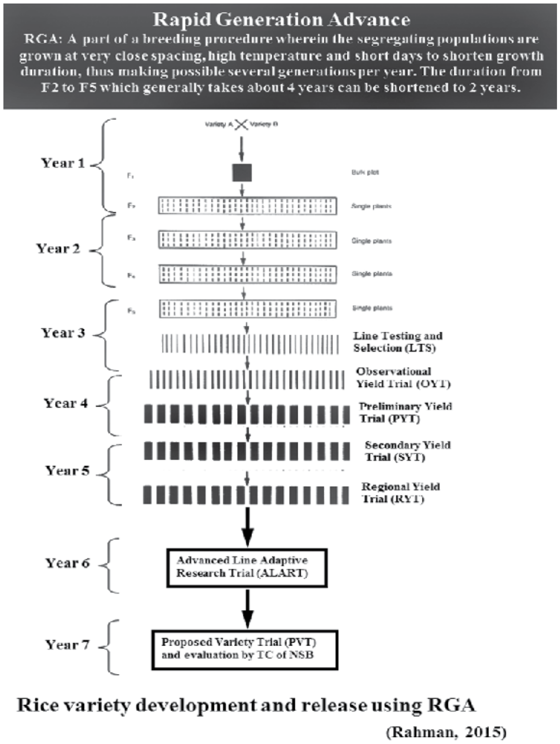



Fig. 4. Rice variety development and release procedure using RGA/FRGA and SSD.

level in the field was lower than field capacity but irrigation was applied before cracks were visible on the soil, which saved irrigation water. Using the second method, particularly during cooler season, 5-7 cm standing water was kept for a couple of weeks just after recovery after transplanting and in this way it was possible to suppress weeds and also to reduce mortality due to cold. Weeding was done when necessary using hand tools. Clipping was done one time and just after flowering. All the tillers were removed except the main tiller to make harvesting easier. Clipping was subsequently avoided and during harvesting only one panicle was collected from each plant, which was uprooted later on it reduced costs and saved more time. Panicles were harvested when they contained more than 50% mature seed. No pedigree records were kept, which saved considerable labour.

Similarly in the 2nd season, $F_3$ and $F_4$ generations were grown in the FRGA nursery. However seedling mortality in FRGA nursery was higher in T. Aman (wet season) because of higher temperature and humid weather aggravating sheath blight and sheath rot diseases. We had sown each panicle separately in the seedbed. Only one healthy seedling per panicle was transplanted in the main FRGA bed (Fig. 5).

Fig. 5. Segregating population was grwn in field RGA mmethod at transplanting and maximum tillering stage.

We harvested one panicle per plant from all 3000-4000 plants per cross. which ensured the representation of progeny from every plant. In the 3rd season, we will have $F_5$ generation and single panicle per plant was harvested following the same procedure described above. After $F_5$-$F_6$, LST trials were done where almost all the plants were homozygous. In this stage progeny rows will be selected on the basis of our desired traits like homogeneity, growth duration, grain type, disease tolerance, and phenotypic acceptability. In the 4th season, OYT and PYT will be carried out followed by other trials e.g. AYT, RYT, ALART and PVT following the normal testing procedure.

Currently a large number of $F_{2:3}$ populations consisting of 160,075 progenies from breeding programme for Boro, cold, salinity and submergence tolerance, disease resistance are being advanced using FRGA at BRRI (Table 3). Moreover, FRGA provides an opportunity to manage bigger breeding population at BRRI to achieve the target of increasing genetic gain.

**Development of premium quality rice (PQR).** Efforts were made to develop aromatic and non-aromatic fine quality rice with national (Kalizira/Chinigura/BRRI dhan34 type) and international (Basmati/Banglamati/Balam type) standards for domestic use and export. Experiments were conducted in T. Aman and Boro seasons. In T. Aman, 11 crosses were made, 15 crosses were confirmed and 111 plants were selected from 15 $F_2$ populations. From pedigree nursery 350 segregating progenies and 36 fixed lines were isolated. Thirty-six genotypes from OYT, 21 from PYT, 10 materials from SYT (SYT#1 and SYT#2) were selected for further evaluation. From RYT, eight promising lines were selected for on farm trials (ALART). In PVT, one genotype, BR7697-15-4-4-2-2 having aroma, higher yield (4.0-4.5 t/ha) and Jasmine rice type grain qualities, was recommended by NSB field evaluation team to release it as BRRI dhan80 (Table 4). In Boro, seven crosses were made, while 20 were confirmed and 226 plants were selected from 25 $F_2$ populations. From pedigree nursery 453 segregating progenies and 293 fixed lines were isolated. Twenty-four genotypes were selected from OYT, seven genotypes were selected from PYT, four materials were selected from SYT and two were selected from RYT for promoting in ALART. None of the materials was found suitable for PVT from ALART.

**Development of rice varieties for favourable Boro environment.** The major objectives of the project were to develop improved genotypes with high yield potential (≥8.0 t/ha), earliness (130-135 days) and acceptable grain quality for favourable irrigated ecosystem in Bangladesh. Sixteen crosses were made. Ten crosses were confirmed as true $F_1$. In total, 211 superior individual plants were selected from $F_2$ populations based on phenotypic performance of each cross. From pedigree nurseries, 211 individual progenies were selected from 11crosses of $F_3$- $F_6$ populations. Forty-three out of 66 genotypes were selected from OT based on growth duration, yield and homogeneity in other morpho-agronomic traits. From PYT-1, eleven genotypes viz BR8904-28-1-2-1-1, BR8904-28-1-2-2-2, BR8554-71-9-2-2-3-2, BR8554-71-9-2-4-1-1, BR8556-36-1-6-2-4-1, PIR-26>CO-2071-1-2, BR9208-4-2-2-1, BR9208-22-2-2-2, IR11A108, IR11A307 and KARJAT5 having 0.6-1.3 t/ha yield advantage over check varieties BRRI dhan28, BRRI dhan29, BRRI dhan58 and BRRI dhan60. From PYT-2, seven genotypes viz BR9675-68-5-1, BR9679-2-3-4 BR9709-55-2-1, BR9208-8-1-1-1, BR8553-25-14-4-1-2, BR9213-45-2-1, and

**Table 3. Current FRGA activities at BRRI, Gazipur, 2016-17.**

| Programme and ecosystem | No. of cross | No. of progeny line |
|---|---|---|
| Breeding for favorable Boro | 42 | 43,207 |
| Breeding for cold tolerance | 31 | 28,127 |
| Breeding for salinity tolerance | 23 | 47,225 |
| Breeding for submergence tolerance | 13 | 17,476 |
| Breeding for disease resistance | 12 | 24,040 |
| Total | 121 | 160,075 |

**Table 4. Performance of the proposed variety for premium quality rice, T. Aman 2015-16.**

| Designation | Plant height (cm) | Growth duration (day)** | Grain yield (t/ha)* | Grain characteristics | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Head rice yield (%) | L-B ratio | Size and shape | Elongation ratio (ER) | Imbibition ratio (IR) | Protein (%) | Amylose (%) |
| BR7697-15-4-4-2-2 (BRRI dhan80) | 121 | 136 | 4.46 | 65.1 | 3.2 | LS | 1.3 | 3.1 | 8.5 | 23.6 |
| BRRI dhan37 (ck.) | 130 | 149 | 3.50 | 67.4 | 3.3 | MS | 1.2 | 3.7 | 10.3 | 23.8 |

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

IR110621-C1-C2-B-B-B-25-1 having 0.5-0.9 t/ha yield advantage over check varieties BRRI dhan28, BRRI dhan29, BRRI dhan58 and BRRI dhan60. In AYT, total 15 genotypes viz IR06N220, IR11A127, IR100008-91-B, IR99061-B-B-7, IR12A288, IR09A235, IR99062-B-B-1, IR14D155, IR100008-88-B, IR14N126, IR99056-B-B-15, IR99090-B-B-62, IR14A193, IR99092-B-B-91 and IR14D111 had 0.8-1.0 t/ha yield advantage over check varieties BRRI dhan28, BRRI dhan29 and BRRI dhan60. In RYT, no genotypes were found superior than the check varieties. In a proposed variety trial, BR7358-5-3-2-1-HR2 (Com) was tested and it showed 0.2-0.3 t/ha higher yield with growth duration similar to BRRI dhan28 (Table 5). National Technical Committee of the NSB meeting recommended it as BRRI dhan81.

**Development of cold tolerant rice.** The major objective of the project was to develop high yielding rice varieties tolerant to cold injury. Sixteen crosses were made. Thirteen crosses were confirmed as true $F_1$. In total, 14,831 individual plants were selected from 11 crosses of $F_2$ population by RGA system based on phenotypic performance. From pedigree nursery in RGA method, 4,792 individual plants were selected from $F_3$-$F_6$ population. In conventional method 692 superior individual plants and 25 fixed lines were isolated from 33 crosses of $F_3$-$F_7$ populations. Twenty-seven genotypes were selected from OYT based on growth duration, yield and homogeneity in other morpho-agronomic traits, and superiority in one or more traits over the check variety. In PYT, six genotypes viz BR8562-18-1-2-3-4-2, BR8562-11-2-6-1-1-2, BR8564-32-1-1-6-1-1, BR8562-11-2-6-1-1-1, BR9989-26-1-1 and BR8562-11-2-6-2-5-2 had 0.6-0.8 t/ha yield advantage over the check varieties BRRI dhan28 and BRRI dhan58.

**Zinc enriched rice (ZER).** The main objective of the programme was to develop high yielding rice varieties with improved nutritional quality in term of high zinc content in polished grain. The experiments were conducted at both T. Aman and Boro seasons. In T. Aman, 28 crosses were made. A total of 15 crosses were confirmed as true $F_1$ comparing with their respective parents. Three crosses were made including back- and top-crosses. From $F_2$ population, 945 progenies were selected from 33 crosses. A total of 1,964 individual superior progenies were selected following pedigree method of selection in $F_3$-$F_7$ generations. Seventy-three fixed progeny rows were bulked from $F_5$-$F_7$ and advanced generations. From OYT, 10 uniform genotypes were selected considering initial yield advantage over the check varieties for further evaluation. Seven genotypes were selected from preliminary yield trial having yield advantage of at least 0.5-0.8 t/ha over the check varieties. Six genotypes from SYT were selected for regional yield trial. None of the genotypes were selected from RYT. In Boro season, 43 crosses were made for developing breeding materials. A total of 18 crosses were confirmed as true $F_1$. From $F_2$ population, 247 individual plants were selected from nine crosses. A total of 335 individual progenies were selected from $F_4$-$F_9$ generations. Thirty-five progeny rows were bulked from advanced generations. From OYT-1, a total of 16 and OYT-2, a total of 19 uniform genotypes were selected based on yield advantage over the check varieties. Four genotypes were selected from PVT considering yield advantage of at least 0.5 t/ha over the check varieties, growth duration and zinc content. Six genotypes from SYT were selected for regional trial. Four genotypes in term of yield advantage (0.6 to 1.2 t/ha) with growth duration more or less similar to the check varieties were selected from RYT-1. In a proposed variety trial, BR7831-59-1-1-4-5-9-P1 was tested that showed 0.5 t/ha higher yield than BRRI dhan28 with growth duration similar to BRRI dhan28 (Table 6). It was recommended by the National Technical Committee of the NSB meeting for release as a variety.

**Table 5. Performance of the proposed lines in the PVT, Boro 2016-17.**

| Designation | GD (day) | Yield (t/ha) | MY (%) | HRY (%) | GL (mm) | GB (mm) | L/B ratio | Size and shape | Protein (%) | Amy (%) | ER | IR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BR7358-5-3-2-1-HR2 (com) | 140 | 6.5 | 73 | 65 | 6.1 | 2.5 | 3.5 | LS | 10.3 | 26.5 | 1.5 | 4.5 |
| BRRI dhan28 (ck) | 141 | 6.3 | 71 | 68 | 6.3 | 2.7 | 3.2 | MS | 8.6 | 27.0 | 1.5 | 4.3 |

GD= Growth duration, MY = Milling yield, HRY = Head rice yield, GL= Grain length, GB = Grain breadth, IR = Imbibition ratio, ER = Elongation ratio.

**Provitamin A enriched rice (Golden Rice).** Vitamin A deficiency (VAD) is a serious public health problem among young children and pregnant women who largely depends for their nutritional requirement on rice or nutritionally poor staple food. In Bangladesh, on average 416 gm rice is consumed per person a day (HIES 2010) accounting 70% of the calorie intake. The genotypes showed wide range of variations in yield and other yield contributing traits. The grain yield ranged from 5.91 t/ha to 6.64 t/ha with an average value of 5.4 t/ha. Growth duration differed from 149 days to 151 days. One line was selected considering similar or higher yield than the non-transgenic control, BRRI dhan29. These lines showed up to 11.2 % yield advantage over BRRI dhan29. All the other lines matured in similar duration to BRRI dhan29. Total carotenoid (TC) was analyzed two months after harvest. At months of storage in brown paper bags in room temperature the rice samples were dehulled using Chinese bench top dehuller. The dehulled samples were immediately polished using Kett Pearlest rice polisher and stored in -80°C until carotenoid analysis. The levels of TC varied from 10.00 tp 13.2 ug/g in the selected lines. However, original Kaybonnet Golden Rice event GR2-R had average TC value of 13.7 ug/g. However, rice is the poor source of vitamins and minerals particularly β-carotene, the precursor of vitamin A is absent in rice endosperm what we eat. Japonica type transgenic Golden Rice (GR) can accumulate β-carotene in the endosperm. $BC_3F_8$ and $BC_4F_3$ backcross introgression lines with beta-carotene traits transferred from transgenic Japonica Golden Rice 2 into BRRI dhan29 were evaluated in confined field trial at Gazipur with permission of the government. The objective of the study was to evaluate agronomic and product performance. This trial also aimed to generate environmental safety data of transgenic Golden Rice.

**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). In T. Aman season, 58 crosses were made. Fourteen crosses were confirmed, 568 progenies from 14 $F_2$ populations, 1,796 progenies (907 for BPH and 889 GM) and 236 fixed lines for BPH and GM were selected from pedigree nursery. Twenty-one lines from OYT, nine lines from PYT were selected. Six lines from SYT#1 and SYT#2 were selected. In Boro season, 35 crosses were made and 26 crosses were confirmed. From $F_2$ populations, 353 as well as 570 progenies for BPH registance were selected from pedigree nursery. Thirty resistant genotypes from OYTs and six genotypes from SYT were selected showing moderately resistant (MR) to resistant (R) for BPH in Boro season.

**Disease resistant rice.** Efforts were made for developing varieties resistant to bacterial blight (BB), rice tungro virus (RTV) and blast diseases. Fifteen crosses for BB and eight for blast in T. Aman and 25 crosses for BB and eight for blast were made in Boro season. Eleven crosses for BB and five for blast during T. Aman and 15 crosses for BB and five for blast in Boro were confirmed as true $F_1$. In total 4,425 progenies for BB and 1,737 progenies for blast were selected from RGA nursery ($F_2$ populations) in T. Aman season and 13,374 resistant progenies for BB and 3,758 progenies for blast were selected from RGA nursery in Boro season. A total of 241 superior progenies for BB, 14 for blast from pedigree nursery ($F_3$-$F_6$ generations) were selected in T. Aman whereas, 772 progenies were selected for BB from $F_2$ populations and 473 superior progenies for BB, 98 for blast were selected from pedigree nursery ($F_3$-$F_6$ generations) during Boro season. Twenty fixed lines for BB, 25 for blast and 9 fixed lines for RTV were isolated during T. Aman season, while 20 fixed lines were

**Table 6. Performance of the proposed lines in the proposed variety trial, Boro 2016-17.**

| Designation | GD (day) | Yield (t/ha) | MY (%) | HRY (%) | GL (mm) | GB (mm) | L/B ratio | Size and shape | Protein (%) | Amylose (%) | Zinc (mg/kg) | ER | IR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BR7831-59-1-1-4-5-9-P1 | 141 | 6.7 | 70.1 | 68.4 | 6.7 | 2.8 | 3.2 | MS | 8.3 | 25.5 | 27.5 | 1.5 | 4.5 |
| BRRI dhan28(ck) | 142 | 6.5 | 72.3 | 70.2 | 6.3 | 2.7 | 3.1 | MS | 7.2 | 25.4 | - | 1.4 | 4.3 |

GD= Growth duration, MY = Milling yield, HRY = Head rice yield, GL= Grain length, GB = Grain breadth, IR = Imbibitional ratio, ER = Elongation ratio.

isolated from $F_6$ generation for BB during Boro season. From OYT, six homogeneous lines for BB, 11 lines for blast and three for RTV in T. Aman, while 16 entries for BB during Boro season showed better yield potential and agronomic performance over the check varieties, and tolerance to BB. From PYT, six genotypes for BB and three breeding lines for RTV in T. Aman and eight genotypes for BB were selected in Boro season. Nine genotypes from SYT and one genotype from AYT were selected for BB during T. Aman season. Two genotypes for BB resistance were selected from RYT during Boro season.

**Submergence and water stagnation tolerant rice varieties.** Totally 18 single crosses were made involving 14 parents and 1,463 $F_1$ seeds were produced. Thirteen crosses were selected and confirmed as true $F_1$s. Totally 17,176 individuals of $F_3$ population were advanced through FRGA. Pedigree generations were grown under controlled submergence and medium stagnant water condition of BRRI RS, Rangpur. A total of 870 tolerant progenies from $F_2$-$F_8$ generations were selected and preserved. Thirty-seven homozygous and tolerant lines were selected for observational yield trial. In marker assisted selection, introgression of SUB1 QTL into the genetic background of BR22 was advanced up to $BC_5F_2$ generation and 12 heterozygote plants were selected. Whereas, introgression of SUB1 QTL into BRRI dhan62 was advancd up to $BC_1F_2$ and >4000 seeds those were produced for advancement of breeding population through RGA. From five OYTs, four PYTs and one AYT conducted under rainfed and flash flooding conditions, 91 genotypes were selected based on grain yield and growth duration. In PVS trial conducted under non-flooded condition, the highest preference score was obtained in favour of IR 85261-18-158-Gaz-3B-62 because of more effective tiller, acceptable grain quality, tall plant type, lodging resistance, long panicle, less disease attack, less sterility and prediction of good yield. Among the tested entries, IR 85261-18-158-Gaz-3B-62 produced the highest grain yield 5.0 t/ha. In PVT, the proposed line BR9159-8-5-40-14-57 produced 5.37 t/ha grain yield, which was significantly higher than the grain yield of BRRI dhan49 (4.12 t/ha). The growth duration of the proposed line was around five days earlier than BRRI dhan52. Though under 16 days of controlled complete submergence pressure the line produced similar grain yield compared to BRRI dhan52 but under 25 days of submergence pressure at BRRI HQ, Gazipur, the line produced 2.3 t/ha more yield than BRRI dhan52 and 3.1 t/ha more grain yield than BRRI dhan49. The proposed line has already been released as BRRI dhan79 in the 92nd NSB meeting on 5 April 2017 (Table 7). In 'head to head' trial, Sub1-varieties were tested under non-flooded conditions of four locations and the highest average grain yield was obtained from BRRI dhan52 being 4.70 t/ha with 141 days growth duration whereas the lowest average growth duration was exhibited by Binadhan-11 which was 122 days with 3.94 t/ha grain yield.

**Development of drought tolerant rice.** In total, 17 crosses were made, 29 crosses were confirmed and 170 plants were selected from 16 $F_2$ populations. From pedigree nursery 846 segregating progenies were selected. In OYT, 26 genotypes performed better than check varieties in respect to yield under reproductive stage drought condition. Under TRB project 13 crosses were made. In OYT, 18 genotypes performed better than check varieties in respect to yield under reproductive stage drought condition. In PYT, 10 genotypes were selected.

**Water saving and aerobic rice varieties for low water environment.** Totally four single crosses were made involving five parents and 56 $F_1$ seeds were produced. Totally 8,900 progenies from 25 crosses were selected and preserved. From three AYTs conducted under AWD condition, 11 genotypes were selected based on grain yield and growth duration in T. Aman season. On the other hand, two PYTs and two AYTs conducted under AWD conditions, six genotypes were selected based on grain yield and growth duration in Boro season.

**Green super rice (GSR)**. The project aims at developing of less input but high yield potential genotypes with tolerance to different stresses. From PYT, seven genotypes from T. Aman season and five genotypes from Boro season were selected on the basis of yield, plant type, grain quality, homogeneity and other agronomic traits. Four genotypes were selected from SYT in T. Aman season, while three genotypes from SYT#1 and four genotypes from SYT#2 were selected in Boro

**Table 7. Performance of the proposed lines in PVT, T. Aman 2015-16.**

| Designation | Plant height (cm) | Growth duration (day) | Grain yield (t/ha) | Grain characteristics | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Head rice yield (%) | L-B ratio | Size and shape | Elongation ratio (ER) | Imbibition ratio (IR) | Protein (%) | Amylose (%) |
| BR9159-8-5-40-14-57 (Proposed variety) | 112 | 140 | 5.37 | 63.3 | 2.3 | IM | 1.3 | 3.1 | 7.8 | 25.2 |
| BRRI dhan49 (Standard ck) | 110 | 141 | 4.12 | 65.0 | 2.7 | SM | 1.1 | 2.8 | 7.0 | 25.0 |
| BRRI dhan52 (Resistant ck) | 128 | 144 | 5.26 | 56.0 | 2.1 | IM | 1.5 | 2.8 | 7.3 | 26.8 |

Growth duration and grain yield are presented as average of 10 locations (Mogholerbag, Sadar, Rangpur; Aditmari, Lalmonirhat; Kulaghat, Sadar, Lalmonirhat; Palashbari, Gaibandha; Batashar, Habiganj; Dewanganj, Jamalpur; Islampur, Jamalpur; Dhobaura, Mymensingh; BRRI RS, Rangpur (Control submergence-16 days submergence); BRRI HQ, Gazipur (Control with 25 days submergence). IR= Imbibition ratio ER= Elongation ratio, IM=Intermediate medium SM=Short medium.

season. Three drought tolerant genotypes from AYT and two salinity tolerant genotypes were selected from participatory variety selection (PVS) trial for T. Aman season. In Boro season, four genotypes were isolated from RYT.

**International Network for Genetic Evaluation of Rice (INGER).** This project focused on sharing and use of germplasm and breeding lines through international platform for the acceleration of genetic improvement of rice varieties. In T. Aman and T. Aus 2016, five genotypes were selected for parent and 21 genotypes were selected for yield trial from International Rainfed Lowland Rice Observational Nursery (IRLON 2016). Four genotypes were selected as parent from International Rice Soil Stress Tolerance Nursery (IRSSTN) - (Coastal salinity, wet season) 2016. Six genotypes were selected for yield trial from International Upland Rice Observational Nursery (IURON 2016). In Boro 2016, 14 genotypes at BRRI HQ, Gazipur and nine genotypes at BRRI RS, Rajshahi were selected for yield trial from International Irrigated Rice Observational Nursery (IIRON).

# Biotechnology Division

SUMMARY

Twenty-five experiments were conducted under eight projects during the reporting period. In total 169 doubled haploid green plants were regenerated from the hybrid anther of different crosses. In that period, 87 homozygous materials were evaluated in different yield trials including OT, PYT, SYT and RYT. Among them 30 promising materials were selected based on phenotypic appearance, growth duration and yield performance for further evaluation. A total of 167 somaclones from EMS treated seeds were selected for further evaluation. In total 124 plants were selected from 145 somaclonal lines of BRRI dhan48. Forty plants were selected from 16 somaclonal lines of BRRI dhan47. A total of 73 somaclonal plantlets were regenerated from five black rice genotypes. Materials developed from yield enhancing QTLs were evaluated as RYT and ALART. Materials developed from salt QTL study were evaluated as PYT and SYT. Five bacterial blight resistance gene pyramided BRRI dhan29 rice lines having BB resistance genes (*Xa4* and *Xa21)* were evaluated as RYT and three lines were selected among them. Twenty-one bacterial blight resistance gene pyramided BRRI dhan28 lines having three BB resistance genes (*Xa4, xa13* and *Xa21)* were evaluated as observational yield trial and among them nine lines were selected depending on the phenotypic acceptability, yield, growth duration and molecular confirmation. QTL mapping population for taller seedling height was developed by cross between BR11/Shadamota and $F_2$ seeds were harvested from this cross. A total of 115 SSR markers were identified as polymorphic from parental survey. For the gene cloning study, *Porteresia coarctata* plants were treated with 100 mM NaCl salt for seven days. cDNA were synthesized from RNA of treated *P. coarctata* and *DREB1* gene was amplified.

DEVELOPMENT OF DOUBLE HAPLOID RICE THROUGH ANTHER CULTURE

**Llow glycemic index (GI) rice variety**

A total of 55,686 hybrid anthers from nine crosses were plated in N6 and M10 medium. In total 522 calli were obtained. The highest numbers of calli (208) were obtained from hybrid anthers of MR219/Kanaklata cross. A total of 125 green plantlets (Fig. 1) were obtained from seven crosses. Besides, 176 $F_1$ seeds were harvested from three crosses for future anther culture programme.

**Salt tolerant rice variety**

A total of 50,922 hybrid anthers from nine crosses were plated in N6 and M10 media. Twelve calli were obtained from four crosses. Besides, 1,636 $F_1$ seeds were harvested from 18 crosses for future anther culture programme.

**Premium quality rice variety**

A total of 17,051 hybrid anthers were plated in N6 and M10 medium and 40 green plants (Fig. 2) were regenerated from the cross of BRRI dhan50/Bashful. Besides, 672 $F_1$ seeds were harvested from three crosses for future anther culture programme.

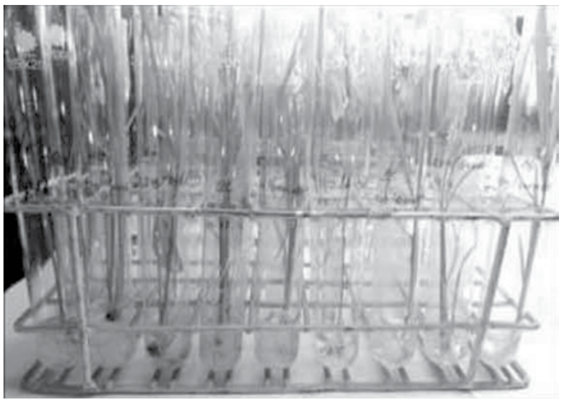


Fig. 1. Anther culture derived plantlets obtained from MR219/BR16 cross at hardening stage.

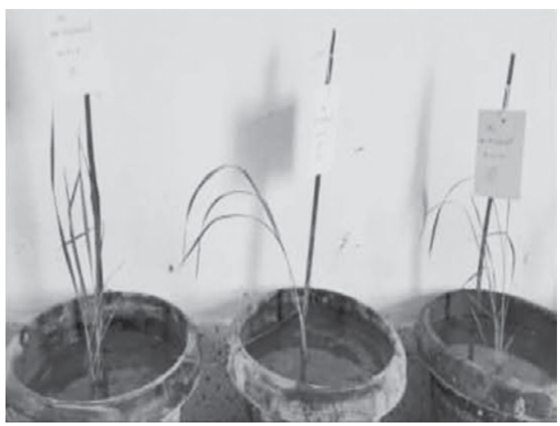


Fig. 2. Anther culture derived plantlets obtained from BRRI dhan50/Bashful at plastic pot.

**Aus rice variety**

A total of 21,671 hybrid anthers from five crosses were plated in N6 and M10 medium. In total 102 calli were produced. Four green plants (Fig. 3) were regenerated from two crosses. A total of 672 $F_1$ seeds were harvested from six crosses for future anther culture programme.

**Swarna type rice variety**

Ten crosses were made between BRRI released varieties and different Swarna rice genotypes. A total of 1,304 $F_1$ seeds were harvested from ten crosses for future anther culture programme.

**Antioxidant enriched black rice**

A total of 35,577 hybrid anthers from 12 crosses were plated in N6 and M10 media. In total 12 calli were obtained from three crosses. For future anther culture programme, 717 $F_1$ seeds were harvested from 12 crosses.

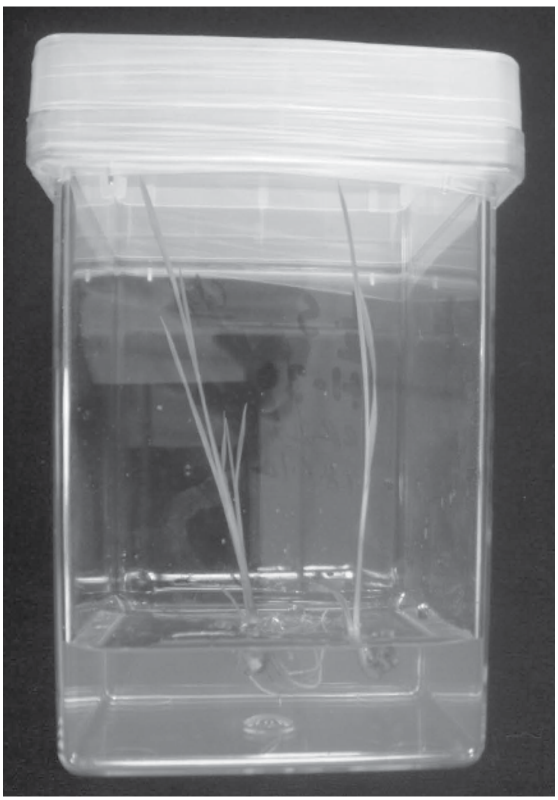


Fig. 3. *In vitro* plantlets regeneration from BR8072-AC5-4-2-1-2-1\ NERICA7cross.

DEVELOPMENT OF RICE VARIETY THROUGH SOMACLONAL VARIATION

**Somaclone using EMS treated rice seed**

A total of 100, 12 and 55 somaclones were obtained from BR(Bio)8072-AC8-1-1-3-1-1, BRRI dhan28 and BRRI dhan29, respectively. $M_1SC_1$ lines from BR11, BRRI dhan48 and Tilbajal are growing in field and $M_1SC_2$ seeds were harvested from BR(Bio)8072-AC8-1-1-3-1-1, BRRI dhan28 and BRRI dhan29.

**Aus somaclone variety**

During the reporting period 124 plants were selected from 145 somaclonal lines of BRRI dhan48.

**Improvement of BRRI dhan47**

In total 40 BRRI dhan47 somaclonal ($SC_2$) plants (Fig. 4) were selected from 16 somaclonal lines of BRRI dhan47.

**Antioxidant enriched somaclonal black rice variety**

Two hundred fifty seeds of each genotype (five) were plated in MS media. A total of 1090 calli (Table 1) were obtained from them. In total 73 green plants (Fig. 5) were regenerated. Seeds ($SC_1$) were harvested from five $SC_0$ plants.

FIELD PERFORMANCE OF TISSUE CULTURE DERIVED LINES

**Progeny selection**

In T. Aman 2016, 31 homozygous lines were bulked from 183 pedigree lines for further evaluation. On

Fig. 4. Field view of somaclones ($SC_2$) derived from BRRI dhan47.

**Table 1. Callus induction and green plant regeneration from *in vitro* culture of black rice.**

| Variety | No. of seed plated | No. of callus obtained | No. of plant regenerated |
|---|---|---|---|
| Lansan | 250 | 180 | 14 |
| PadiKool | 250 | 240 | 19 |
| PadiChelum | 250 | 250 | 1 |
| PadiBungaiNuing | 250 | 240 | 26 |
| Selasih | 250 | 180 | 13 |
| Total | 1250 | 1090 | 73 |

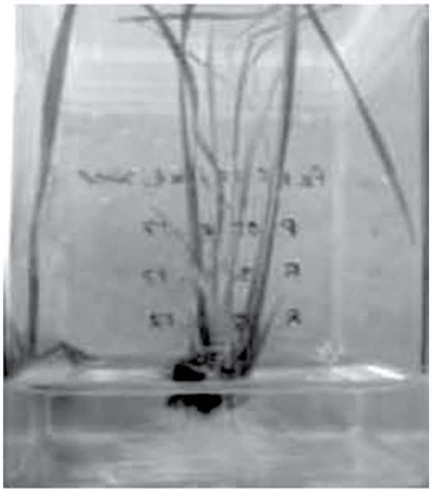


Fig. 5. *In vitro* regenerated plantlets from black rice.

the other hand, in Boro 2016-17, 86 plants were selected and 24 lines were bulked from 112 pedigree lines for further evaluation.

**Observational trial (OT)**

During T. Aman 2016, five anther culture derived doubled haploid lines were evaluated as OT with standard checks to select agronomically desirable and high yield potential materials. None of them was selected.

**Preliminary yield trial** (PYT)

In T. Aman 2016, six doubled haploids were evaluated with standard checks in a PYT (Table 2). Among them four lines were selected depending on the duration and comparable yield with checks for further evaluation.

**Secondary yield trials (SYT)**

During T. Aman 2016, six doubled haploid lines were evaluated with standard checks in a SYT. None of them was selected.

**Table 2. Agronomic characteristics of double haploids during T. Aman 2016 (PYT).**

| Designation | PH | GD | Yield |
|---|---|---|---|
| BR(Bio)8961-AC3-1 | 126 | 125 | 4.77 |
| BR(Bio)8961-AC10-6 | 127 | 126 | 4.70 |
| BR(Bio)8961-AC14-9 | 124 | 124 | 5.61* |
| BR(Bio)8961-AC15-10 | 120 | 126 | 5.65* |
| BR(Bio)8961-AC22-14 | 118 | 125 | 5.56* |
| BR(Bio) 8961-AC26-16 | 128 | 126 | 5.70* |
| BRRI dhan39 (ck) | 106 | 123 | 4.65 |
| BRRI dhan49 (ck) | 101 | 134 | 5.29 |

* Four entries were selected.

**Regional yield trials**

Six advanced breeding materials were evaluated at eight regional stations in Aus 2016 as RYT. None of them was selected. Besides these, six advanced breeding materials were evaluated at eight regional stations during T. Aman 2016 as RYT. None of them was selected.

DEVELOPMENT OF RICE VARIETY THROUGH WIDE HYBRIDIZATION

**Wide hybridization followed by embryo rescue**

Embryo rescued plants (Fig. 6) were backcrossed with high yielding rice variety. In total, 171 seeds of $BC_1F_1$ were harvested from five cross combinations between three wild rice genotypes and two BRRI varieties.

**Wide hybridization followed by anther culture**

BR11, BRRI dhan33, BRRI dhan66 and BRRI dhan52 were used as Recipient and different wild rice were used as donor parent. Backrossing was done for anther culture. In total, 499 $BC_1F_1$ seeds were harvested from eight crosses (Table 3) for future anther culture programme.

ALLELE MINING

**Identification of yield enhancement QTLs**

Three advanced backcross populations ($BC_2F_2$) were developed through backcross breeding method. BRRI dhan28 and BRRI dhan29 were used as recurrent parent and *Oryza rufipogon* (acc. no. 103404) and *Oryza rufipogon* (acc. no. 105890) were used as donor parents. In the reporting

Fig. 6. Embryo rescued plants from BRRI dhan28/*O. nivara* cross.

**Table 3. List of crosses for wide hybridization followed by anther culture.**

| Cross combination | Seed |
|---|---|
| BRRI dhan39*$_2$/*O. Officinalis* (acc. no. 106174) | 117 |
| BRRI dhan33*$_2$/ *O. Officinalis* (acc. no. 106112) | 60 |
| BRRI dhan33*$_2$/ *O. Officinalis* (acc. no. 106174) | 28 |
| BRRI dhan11*$_2$/*Oryza rufipogon* (acc. no. 103404) | 108 |
| BRRI dhan11*$_2$/*Oryza rufipogon* (acc. no. 103844) | 45 |
| BRRI dhan33*$_2$/*Oryza rufipogon* (acc. no. 103404) | 38 |
| BRRI dhan66*$_2$/*Oryza rufipogon* (acc. no. 105890) | 47 |
| BRRI dhan52* /*Oryza rufipogon* (acc. no. 103404) | 56 |
| Total | 499 |

period, advanced materials developed from these crosses were evaluated as RYT and ALART. In Aus 2016, three lines developed from QTL mapping population of BRRI dhan28*$^3$/*O. rufipogon* (acc. no. 105890) cross were evaluated as RYT. None of them were selected. During T. Aman 2016, two lines developed from QTL mapping population of BRRI dhan29*$^3$/ *O. rufipogon* (acc. no. 103404) cross were evaluated as ALART. One line of them was selected for PVT. During Boro 2016-17, four lines developed from QTL mapping population of BRRI dhan28*$^3$/ *O. rufipogon* (acc. no. 105890) cross were evaluated as RYT (Table 4). Two lines of them were selected for ALART (Fig. 7). Moreover, four materials developed from QTL mapping population of BRRI dhan29*$^3$/*O. rufipogon* (acc. no. 103404) cross were evaluated as ALART (Table 4). One line of them was selected for PVT (Fig. 8).

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

In Boro 2016-17 season 14 lines were evaluated with standard checks in a PYT. Seven lines were selected from them for SYT. On the other hand, seven lines developed from QTL mapping population of BRRI dhan29/IR4630-22-2-5-1-3 were evaluated with standard checks in a SYT in the Boro/2016-17 season (Table 5). Four lines were selected from them for RYT.

**Identification of QTLs for taller seedling height**

QTL mapping population was developed by crossing between BRRI dhan11/Shadamota (acc. no. 1576). $F_2$ seeds were harvested for genotyping and phenotyping. Parental polymorphism survey was carried out and 115 SSR markers were identified as polymorphic.

## RICE GENETIC ENGINEERING

**Development of salt tolerant transgenic rice**

Transformation works are advancing for generating new events. Putative transformed calli are on different selection media.

**Table 4. Agronomic characteristics of four lines developed from QTL mapping population of BRRI dhan28*$^3$/ *O. rufipogon* (acc. no. 105890) cross in Boro 2016-17 (RYT).**

| Designation | PH (cm) | GD (day) | Yield (t/ha) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Bar | Bha | Sat | Kus | Raj | *Ran | Hab | Son | *Com | Gaz | Avg |
| BR (Bio)9785-BC2-6-2-2 | 97 | 142 | 5.41 | 7.24 | 6.04 | 7.41 | 5.77 | 4.27 | 5.80 | 6.58 | 5.12 | 6.73 | 6.37* |
| BR (Bio)9785-BC2-19-3-1 | 96 | 143 | 5.15 | 7.07 | 6.24 | 7.14 | 6.12 | 4.57 | 5.73 | 6.52 | 5.43 | 6.17 | 6.29 |
| BR(Bio)9785-BC2-20-1-3 | 97 | 143 | 5.47 | 7.31 | 6.47 | 7.17 | 5.90 | 4.78 | 5.88 | 6.76 | 4.30 | 6.31 | 6.41* |
| BR (Bio)9785-BC2-19-3-5 | 94 | 143 | 5.55 | 7.57 | 5.76 | 6.89 | 6.30 | 4.61 | 5.78 | 6.40 | 4.41 | 6.26 | 6.33 |
| BRRI dhan28 (ck) | 97 | 142 | 5.18 | 6.77 | 6.19 | 6.9 | 5.88 | 5.01 | 5.30 | 6.55 | 3.53 | 6.35 | 6.13 |

*Two entries selected.

Fig. 7. Field view of advanced line BR(Bio)9785-BC2-6-2-2 selected for ALART.

Fig. 8. Field view of advanced line BR(Bio)9786-BC2-59-1-2 selected for PVT.

**Table 5. Agronomic characteristics of seven lines developed from QTL mapping population of BRRI dhan29/IR4630-22-2-5-1-3cross in Boro 2016-17 (SYT).**

| Designation | GD (day) | Yield (t/ha) |
|---|---|---|
| BR(Bio)9777-26-4-3 | 154 | 7.96* |
| BR(Bio)9777-26-4-1 | 154 | 7.19 |
| BR(Bio)9777-41-6-1 | 156 | 7.63* |
| BR(Bio)9777-106-7-4 | 147 | 7.03 |
| BR(Bio)9777-113-12-5 | 155 | 7.70* |
| BR(Bio)9777-118-6-4 | 156 | 7.80* |
| BR(Bio)9777-120-8-3 | 156 | 7.31 |
| BRRI dhan58 (ck) | 153 | 7.37 |

* Four entries selected.

**_PDH45_ transgenic lines tested for salinity tolerance at seedling stage**

To characterize high-yielding mega rice varieties containing *PDH45* against salinity at seedling stage in the contained facility, 14 transgenic lines along with respective parents were tested for seedling stage salinity tolerance in the hydroponics culture (Fig. 9). IR58443 and IR154 were used as tolerant and sensitive check respectively. Considering their salinity tolerance at seedling stage, five transgenic lines *PDH_BR47-1*, *PDH_BR47-2*, *PDH_BR29-2, PDH_BR28-3* and *PDH_BR36-2* were selected for reproductive stage characterization.

Fig. 9. Experimental set-up of *PDH45* containing transgenic lines during seedling stage salinity.

GENE PYRAMIDING

**Gene pyramiding for resistance to bacterial blight disease in rice**

Five bacterial blight (BB) gene pyramided BRRI dhan29 rice lines having two BB resistant genes (*Xa4* and *Xa21*) were evaluated as RYT in Boro 2016-17 season with standard checks (Table 6). Three lines were selected for ALART depending on the phenotypic acceptance, yield performance, BB scoring and presence of BB resistance genes. These lines were also confirmed by PCR with gene specific primers. Twenty-one BB gene pyramided materials having three BB resistant genes (*Xa4*, *xa13* and *Xa21*) were evaluated during Boro 2016-17 in a observational trial with standard checks. These lines were also confirmed by PCR with gene specific primers. Nine lines were selected for PYT depending on the phenotypic acceptability; yield performance, BB scoring (Fig. 10).

GENE CLONING

**Isolation and cloning of salt and drought tolerant gene**

cDNA was synthesized from RNA of treated *P. coarctata* and amplified with DREB1 primes

**Table 6. Agronomic characteristics of bacterial blight (BB) gene pyramided BRRI dhan29 rice lines having two BB resistant genes (*Xa4* and *Xa21*) in Boro 2016-17 (RYT).**

| Designation | PH (cm) | GD (day) | Yield (t/ha) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Bar | Bha | Sat | Kus | Raj | *Ran | *Hab | Son | Com | Gaz | Avg |
| BR (Bio) 8333-BC5-1-1 | 100 | 162 | 6.29 | 8.07 | 7.10 | 7.09 | 7.18 | 5.31 | 5.78 | 7.20 | 6.56 | 7.50 | 7.12 |
| BR (Bio) 8333-BC5-1-20 | 104 | 161 | 6.63 | 7.63 | 7.50 | 7.35 | 7.49 | 5.78 | 5.59 | 7.43 | 7.34 | 7.66 | 7.38* |
| BR (Bio) 8333-BC5-2-16 | 101 | 157 | 7.20 | 8.84 | 7.58 | 7.55 | 7.66 | 6.53 | 4.80 | 7.65 | 6.79 | 7.68 | 7.62* |
| BR (Bio) 8333-BC5-2-22 | 105 | 161 | 6.93 | 8.85 | 7.48 | 7.33 | 7.65 | 5.66 | 5.98 | 6.94 | 7.17 | 7.77 | 7.51* |
| BR (Bio) 8333-BC5-3-10 | 105 | 160 | 7.16 | 8.41 | 7.45 | 7.44 | 7.48 | 5.26 | 5.05 | 7.53 | 7.09 | 7.44 | 7.50 |

*Three lines selected.

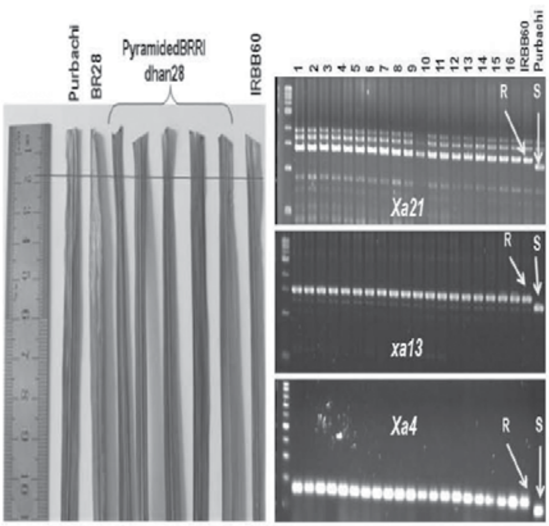



Fig. 10. BB gene pyramided BRRI dhan28 after 21 days of bacterial inoculation with BxO9 isolate and molecular confirmation with gene specific primers.

(Fig. 11). Primers for serine rich protein (SPR), inositol phospatage synthese (PIN), vacuolar H+ ATPase (AVP1) salt tolerant gene were designed from *Porteresia coarctata* sequence.

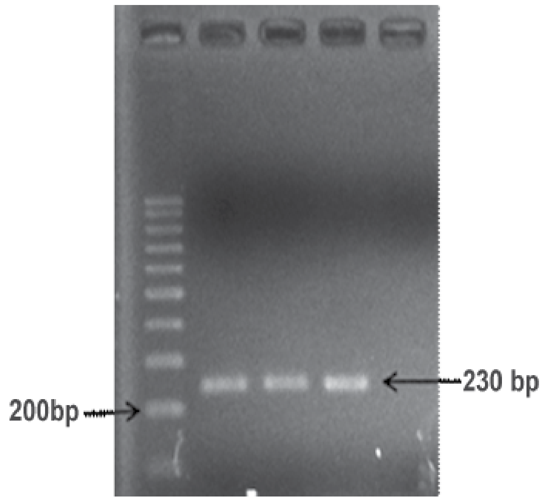



Fig. 11. *DREB1* gene was amplified by PCR for cloning.

## PROPOSED VARIETY TRIAL (PVT) FOR SHORT DURATION HIGH YIELDING VARIETY

Under PVT, two anther culture derived lines was evaluated at ten different locations of the country by the NSB team for the recommendation of release as a new variety.

# Genetic Resources and Seed Division

## SUMMARY

In total, 253 rice germplasm were collected from different districts of Bangladesh during 2016-17. Moreover, 91 germplasm were also collected under Asian Food and Agriculture Cooperation Initiative (AFACI) project of BARC. Thirty-four germplasm accessions in T. Aus, 145 in T. Aman and 18 in Boro seasons were characterized against 53 morpho-agronomic traits. Molecular characterization of 36 aromatic local germplasm was performed using 42 SSR markers. Rejuvenation and conservation (in short term) of 2,004 accessions were performed of which 301 accessions in T. Aus, 1,197 accessions in T. Aman and 506 accessions in Boro. Again, 126 and 184 accessions in Aus and 270 and 350 accessions in T. Aman were conserved in medium and long term storages, respectively during the reporting year. Apart from this, 119 new germplasm were registered as new accessions (from accession number 8082 to 8200) in BRRI Genebank. Moreover, 1,890 samples of rice germplasm and BRRI developed varieties were supplied to different users. Molecular diversity of 36 local aromatic germplasm were performed using 42 SSR marker and the entries were grouped into four major clusters through UPGMA cluster analysis. DNA finger printing of 77 wild rice were performed using 42 SSR marker and the UPGMA clustering analysis group the germplasm into six major clusters.

Eighty-five BRRI developed and recommended rice varieties were maintained and nucleus seed of 56 varieties were produced for the breeder seed source. In total, 142.90 tons of breeder seed of which 57.00 tons from 42 varieties in T. Aman and 85.90 tons from 22 varieties in Boro seasons were produced during 2016-17. Among the total production, 134.22 tons were produced by GoB fund and 8.68 tons were produced by project fund viz. HarvestPlus, Transforming Rice Breeding (TRB) and STRASA. At the same time, 130.70 tons of breeder seed of which 79.06 tons from 19 varieties in Boro, 5.37 tons from 12 varieties in Aus and 46.23 tons from 34 varieties in T. Aman were distributed among the ‘Rice Seed Network’ partners. The number of seed receiving network partners (GO, NGO and PS) reached to 858 in 2017. Breeder and foundation seed producing plots and farms were also visited to observe the varietal purity and performance of respective seed.


## RICE GERMPLASM CONSERVATION AND MANAGEMENT

**Germplasm collection and acquisition.** Four collection missions were made during the reporting year and 253 rice germplasm of which 34 in Aus, 56 from Jhum (hill rice), 145 in T. Aman and 18 in Boro were collected from different districts of Bangladesh.

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

A total of 2,004 germplasm of which 301 accessions in T. Aus, 1,197 accessions in T. Aman 2016 and 506 accessions in Boro 2016-17 were rejuvenated in field for getting fresh seed and on average 500 g of seeds were produced per accession.

**Characterization of germplasm accessions.** Rice germplasm accessions were characterized through morphological and molecular characters for using in different hybridization programme.

**Morphological characterization.** Three experiments were conducted to characterize rice germplasm using 53 morpho-agronomic traits. The experiments were conducted in BRRI HQ, Gazipur using a single row of 5.4 m long for each entry/accession with a spacing of 25 × 20 cm between rows and plants respectively. A total of 218 genotypes of which 102 (76 Jhum and 26 Aus) in T. Aus, 55 in T. Aman (new collection) and 61 in Boro were used for characterization. Fertilizers were applied @ 60:20:40 kg NPK/ha in T. Aus and T. Aman and @ 80:20:40 kg NPK/ha in Boro.

In Aus 2016, three genotypes had short (<100 days), 69 had medium (100-120 days) and 30 had long (>120 days) growth duration (Table 1). Sixty-six genotypes were found medium (90-125 cm) and 36 genotypes were found with long (>125) plant height. Sixteen genotypes were found with very long (>30 cm), 53 with long (26-30 cm), 17 with medium (21-25 cm) and the rest 16 with (<20 cm) panicle length. Maximum 66 genotypes possessed intermediate (6-10) effective tiller whereas 21 genotypes possessed low number (<6) and 19 had (>10) effective tillers. Thirty-five genotypes possessed slender (>3.0) grain type. One genotype had very low (<15), 25 with low (16-19), 14 had medium (20-23), 34 had high (24-27) and 28 had very high (>27g) thousand grain weight (TGW). Eight genotypes (new collection) had (>10 g) yield per hill.

The shortest growth duration (96 days) observed in Chakula Aus (NC) and the longest (144 days) Kangbui (Table 1). Also the shortest plant height (89.4 cm) was observed in Lonkapura binni (NC) and the longest (148.40 cm) in unknown genotypes (NC). Again, the highest effective tillers (18) and grain length breadth ratio (3.88) was observed in Hule Gambir (NC) and Kangbui (NC), respectively. Besides, the highest TGW (32.2 g) was observed in Kamaramg (NC). Moreover, the highest yield per hill was observed in Ratul (13.0 g) and the lowest (3.07 g) in Kuttosa binni (NC).

In T. Aman 2016, thirteen genotypes had short (<120 days) growth duration (Table 1). One entry was found with very long (>30) and 11 with long (26-30 cm) panicle length. Twenty-eight genotypes possessed many (>10) number of effective tillers. TGW of 14 genotypes was found very low (≤15 g), three had very high (>27g). Seventeen genotypes had higher (>10) yield/hill. Kajal lata gave the shortest growth duration (110 days). Haijam was the shortest plant (86.6 cm) and Dolni the longest (191). Indursail possessed the longest panicle length (31.6 cm) and Malshira the highest number of effective tillers (18). The highest grain length-breadth ratio (3.48) was observed in Subal lata. Molla digha had the highest (31.2 g) TGW and Indursail the highest yield per hill (24.26).

In Boro 2016-17, all of the germplasm had long (>130 days) growth duration (Table 1). Only one genotype had very long (>30) panicle length. Forty-three genotypes possessed high (>10) effective tillers. Moreover, the shortest growth duration (137 days) was observed in six genotypes viz Kala IRRI, IA-37, Vawailia, Jaymati, Lal Boro, Shita Boro. The shortest plant height (67.6 cm) was observed in Lal dhan (Acc. 6853). The highest effective tiller (23.6) was observed in Asami Boro (Acc. 7667). The highest yield per hill (34.0 g) was observed in Boro habji (Acc. 8100) in Boro 2016-17. Finally, the varieties having higher yield would be utilized in crossing programme, if other characters satisfy the breeder's objectives.

**Molecular characterization.** Thirty-six aromatic rice landraces were characterized using 36 SSR markers in the molecular laboratory of GRS Division, BRRI for varietal identification and establishment of property right.

DNA was extracted from young leaf of three weeks old plants following a simple and modified protocol of Zheng *et al.* (1995). PCR was performed in 12.5 µl reaction containing 5-25 ng of DNA template, 1.25 µl of $MgCl_2$ free 10X PCR buffer (100 mMTris-HCl pH 9.0 at 25°C, 500 mMKCl, 0.1% Triton® X-100 and $H_2O$), 1.5 µl of 25 mM $MgCl_2$, 0.25 µl of 10mM dNTP, 0.25 µl of 5 U/µl Taq polymerase enzyme, 0.625 µl each of 10 µM forward and reverse primers using a MJ research single 96 well thermal cycler. The mixture was over laid with one drop of mineral oil to prevent evaporation. The temperature profile was an initial denaturation step for five minute at 94°C, followed by 35 cycles of one minute denaturation at 94°C, one minute annealing at 55°C, and two minutes extension at 72°C with a final seven minutes extension at 72°C. The PCR products were mixed with bromophenol blue gel loading dye and were analyzed by electrophoresis on 8% polyacrylamide gel using mini vertical polyacrylamide gels for high through put manual genotyping (CBS Scientific Co. Inc., CA, USA). The amplification products of 2.5 µl were resolved by running gel in 1xTBE buffer for 2-2.5 hrs depending upon the allele size at around 75 volts and 180 mA current. The gels were stained in 0.5 mg/ml ethidium bromide and were documented using UVPRO (Uvipro Platinum, EU) gel documentation unit. The data were analyzed in computer using AlphaEase FC version 5.0, PowerMarker version 3.25 (Liu and Muse, 2005) and NTSYS-pc version 2.2 (Rohlf, 2002) software.

All the 36 aromatic rice landraces were genotyped with 42 simple sequence repeat (SSR) markers. Out of 42 SSR markers, six markers (RM224, RM215, RM536, RM537, RM192 and RM193) were found monomorphic and most polymorphic 36 SSR markers were selected to use for molecular characterization of the aromatic rice landraces. A total of 109 alleles were detected across the 36 SSR markers. The number of alleles per locus ranged from 2 to 5, with an average of

**Table 1. Some important features of characterized germplasm in T. Aus 2016, T Aman 2016 and Boro 2016-17.**

| Growth duration (day) | | Plant height (cm) | | Panicle length (cm) | | No. of tiller | | No. of effective tiller | | Grain LB ratio | | 1000-grain weight (g) | | Yield/hill (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range | No. of entries | Range | No. of entries | Range | No. of entries | Range | No. of entries | Range | No of entries | Range | No of entries | Range | No of entries | Range | No. of entries |
| | | | | | | | | **T. Aus 2016** | | | | | | | |
| <100 | 3 | <90 | 1 | <20 | 16 | <10 | 67 | <6 | 21 | <2.5 | 32 | <15 | 1 | <5 | 37 |
| 100-120 | 69 | 90-125 | 65 | 21-25 | 17 | 11-15 | 29 | 6-10 | 62 | 2.6-3.0 | 35 | 16-19 | 25 | 5-10 | 57 |
| >120 | 30 | >125 | 36 | 26-30 | 53 | >15 | 6 | >10 | 19 | >3.0 | 35 | 20-23 | 14 | >10 | 8 |
| | | | | >30 | 16 | | | | | | | 24-27 | 34 | | |
| | | | | | | | | | | | | >27 | 28 | | |
| Shortest (96) | NC (Chakula aus) | Shortest (89.44) | NC (Lonkapura Binni) | Shortest (18.40) | NC (Noroi) | Lowest (5) | NC (Wasa, Fulbadam, Nolabinni) | Lowest (3) | NC (Wasa) | Lowest (1.89) | NC (Koborok) | Lowest (13.30) | NC (Ameosori) | Lowest (3.07) | NC (Kuttosa Binni) |
| Longest (144) | NC (Kanbui) | Longest (148.40) | NC (Unknown) | Longest (35.60) | NC (Kamarang) | Highest (21) | NC (Noroi) | Highest (18) | NC (Hule Gambir) | Highest (3.88) | NC (Kangbui) | Highest (32.20) | NC (Kamaramg) | Highest (13.00) | NC (Ratul) |
| Mean | 114.78 | | 121.02 | | 27.32 | | 9.59 | | 7.95 | | 2.84 | | 13.30 | | 3.07 |
| Std. Dev. | 9.29 | | 11.31 | | 2.99 | | 3.15 | | 2.91 | | 0.52 | | 4.82 | | 2.25 |
| CV | 8.10 | | 9.34 | | 10.95 | | 32.83 | | 36.63 | | 18.29 | | 20.26 | | 35.90 |
| LSD | 1.80 | | 2.19 | | 0.58 | | 0.61 | | 0.57 | | 0.10 | | 0.94 | | 0.44 |
| | | | | | | | | **T. Aman 2016** | | | | | | | |
| <120 | 13 | <110 | 3 | ≤20 | 4 | <10 | 4 | <6 | 1 | <1.5 | 0 | ≤15 | 14 | <5 | 11 |
| 120-130 | 7 | 110-130 | 12 | 21-25 | 39 | 10-15 | 46 | 6-10 | 26 | 1.5-2.0 | 12 | 16-19 | 11 | 5-10 | 27 |
| >130 | 35 | >130 | 40 | 26-30 | 11 | >15 | 5 | >10 | 28 | 2.1-2.5 | 35 | 20-23 | 19 | >10 | 17 |
| | | | | >30 | 1 | | | | | 2.6-3.0 | 4 | 24-27 | 8 | | |
| | | | | | | | | | | >3.0 | 4 | >27 | 3 | | |
| Shortest (110) | Kajal lata | Shortest (86.6) | Haijam | Shortest (16) | Double rice | Lowest (8) | Modhu sail | Lowest (2) | Harharia | Lowest (1.89) | Vaeulu & Depor dhan | Lowest (8.0) | Komka mane | Lowest (2.48) | Biropa |
| Longest (143) | Ranga and Sada gasa | Longest (191) | Dolni | Longest (31.6) | Indursail | Highest (23) | Malshira | Highest (18) | Malshira | Highest (3.48) | Subal lata | Highest (31.2) | Molla digha | Highest (24.26) | Indursail |
| Mean | 129 | | 138.6 | | 24.2 | | 13 | | 10 | | 2.3 | | 19.6 | | 8.87 |
| Std. Dev. | 8.59 | | 19.93 | | 2.72 | | 2.58 | | 2.38 | | 0.35 | | 5.79 | | 4.71 |
| CV | 6.64 | | 14.38 | | 11.22 | | 20.61 | | 22.71 | | 15.28 | | 29.58 | | 53.06 |
| LSD | 2.27 | | 5.27 | – | 0.72 | | 0.68 | | 0.63 | | 0.09 | | 1.53 | – | 1.24 |

**Table 1. Continued.**

| Growth duration (day) | | Plant height (cm) | | Panicle length (cm) | | No. of tiller | | No. of effective tiller | | Grain LB ratio | | 1000-grain weight (g) | | Yield/hill (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range | No. of entries | Range | No. of entries | Range | No. of entries | Range | No. of entries | Range | No of entries | Range | No of entries | Range | No of entries | Range | No. of entries |
| | | | | | | | | Boro 2016-17 | | | | | | | |
| <120 | 0 | <110 | 39 | ≤20 | 11 | <10 | 5 | <6 | 0 | <1.5 | 0 | ≤15 | 1 | <5 | 2 |
| 120-130 | 0 | 110->130 | 21 | 21-25 | 39 | 10-15 | 50 | 6-10 | 18 | 1.5-2.0 | 0 | 16-19 | 17 | 5-10 | 6 |
| >130 | 61 | | 1 | 26-30 | 9 | >15 | 6 | >10 | 43 | 2.1-2.5 | 17 | 20-23 | 15 | >10 | 53 |
| | | | | >30 | 1 | | | | | 2.6-3.0 | 25 | 24-27 | 16 | | |
| | | | | | | | | | | >3.0 | 19 | >27 | 10 | | |
| Shortest (137) | Kala IRRI, IA-37 VAWAILIA, Jaymati, Lal Boro, Shita Boro | Shortest (67.6) | Lal Dhan | Shortest (16.6) | Khato Badam | Lowest (7.2) | Unknown | Lowest (6.2) | Unknown | Lowest (2.32) | 33-NO-DHAN | Lowest (11.6) | ChiniKuri | Lowest (2.63) | Nerica Mutant |
| Longest (166) | Dholi Boro | Longest (131) | Alai Dhan | Longest (32.2) | Alai Dhan | Highest (29.8) | | Highest (23.6) | Asami Boro | Highest (4.57) | Minekat | Highest (30.6) | Luit | Highest (34.00) | Boro Habj1 |
| Mean | 148.21 | 101.60 | | 22.44 | | | 13.10 | 11.44 | | | 2.92 | 22.30 | | 15.92 | |
| Std. Dev. | 7.42 | 17.47 | | 2.81 | | | 3.79 | 2.84 | | | 0.50 | 4.40 | | 7.13 | |
| CV | 5.007 | 17.195 | | 12.5 | | | 28.927 | 24.801 | | | 17.103 | 19.730 | | 44.782 | |
| LSD | 2.70 | 6.34 | | 1.02 | | | 1.37 | 1.03 | | | 0.18 | 1.59 | | 2.60 | |

3.03. The PIC values ranged from 0.14 to 0.69, with an average of 0.41. It is appeared that the RM496 had the highest PIC value (0.69) and the highest number of alleles (5), therefore it was the best marker. The frequency of the most common allele at each locus ranged from 31.00% (RM496) to 96.00% (RM500, RM554). On average, 64.33% of the 36 rice landraces shared a common major allele at any given locus. The DNA profiles of 36 aromatic rice landraces with SSR marker RM447 are shown in Fig. 1. Besides, the UPGMA cluster analysis were grouped into four major clusters at a coefficient of 0.54 and the similarity coefficient value ranged from 0.33 to 0.97 (Fig. 2).

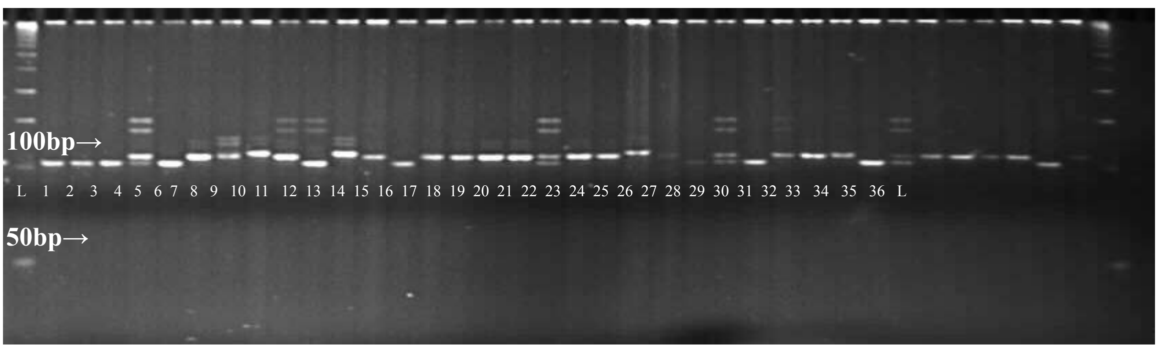
**Germplasm processing, registration and storage.** In total, 2,428 germplasm were processed to conserve with respective accession number in different storages of Genebank. The germplasm were cleaned and dried with a seed moisture content of less than 9%.

In details, 611 accessions in Aus and 1,817 in T. Aman 2016-17 were processed and kept in short term storage. Similarly, 126 and 184 accessions in Aus and 270 and 350 accessions in T. Aman were stored in medium and long term storages respectively. On the other hand, 119 germplasm were registered in accession book as new accession (from acc. 8082 to 8200).

**Viability testing, periodic evaluation and routine monitoring of stored germplasm.** One hundred and thirty accessions in Aus, 175 in T. Aman and 145 in Boro seasons were checked randomly for viability (germination %) test in short term storage during 2016-17. Five varieties namely Dharial (Acc. 649), Hashikalmi (3575), Purbachi (6207), Nizersail (1229) and Patnai-23 (52) were used as testers in the medium and long term storages and their viability were measured on six month interval of each year usually in October and March to predict the viability status of germplasm in the respective storages. The seed viability was also monitored before storage of rice germplasm in the Genebank.

Among the randomly selected 450 stored germplasm, 270 had viability between 80-90% and 100 had viability above 90%. The germplasm accessions stored during 2016-17 in short term storage were also found with more than 90% germination. The germplasm that possessed less than 80% germination will be grown in the following season. On the other hand, the range of germination percentages of the five test samples/testers in the medium and long term storages conducted in October 2016 and March 2017 were 63-94% and 72-94% respectively, which indicate the viability condition of stored germplasm in medium and long term storages.

**Germplasm distribution/exchange.** A total of 2,315 samples of rice germplasm as well as BRRI developed rice varieties were supplied to different users in the reporting year. Among the samples, 1,781 germplasm accessions were supplied for research purpose and 534 samples of BRRI




Legend: 1.Chinigura, 2. Chinigura, 3. Chinigura, 4. Chinigura, 5. Chiniguri, 6. Chiniguri, 7. Sakkorkhora,8. Sakkorkhana, 9. Sakkorkhana,10. Sakkorkhana,11. Sakkorkhana,12. Sakkorkhora, 13 Kataribhog,,14. Kataribhog,15. Kataribhog,16. Kataribhog TAPL-78, 17.Kataribhog TAPL-79,18. Kataribhog TAPL-80, 19.Kataribhog TAPL-81, 20. Kataribhog TAPL-82, 21. Kataribhog TAPL-83,22. Kataribhog, TAPL-84, 23. Kataribhog TAPL-85,24. Kataribhog, TAPL-86, 25.Kataribhog TAPL-87,26. Kataribhog TAPL-88, 27. Kataribhog, 28. Kataribhog, 29. Kataribhog, 30. Kataribhog, 31. Begunbichi, 32. Begunbichi, 33. Begunbichi, 34. Begunbichi, 35. Begunbichi, 36. Begunbichi

Fig. 1. Gel picture of marker RM447 showing banding pattern in 36 aromatic rice landraces.

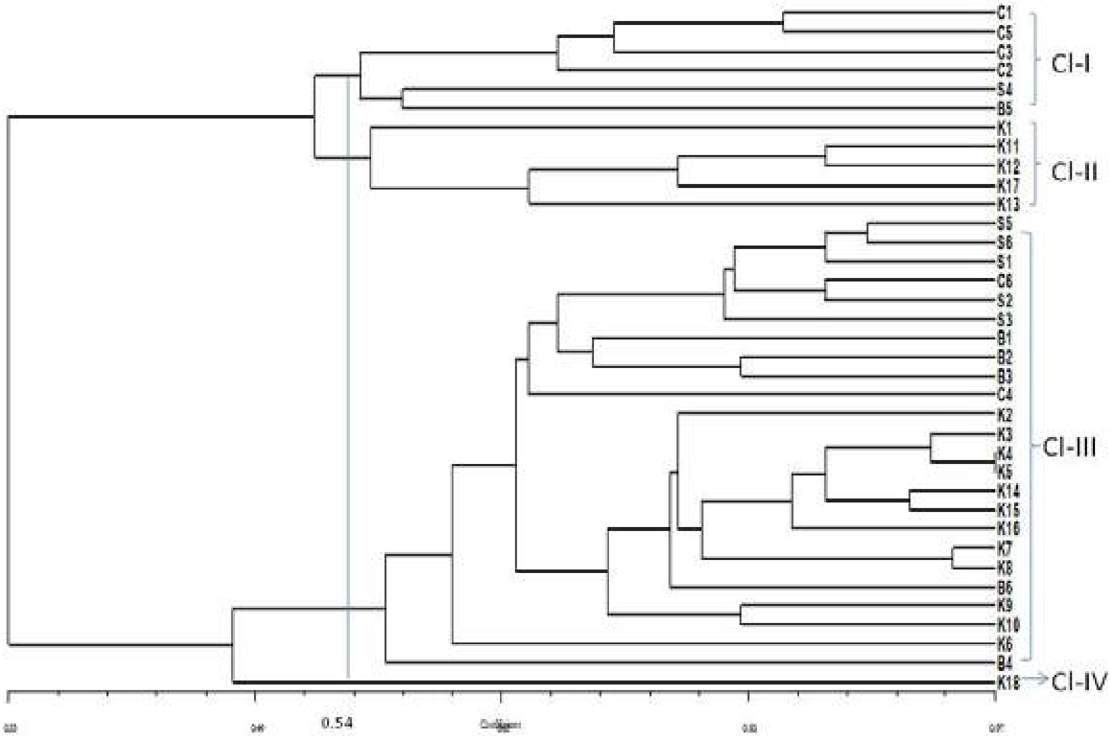



Fig. 2. An UPGMA cluster dendrogram showing the genetic relationships between 36 aromatic rice landraces of Bangladesh based on the alleles detected by 36 microsatellite markers.

varieties were supplied to researchers, Department of Agricultural Extension (DAE) personnel and university students for research, demonstration as well as other purposes.

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

## SEED PRODUCTION AND VARIETY MAINTENANCE

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

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

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

**Breeder seed production and distribution.** GRS Division, Farm Management Division and eight regional stations of BRRI were engaged in breeder seed (BS) production as per national demand during 2016-17. The BS plots were visited to monitor the varietal purity and performances. Off-type plants were identified and rogued out in every growth stage. After harvesting of a variety, the

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

| Type | Number | Variety |
|---|---|---|
| | | T. Aman |
| MV | 38 | BR4, BR5, BR10, BR11, BR21, BR22, BR23, BR24, BR25, BRRI dhan27, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan40, BRRI dhan41, BRRI dhan42, BRRI dhan43, BRRI dhan44, BRRI dhan46, BRRI dhan48, BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan72, BRRI dhan73 |
| LIV | 8 | Nizersail, Latisail, Rajasail, Kalijira, Kataribhog, Basmati-D, Patnai23, Tilockkachari |
| | | Boro |
| MV | 33 | BR1, BR2, BR3, BR6, BR7, BR8, BR9, BR12, BR14, BR15, BR16, BR17, BR18, BR19, BR26, BRRI dhan28, BRRI dhan29, BRRI dhan35, BRRI dhan36, BRRI dhan45, BRRI dhan47, BRRI dhan50, BRRI dhan55, BRRI dhan58, BRRI dhan59, BRRI dhan60, BRRI dhan61, BRRI dhan63, BRRI dhan64, BRRI dhan65, BRRI dhan67, BRRI dhan68, BRRI dhan69 |
| LIV | 6 | Hbj Boro II, Hbj Boro IV, Hbj Boro VI, Hbj Boro VIII, Purbachi, IR8 |

seeds were separately threshed, dried, cleaned and stored in controlled temperature (20°C with about 40% RH) at BRRI HQ, Gazipur. The harvested seeds then offered as seed lot for getting 'tag' from Seed Certification Agency (SCA) for distribution.

A total of 142.90 tons of breeder seed, of which 57.00 tons from 42 varieties in T. Aman and 85.90 tons from 22 varieties in Boro seasons were produced during 2016-17 (Table 3 and 4). Among the total production, 134.22 tons were produced by GoB fund and 8.68 tons were produced by project fund viz HarvestPlus, Transforming Rice Breeding (TRB) and STRASA (Table 5). On the other hand, 130.70 tons of breeder seed of which 79.06 tons from 19 varieties in Boro, 5.37 tons from 12 varieties in Aus and 46.23 tons from 34 varieties in T. Aman were distributed among the 'Rice Seed Network' partners (Tables 6, 7 and 8).

**Monitoring seed production plots and farms.** Breeder seed production plots of BRRI RSs Rangpur, Rajshahi, Habiganj, Comilla, Bhanga, Sonagazi, Barisal and Satkhira and foundation seed production farms of Haychem Bangladesh Limited, Dinajpur, Bolokhi Seed, Bogra, Doel Traders, Bogra, Asha Agro, Nilphamari and BADC, Pangsa, Rajbari were visited to observe the varietal purity and performances of breeder and foundation seeds. During the visit, no major insect-pest damage was noticed in the plots. Varietal purity (%) was observed as average of more than 99% in all the varieties. The crops were found almost free from weeds. In maximum cases, isolation distance was properly maintained. Foundation seed (FS) producers were advised to discard three meters boarder lines, where isolation distance was not maintained. Overall crop conditions and management was satisfactory. The seed producers were also advised for thorough roguing by themselves for one more time before harvesting.

## EXPLORATORY AND GENETIC STUDIES

**Pure line selection of popular rice germplasm.** After transplanting following panicle to row method and thoroughly roguing at each growth stage, three

**Table 3. Production (in kg) of breeder seed during T. Aman 2016.**

| 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 |
| BR10 | 160 | | | | | | | | | 1150 | 1310 |
| BR11 | 300 | | | 2800 | | | | 3160 | | | 6260 |
| BR21 | 50 | | | | | | | | | | 50 |
| BR22 | 190 | | | | | 1800 | | | | | 1990 |
| BR23 | 330 | | | | | | | | 890 | | 1220 |
| BR24 | 70 | | | | | | | | | | 70 |

**Table 3. Continued.**

| 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 |
| BR25 | 70 | | | | | | | | | | 70 |
| BR25 | 360 | | | | | | | | | | 360 |
| BRRI dhan27 | 180 | | | | | | | | | | 180 |
| BRRI dhan30 | 280 | | | | | | | | | 1170 | 1450 |
| BRRI dhan31 | 50 | | | | | | | | | | 50 |
| BRRI dhan32 | | | | | | 360 | | | | | 360 |
| BRRI dhan33 | 200 | | | 2040 | | | | | | | 2240 |
| BRRI dhan34 | 480 | | | 1840 | | | | 1240 | 1320 | | 4880 |
| BRRI dhan37 | 20 | | | | | | | | | | 20 |
| BRRI dhan38 | 0 | | | | | | | | | | 0 |
| BRRI dhan39 | 180 | 650 | | | | | | | | | 830 |
| BRRI dhan40 | 40 | | | | | | | | | | 40 |
| BRRI dhan41 | 230 | | | | | | | | 600 | | 830 |
| BRRI dhan42 | 100 | | | | | | | | | | 100 |
| BRRI dhan43 | 260 | | | | | | | | | | 260 |
| BRRI dhan44 | 40 | | | | | | | | 480 | | 520 |
| BRRI dhan46 | 170 | | | | | | | | | | 170 |
| BRRI dhan48 | 50 | | 880 | | 640 | 720 | | | | 1080 | 3370 |
| BRRI dhan49 | 170 | 1250 | | | | 4800 | | | | 4200 | 10420 |
| BRRI dhan51 | 1040 | | | | | | | | | | 1040 |
| BRRI dhan52 | | | | | 1550 | | | | 4040 | | 5590 |
| BRRI dhan53 | 520 | | | | | | | | | | 520 |
| BRRI dhan54 | 150 | | | | | | | | | | 150 |
| BRRI dhan56 | 300 | | | 650 | | | | | | | 950 |
| BRRI dhan57 | 200 | | | | | | | | | | 200 |
| BRRI dhan62 | 590 | | | | | 1350 | | | | | 1940 |
| BRRI dhan65 | 150 | | | | | | | | | | 150 |
| BRRI dhan66 | 360 | | 550 | | | | | | | | 910 |
| BRRI dhan70 | 140 | | | | | | | 680 | | | 820 |
| BRRI dhan71 | 380 | | 600 | 600 | | | | | | | 1580 |
| BRRI dhan72 | 1220 | | | | | | | | | | 1220 |
| BRRI dhan73 | 390 | | | | | | | | 1370 | | 1760 |
| BRRI dhan75 | 180 | | | | | 2050 | | | | | 2230 |
| BRRI dhan76 | 80 | | | | | | | | 360 | | 400 |
| BRRI dhan77 | 50 | | | | | | | | 400 | | 450 |
| Nizersail | 40 | | | | | | | | | | 40 |
| Sub total | 9770 | 1900 | 2030 | 7930 | 2190 | 11080 | 0 | 5080 | 9460 | 7600 | 57000 |

**Table 4. Production (in kg) of breeder seed during Boro 2016-17.**

| 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 |
| BR3 | 120 | | | | | | | | | | 120 |
| BR14 | 660 | | | | | | | | | | 660 |
| BR16 | | | | | | | | | | | 0 |
| BR26 | 640 | | | 2880 | | | | | 200 | | 5520 |
| BRRI dhan28 | 3040 | 2720 | 960 | 5000 | 4720 | 5200 | 7200 | 1080 | 2520 | 6800 | 39240 |
| BRRI dhan29 | 1400 | | | | | 4600 | 5600 | 2720 | 1960 | | 16280 |
| BRRI dhan36 | 150 | | | | | | | | | | 150 |
| BRRI dhan45 | 240 | | | | | | | | | | 240 |
| BRRI dhan47 | 400 | | | | | | | | | | 400 |
| BRRI dhan50 | 200 | | | | | | | | | 3880 | 4080 |
| BRRI dhan55 | 130 | | | | | | | | | | 130 |
| BRRI dhan58 | 100 | | 1200 | | | 4320 | | | | | 5620 |
| BRRI dhan59 | 250 | | | | | | | | | | 250 |
| BRRI dhan60 | 200 | | | | | | | | 520 | | 720 |
| BRRI dhan61 | | | | | | | | | 800 | | 800 |
| BRRI dhan63 | 120 | | | | | | | | | | 120 |
| BRRI dhan64 | 1100 | | | | | 3160 | | | | | 4260 |
| BRRI dhan65 | 130 | | | | | | | | | | 130 |
| BRRI dhan67 | 80 | | | | | | | | 900 | 1800 | 2840 |
| BRRI dhan68 | 360 | | | | | | | | | | 360 |
| BRRI dhan69 | 2680 | | | | | | | | | | 2680 |
| BRRI dhan74 | 1300 | | | | | | | | | | 1300 |
| Total | 13300 | 2720 | 2160 | 7880 | 4720 | 17280 | 12800 | 3800 | 6900 | 12480 | 85900 |

**Table 5. Production (in kg) of breeder seed under different project of GRS Division.**

| Variety | Project/ Quantity (kg) | | |
|---|---|---|---|
| | HarvestpPlus | TRB | STRASA |
| BRRI dhan62 | 1800 | - | - |
| BRRI dhan64 | 4260 | - | - |
| BRRI dhan71 | - | 140 | 60 |
| BRRI dhan72 | 1080 | 100 | - |
| BRRI dhan73 | - | 160 | 80 |
| BRRI dhan74 | 1000 | - | - |
| Total | 8140 | 400 | 140 |
| Grand total | 8,680 | | |

Balam varieties viz. acc. no. 516, 1011, 4836, seven Jesso-Balam; acc. no. 2456, 2459, 2464, 2469, 2472, 2473, 2480, four Sadamota; acc. no. 1040, 1576, 7788, 7923, three Lalmota; acc. no. 1583, 1584, 7889, one each from Khejur Jhupi; acc. no. 40 and Khejur Chhori; acc. no. 4246 and two Bashful; acc. no. 3996, 4010 lines were selected for next T. Aman 2017 for observational trial (OT) along with BR7 and BR25 as check variety.

**DNA fingerprinting of wild rice.** Seventy-seven wild rice germplasm were characterized using well distributed 42 SSR markers for varietal identification and establishment of property right. DNA extracted, PCR products, temperature profiles, gel documentation and data analysis were performed as same as described earlier in molecular characterization of rice germplasm under rice germplasm conservation and management section.

All the markers showed polymorphism of 200 alleles and varied from 2 (RM454) to 9 (RM154) with an average of 4.76 per locus. The PIC values range from 0.12 (RM237) to 0.76 (RM154) with an average of 0.44. SSR marker RM154 (0.76) was supposed to be the best marker for characterizing the 77 wild rice germplasm. Figure 3 shows the DNA profiles of 77 wild rice germplasm with RM20. Finally, the UPGMA (Fig. 4) clustering analysis grouped the germplasm into six major clusters.

**Table 6. Distribution of breeder seed in Boro 2016-17.**

| Organization | Organization (no.) | Variety and quantity (in kg) | | | | | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BR3 | BR14 | BR26 | BRRI dhan28 | BRRI dhan29 | BRRI dhan36 | BRRI dhan47 | BRRI dhan50 | BRRI dhan55 | BRRI dhan58 | BRRI dhan59 | BRRI dhan60 | BRRI dhan61 | BRRI dhan63 | BRRI dhan64 | BRRI dhan67 | BRRI dhan68 | BRRI dhan69 | BRRI dhan74 | |
| GO | 10 | 100 | 60 | 870 | 15630 | 7546 | 0 | 400 | 580 | 40 | 1176 | 100 | 140 | 100 | 110 | 4290 | 2450 | 30 | 1080 | 30 | 34732 |
| NGO | 6 | 0 | 10 | 0 | 510 | 180 | 0 | 0 | 10 | 30 | 110 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 20 | 10 | 900 |
| PS | 842 | 0 | 220 | 3450 | 22450 | 8240 | 150 | 0 | 2700 | 40 | 4360 | 70 | 60 | 70 | 0 | 0 | 20 | 170 | 180 | 1250 | 43430 |
| Total | 858 | 100 | 290 | 4320 | 38590 | 15966 | 150 | 400 | 3290 | 110 | 5646 | 170 | 200 | 170 | 110 | 4290 | 2470 | 220 | 1280 | 1290 | 79062 |

**Table 7. Distribution of breeder seed in Aus 2017.**

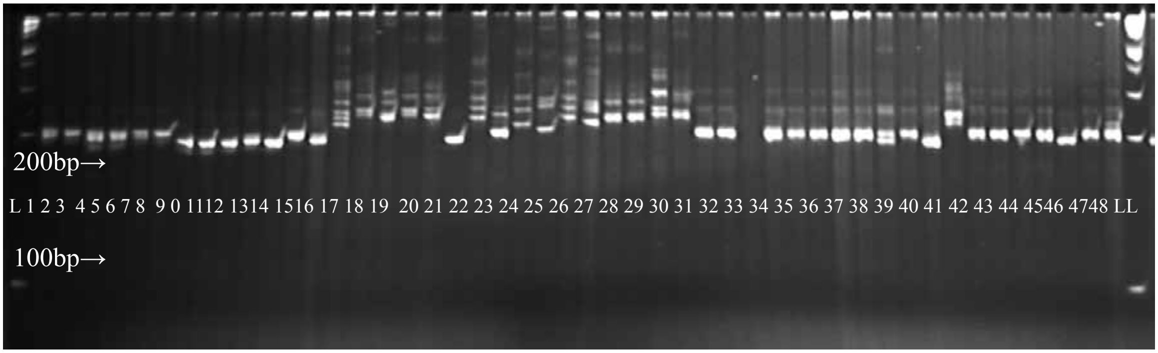
| Organization | Organization (no.) | Variety and quantity (in kg) | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BR3 | BR14 | BR16 | BR21 | BR24 | BR26 | BRRI dhan27 | BRRI dhan42 | BRRI dhan43 | BRRI dhan48 | BRRI dhan55 | BRRI dhan65 | |
| GO | 3 | 20 | 60 | 0 | 50 | 50 | 1100 | 50 | 100 | 200 | 3028 | 0 | 0 | 4658 |
| PS | 12 | 0 | 0 | 0 | 0 | 0 | 1 | 21 | 0 | 56 | 354 | 0 | 281 | 713 |
| Total | 15 | 20 | 60 | 0 | 50 | 50 | 1101 | 71 | 100 | 256 | 3382 | 0 | 281 | 5371 |

**Table 8. Distribution (in kg) of breeder seed (BS) in T. Aman 2017.**

| Organization | Organization (no.) | BR10 | BR11 | BR22 | B R23 | BR25 | BRRI dhan30 | BRRI dhan31 | BRRI dhan32 | BRRI dhan33 | BRRI dhan34 | BRRI dhan37 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GO | 32 | 800 | 2185 | 1300 | 1100 | 0 | 1300 | 2 | 300 | 1002 | 510 | 5 |
| NGO | 9 | 20 | 220 | 30 | 10 | 0 | 10 | 0 | 0 | 70 | 120 | 0 |
| PS | 234 | 460 | 3240 | 520 | 110 | 50 | 110 | 0 | 50 | 1050 | 3260 | 0 |
| Total | 275 | 1280 | 5645 | 1850 | 1220 | 50 | 1420 | 2 | 350 | 2122 | 3890 | 5 |

| Organization | Organization (no.) | BRRI dhan38 | BRRI dhan39 | BRRI dhan40 | BRRI dhan41 | BRRI dhan44 | BRRI dhan46 | BRRI dhan49 | BRRI dhan51 | BRRI dhan52 | BRRI dhan53 | BRRI dhan54 | BRRI dhan56 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GO | 32 | 5 | 830 | 40 | 350 | 30 | 0 | 4082 | 680 | 1747 | 0 | 40 | 217 |
| NGO | 9 | 0 | 0 | 0 | 60 | 0 | 0 | 210 | 220 | 825 | 30 | 80 | 480 |
| PS | 234 | 0 | 0 | 0 | 350 | 150 | 120 | 4840 | 210 | 2240 | 0 | 10 | 260 |
| Total | 275 | 5 | 830 | 40 | 760 | 180 | 120 | 9132 | 1110 | 4812 | 30 | 130 | 957 |

| Organization | Organization (no.) | BRRI dhan57 | BRRI dhan62 | BRRI dhan66 | BRRI dhan70 | BRRI dhan71 | BRRI dhan72 | BRRI dhan73 | BRRI dhan75 | BRRI dhan76 | BRRI dhan77 | Nizersail | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GO | 32 | 20 | 364 | 329 | 539 | 966 | 197 | 1227 | 998 | 397 | 322 | 40 | 21924 |
| NGO | 9 | 35 | 10 | 210 | 65 | 625 | 30 | 65 | 620 | 0 | 0 | 0 | 4045 |
| PS | 234 | 150 | 1510 | 10 | 130 | 100 | 1030 | 0 | 340 | 0 | 0 | 0 | 20300 |
| Total | 275 | 205 | 1884 | 549 | 734 | 1691 | 1257 | 1292 | 1958 | 397 | 322 | 40 | 46269 |




Legend:1.WR1,2.WR2,3.WR3,4.WR4,5.WR5,6.WR6,7.WR7,8.WR8,9.WR9,10.WR10,11.WR11,12.WR12,13.WR13,14.WR14,15.WR15,16.WR16,17.WR17,18.WR18,19.WR19,20.WR20,21.WR21,22.WR22,23.WR23,24.WR24,25.WR25,26.WR26,27.WR27,28.WR28,29.WR29, 30.WR30,31.WR31, 32.WR32, 33.WR33,34.WR34,35.WR35,36.WR36, 37.WR37, 38.WR38,39.WR39, 40.WR40, 41.WR41, 42.WR42, 43.WR43, 44.WR44, 45.WR45, 46.WR46, 47.WR47, 48.WR48


Legend:49.WR49,50.WR50,51.WR51,52.WR52,53.WR53,54.WR54,55.WR55,56.WR56,57..WR57,58.WR58,59.WR59,60.WR60,61.WR61,62.WR62,63.WR63,64.WR64,65.WR65,66.WR66,67.WR67,68.WR68,69.WR69,70.WR70,71.WR71,72.WR72,73.WR73,74.WR74,75.WR75,76.WR76, 77.WR77

Fig. 3. DNA profile of 77 wild rice germplasm with RM20.

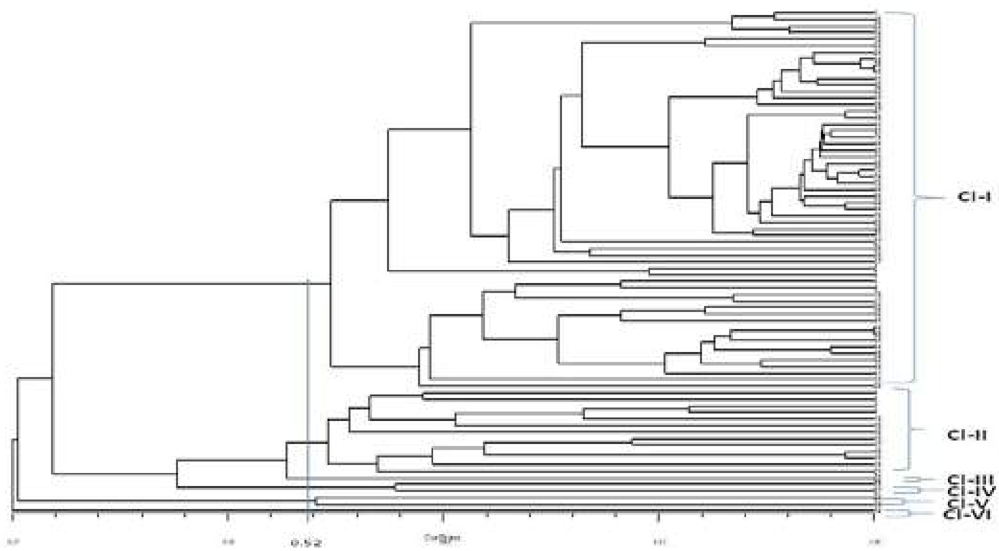



Fig. 4. A UPGMA cluster dendrogram showing the genetic relationships among 77 wild rice germplasm.

# Grain Quality and Nutrition Division

SUMMARY

To ensure desirable qualities the physicochemical and cooking properties of 195 breeding lines were analyzed. Most of the lines had acceptable physical, chemical and cooking properties. Twenty-five lines were undesirable due to their low amylose. One hundred seventy four lines were good since they have more than 7% protein, but 21 lines had less than 7% protein which was not acceptable.

A total of 283 transforming breeding lines were evaluated for physicochemical and cooking properties for superior quality. Based on the performance on grain quality, we recommend 13 lines for further advancement.

Thirty breeding materials were analyzed for Zn and Fe. The highest value of Zn was found in BR8253-9-3-3-1 among all tested lines. Both BR(BE)6158-RWBC2-1-2-1-1 and BR(Bio)9787-BC2-127-1-5 showed the highest level of Fe at 7.4 ppm among all tested breeding lines.

Rice bran oil collected from market had slightly higher acid value and free fatty acid than the acceptable range (>0.5) and (0.15-0.2%) respectively. Peroxide value of edible oil was highly significant and negatively correlated with iodine value.

Twenty-one puffed, seven flattened rice and four auto rice mills were visited to collect data on indigenous rice products of BRRI varieties. The present data reveal that usually puffed rice producers on average use around 710 metric ton milled rice yearly that produces almost 625 metric ton puffed rice. On the other hand, every flattened rice producers uses on average 650 metric ton rough rice yearly that produces almost 406 metric ton flattened rice. BR11, BR16, Hybrid rice and Gutiswarna are more popular varieties for puffed rice, whereas BR11, BR16, BRRI dhan28, BRRI dhan29, BRRI dhan49 and Gutiswarna are commonly used for producing flattened rice. Among these varieties, BR16 and BRRI dhan28 are more popular for production of flattened rice. There are many auto rice mills, which produce special milled rice using to produce puffed rice. In Rangpur and Dinajpur districts, average production of milled rice 1,526 metric ton from four auto rice mills for producing puffed rice per year. Auto rice mills produce milled rice mainly from the variety BR16.

Profiled mineral composition for Zn, Fe, Ca, P and anti-nutrient components such as phytic acid (PA) and molar ratio of PA to minerals for 68 HYVs including Aus (10), Aman (28) and Boro (30) seasons in Bangladesh. The result reveals that BRRI dhan43 possess the highest Zn content of 38.4 ppm followed by Fe (17 ppm), Ca (68.1 ppm) and P (2.5 $gkg^{-1}$) at unparboiled milled rice condition. It was also noticed that its molar ratio to Zn (PA/Zn); Fe (PA/Fe); Ca(PA/Ca) and P(PA/P) are lower among all the selected high Zn enriched HYVs by 3.56, 6.93,1.24 and 25.69 respectively. Since there is no single HYV reported yet, BRRI dhan43 might be a potential micronutrient enriched BRRI HYV for Aus season and it could be used as parental source for micronutrient enriched rice specially zinc enriched rice breeding in Bangladesh.

GRAIN QUALITY CHARACTERISTICS FOR VARIETY DEVELOPMENT

**Determination of physicochemical and cooking properties of breeding lines**

To ensure desirable qualities the physicochemical and cooking properties of 195 breeding lines from the Plant Breeding Division were analyzed. Most of the lines had satisfactory milling outturn. As many as 74 lines had 68-70% and 103 lines had more than 70% milling outturn. Only 18 lines had less than 68% milling outturn. Kernels of more than 82% lines were translucent. Thirty-four lines had either white belly or white center. Size and shape of the grain are also important factors to consumer. Of the breeding lines, 27 had long, 77 had medium and 91 short kernels. Twenty-five lines had slender, 126 had bold grains and forty four had round grain.

Amylose content of rice starch is the major eating quality. It has influence on volume expansion, water absorption, tenderness and stickiness of cooked rice. Amylose content higher than 25% gives non-sticky soft or hard cooked rice. Rice having 20-25% amylose gives soft comparatively sticky cooked rice. Of the breeding lines, 70 had more than 25%, 100 had 20-25% and only 25 had below 20% amylose content. Amylose content below 20% usually produces sticky cooked rice that is not desirable. Protein content in rice is important. Milled rice should not have less than 7% protein.

Twenty lines had more than 9%, 154 lines had 7-9% and 21 lines had less than 7% protein. Alkali spreading value (ASV) has inverse relation with gelatinization temperature (GT). High ASV (6-7) corresponds to low GT. Intermediate ASV (3-5) corresponds to intermediate GT and low ASV (1-3) corresponds to high GT. Among the breeding lines, 29 had alkali spreading value ranging 6.0-7.0. In total, 150 had between 3.0 and 5.0 and only 16 had alkali spreading value between 1.0 and 3.0. Grain with high gelatinization temperature is not desirable.

Cooking time of rice depends on coarseness and gelatinization temperature of the grain. Cooking time determines the tenderness of cooked rice as well as stickiness to some extent. One hundred eighteen lines had 15-20 and 77 had less than 15 minutes cooking time. The lines, having more than 20 minutes cooking time will give comparatively hard cooked rice.

Elongation ratio is an important parameter for cooked rice. If rice elongates more lengthwise it will give finer appearance and if it expands girth wise, it will give a coarse look. Long slender and medium slender rice should elongate more lengthwise because these varieties are preferred by comparatively higher income groups of people. The elongation ration of 83 lines ranged from 1.3 to 1.5. Eighty lines had more than 1.5 elongation ratio, which were desirable. Only 32 lines had less than 1.3 elongation ratio. The low income groups of people consider high imbibition ratio of rice as a positive quality. The imbibition ratio of 157 lines ranged from 3.5 to 4.0. Sixteen breeding lines had more than4.0 and 22 lines had less than 3.5.

The study identified some of the promising lines for high milling and head rice yield and acceptable other physicochemical properties (Table 1).

**Determination of physicochemical and cooking properties of transforming breeding lines**

Grain quality is an important component for consumer's preference and profitability. Milling is one of the parameters determining milled rice yield per unit paddy weight. Among 283 advanced lines 37 had high (>70%) and 55 lines had intermediate (68.0-70.0%) milling yield. On the contrary, 283

**Table 1. Physicochemical properties of promising breeding lines.**

| Genotype | Milling yield (%) | Amylose content (%) | Alkali spreading value | Protein content (%) | Elongation ratio | Grain size and shape |
|---|---|---|---|---|---|---|
| BR8204-5-3-2-5-2 | 73.0 | 26.7 | 5.4 | 7.5 | 1.5 | MB |
| BR8192-10-1-2-3-4 | 72.0 | 26.3 | 7.0 | 8.5 | 1.5 | MB |
| BR8189-10-2-3-1-5 | 74.0 | 28.0 | 5.5 | 7.0 | 1.3 | MB |
| BR8208-5-3-19 | 71.0 | 28.1 | 6.0 | 7.1 | 1.5 | MB |
| BR8526-1-2-3 | 72.0 | 25.7 | 5.3 | 7.7 | 1.5 | MB |
| BR10247-14-18 | 72.0 | 25.3 | 5.3 | 9.0 | 1.5 | MB |
| BR10238-5-1 | 71.0 | 25.1 | 5.8 | 9.1 | 1.5 | MB |
| IR05N412 | 71.0 | 26.4 | 5.3 | 8.6 | 1.5 | LS |
| BR8631-12-3-5-P2 | 71.0 | 26.5 | 4.4 | 8.1 | 1.5 | MB |
| BR7831-59-1-1-4-5 | 71.0 | 26.5 | 5.2 | 9.3 | 1.4 | MB |
| BR8253-9-3-3-1 | 73.0 | 27.3 | 3.9 | 8.4 | 1.3 | MB |
| BR8609-2-B-9-1-B5 | 74.0 | 27.0 | 6.9 | 8.8 | 1.5 | LB |
| BR8850-10-8-3-3 | 72.9 | 25.5 | 5.4 | 7.2 | 1.3 | SB |
| BR8850-10-12-4-2 | 71.7 | 24.5 | 5.7 | 7.3 | 1.4 | SR |
| BR8850-10-12-4-4 | 72.1 | 25.0 | 5.6 | 7.2 | 1.4 | SR |
| BR8850-20-3-5-1 | 72.0 | 25.0 | 5.8 | 7.1 | 1.4 | SR |
| BR8850-26-3-2-3 | 72.0 | 25.0 | 5.7 | 7.5 | 1.4 | SR |
| BR8536-27-4-3-5 | 71.7 | 25.5 | 4.1 | 7.9 | 1.3 | SB |
| BR7465-1-4-1 | 72.8 | 25.0 | 5.8 | 6.4 | 1.2 | MB |
| BR8522 | 72.0 | 26.2 | 5.4 | 7.5 | 1.4 | SB |
| BR8528-2-2-3 | 70.8 | 28.0 | 5.8 | 7.6 | 1.3 | MB |
| BR8514-17-1-5 | 71.8 | 25.0 | 5.5 | 8.3 | 1.4 | SB |
| BR8522-53-1-3 | 71.0 | 25.0 | 5.5 | 7.3 | 1.4 | SR |
| BR6848-3B-12 | 71.5 | 25.3 | 3.6 | 7.2 | 1.4 | LB |
| BR8526+38-2-1-HR2 | 72.5 | 25.0 | 5.0 | 7.5 | 1.5 | MB |
| HHZ23-DT16-DTI-DTI (Boro) | 71.0 | 25.9 | 7.0 | 8.4 | 1.3 | LS |

lines had less than 68% head rice yield. Chalkiness in grain is not a positive quality factor for the non-parboiled rice consumers. Around 26% lines had translucent grains. Grain length and length to breadth ratio determines the grain size and shape. One hundred sixty one lines had long (>6.0 mm), 117 had medium (5.0-6.0 mm) and only five had short (< 5.0 mm) grains. One hundred twenty lines had long slender.

Amylose content determines the quality of cooked rice. Out of 283 lines, 102 had high (>25%), 90 had intermediate (20-25%) and 91 had low (<20%) amylose content. Low amylose rice is not acceptable to our people.

Protein content measures the nutritional value of rice. In total, 123 lines had high (9.0%) and 89 had intermediate protein content (7.0-9.0%). Generally a variety of having less than 7% protein content in brown rice is not recommended for release as a variety.

Alkali spreading value has inverse relationship with gelatinization temperature. Among the lines, 33 had low, 57 had intermediate and 10 had high gelatinization temperature.

High volume expansion of rice is a positive quality factor for low low-income group of people. Nineteen lines had high (>4.0) and 98 had intermediate (3.5-4.0) volume expansion ratio. Elongation ratio is the important quality indicator. The grain that elongates more in length looks finer. On the contrary, the grain that expands more in girth looks coarse. Only two lines had high (1.5), 77 lines had intermediate (1.3-1.5) and 38 lines had low (<1.3) elongation ratio.

This study identified some of the promising lines for high milling and acceptable other physicochemical properties (Table 2).

**Determination of Zn and Fe content of breeding lines**

A total of 30 advanced breeding materials including both Breeding and Biotechnology Divisions of BRRI were analyzed for Zn and Fe according to their requirements. The highest value of Zn in ppm was found in BR8253-9-3-3-1 among all tested lines. BR(Bio)9786-BC2-59-1-2, BR(BE)6158-RWBC2-1-2-1-1 and BR(Bio)8072-AC8-1-1-3-1-1 have shown Zn content at 18.55, 18.42 and 18.12 ppm respectively. Both BR(BE)6158-RWBC2-1-2-1-1 and BR(Bio) 9787-BC2-127-1-5 showed the highest level of Fe at 7.4 ppm among all tested lines (Table 3).

## GRAIN QUALITY PARAMETER FOR CONSUMER PREFERENCE

**Evaluation of commercial rice bran, soybean and mustard oil available in the local market**

Most of the edible oils produced in the world are consumed as food, it is an important source of energy in the diets of the world population. Oils were the most concentrated of all food materials, furnishing about 9 Calories of energy per gram, as compared with about 4 Calories each furnished by proteins and carbohydrates. So, oils also have the highest caloric density of any food stuff. Therefore, this study was carried out to determine the acid value, free fatty acid, glycerin, saponification value, iodine value and peroxide value present in the edible oil. These parameters were analyzed by the method of the Association of Official Analytical Chemists (AOAC, 2005). Statistical analysis was done by SPSS (Ver-17).

Eight commercial edible oil products collected from the local market were analyzed. Table 4 shows the result of the acid value, free fatty acid, glycerin, saponification value, iodine value and peroxide value of the rice bran oil, soybean oil and mustard oil. Acid value varied from 0.55 to 4.3 mg KOH/g among the total samples. Metro Rice Bran Oil (RBO) had the highest acid value but Rupchanda (SO) had the lowest acid value. Free fatty acid varied from 0.28 to 2.16% among the total samples. Metro Rice Bran Oil (RBO) had the highest free fatty acid but Fresh soybean oil (Fortified, SO) and Rupchanda soybean oil (SO) both had the lowest free fatty acid. Glycerin varied from 9.5 to 10.9% among the all samples. Fresh soybean oil (Fortified, SO) had the highest glycerin but Metro Rice Bran Oil (RBO) had the lowest glycerin. Saponification value varied from 178.9 to 199.2 mg KOH/g for the all samples. Fresh soybean oil (Fortified, SO) had the highest saponification value but Metro Rice Bran Oil (RBO) had the lowest saponification value. Iodine value varied from 99.6 to 132.7 g iodine/100 g among the all samples. Fresh soybean oil (Fortified, SO) had the highest iodine value but White Gold (RBO) had the lowest iodine value. Peroxide value varied

**Table 2. Physicochemical properties of promising transforming breeding lines.**

| Genotype | Milling yield (%) | Size and shape | Amylose content (%) |
|---|---|---|---|
| BR9140-15-20-6-4 | 70.5 | LS | 25.0 |
| BR9140-5-22-5-1 | 67.5 | LS | 26.8 |
| BR9140-8-25-6-3 | 67.3 | LS | 25.0 |
| BR9138-8-10-5-3 | 68.3 | LS | 26.8 |
| BR9011-25-4-1-1 | 70.0 | LS | 25.9 |
| BR9039-20-2-2-1 | 68.3 | LS | 25.1 |
| IR11C123 | 66.4 | LS | 26.7 |
| TL Aus (Gaz)-3 | 60.8 | LS | 25.3 |
| TL Aus (Gaz)-9 (SP-17) | 68.7 | LS | 25.8 |
| TL Aus Gaz-10-1 (SP-18) | 64.8 | LS | 25.2 |
| TL Aus Kushtia-8-1 (SP-16) | 69.0 | LS | 25.7 |
| TL early Aus | 66.0 | LS | 26.2 |

**Table 3. Zn and Fe content of unparboiled milled rice of breeding lines.**

| Advanced lines and check | Mean Zn (ppm) | Mean Fe (ppm) |
|---|---|---|
| BR(Bio)9787-BC2-63-2-2 | 11.6 | 6.7 |
| BR(Bio)9787-BC2-63-2-4 | 10.37 | 5.3 |
| BR(Bio)9787-BC2-173-1-3 | 12.46 | 5.8 |
| BR(Bio)9787-BC2-16-3-1 | 13.98 | 7.3 |
| BR(Bio)9787-BC2-127-1-5 | 10.29 | 7.4 |
| BRRI dhan28 | 18.8 | 7.8 |
| BR(Bio)9786-BC2-122-1-3 | 11.94 | 5.5 |
| BR(Bio)9786-BC2-15-2-2 | 14.5 | 5.9 |
| BR(Bio)9786-BC2-15-2-3 | 14.58 | 6.2 |
| BR(Bio)9786-BC2-49-1-2 | 10.8 | 5.1 |
| BR(Bio)9786-BC2-59-1-2 | 18.55 | 6.4 |
| BR(Bio)9786-BC2-124-1-1 | 10.22 | 5.2 |
| BR(Bio)9786-BC2-142-1-1 | 17.68 | 5.9 |
| BRRI dhan29 | 18.8 | 8.2 |
| BR(Bio)8072-AC5-4-2-1-2-1 | 15.4 | 6.1 |
| BR(Bio)8072-AC8-1-1-3-1-1 | 18.16 | 6.5 |
| BR(BE)6158-RWBC2-1-2-1-1 | 18.42 | 7.4 |
| BR8631-12-3-5-P2 | 15.85 | - |
| BR8631-12-3-6-P3 | 15.90 | - |
| BR7831-59-1-1-4-5 | 17.40 | - |
| BR8253-9-3-3-1 | 19.00 | - |
| BR8609-2-B-9-1-B5 | 15.45 | - |
| BR7815-18-1-3-2-1 | 16.85 | - |
| BR7671-37-2-2-3-7-3-P10 | 17.13 | - |
| BR7671-37-2-2-3-7-3-P11 | 16.70 | - |
| BR7831-59-1-1-4-5-1-9-P1 | 15.80 | - |
| BR7831-59-1-1-4-9-1-2-P3 | 16.56 | - |
| BRRI dhan28 | 18.80 | - |
| BRRI dhan58 | 17.80 | - |
| BRRI dhan74 | 21.00 | - |

from 9.8 to 88.2 meq/kg among the all samples. Rupchanda (MO) had the highest peroxide value but Kollany rice bran oil (RBO) had the lowest peroxide value (Table 4).

Table 5 shows Pearson correlation coefficient for rice bran oil, soybean oil and mustard oil based on acid value, free fatty acid, glycerin and saponification value, iodine value and peroxide value. Free fatty acid was highly significant and positively correlated with acid value. Glycerin was significant and negatively correlated with both acid value and free fatty acid. Saponification value was

**Table 4. Chemical characteristics for different types of edible oil available in the local market.**

| Sample | Acid value (mg KOH/g) | Free fatty acid (%) | Glycerin (%) | Saponification value (mg KOH/g) | Iodine value (g iodine/100g) | Peroxide value (meq/kg) |
|---|---|---|---|---|---|---|
| ACI Nutrilife (RBO) | 2.2 | 1.11 | 9.9 | 183.5 | 105.6 | 19.8 |
| Metro Rice Bran Oil (RBO) | 4.3 | 2.16 | 9.5 | 178.9 | 115 | 25 |
| Kollany (RBO) | 2.2 | 1.11 | 10.5 | 193.9 | 106 | 9.8 |
| White Gold (RBO) | 3.3 | 1.66 | 10.5 | 195.7 | 99.6 | 24.7 |
| Fresh (Fortified, SO) | 0.56 | 0.28 | 10.9 | 199.2 | 132.7 | 19.5 |
| Rupchanda (SO) | 0.55 | 0.28 | 10.6 | 194.2 | 132.6 | 24.9 |
| Raduni (MO) | 1.1 | 0.55 | 10.0 | 184.5 | 104.6 | 80.3 |
| Rupchanda (MO) | 3.2 | 1.61 | 9.7 | 181.5 | 112.1 | 88.2 |
| Maximum | 4.3 | 2.16 | 10.9 | 199.2 | 132.7 | 88.2 |
| Minimum | 0.55 | 0.28 | 9.5 | 178.9 | 99.6 | 9.8 |

*RBO= Rice bran oil; SO= Soybean oil; MO= Mustard oil.

**Table 5. Correlations among the bio-chemical characters of rice bran oil available in the local market.**

| | Correlation | | | | |
|---|---|---|---|---|---|
| Parameter | Acid value (mg KOH/g) | Free fatty acid (%) | Glycerin (%) | Saponification value (mg KOH/g) | Iodine value (g iodine/100g) |
| Free fatty acid (%) | 1.000** | | | | |
| Glycerin (%) | -.597* | -.597* | | | |
| Saponification value (mg KOH/g) | .086 | .086 | .746** | | |
| Iodine value (g iodine/100g) | -.561* | -.561* | .266 | -.122 | |
| Peroxide value (meq/kg) | .283 | .283 | .049 | .288 | -.672** |

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

positively correlated with both acid value and free fatty acid as well as highly significant and positively correlated with glycerin. Iodine value was significant and negatively correlated with both acid value and free fatty acid as well as only negatively correlated with saponification value but positively correlated with glycerin. Peroxide value was highly significant and negatively correlated with iodine value but only positively correlated with all other parameters.

Higher acid value indicates longer storage time of the edible oil. Acid value determines the rancidity of the oil due to its higher free fattyacid. Lower saponification value indicates higher fatty acid chain length in the oil. Higher iodine value indicates greater carbon-carbon double bond (unsaturation). Rice bran oil collected from market had slightly higher acid value and free fatty acid than the acceptable range >0.5 and 0.15-0.2% respectively. Iodine value and peroxide value of all edible oil, which were collected from the market had higher value. In this case peroxide value of all edible oil was also higher, which indicates older products.

COMMERCIAL RICE BASED PRODUCTS

**Survey on indigenous rice products of BRRI varieties**

Puffed rice called *muri* is made by heating rice in a sand filled oven. The puffed rice processing involved to make rice less perishable. Puffed rice is formed by the reaction of both starch and moisture when heated within the shell of the grain. Traditional puffed and flattened rice are recognized as important food items especially for rural people of this country. People of the Muslim community are used to eat puffed rice with other food items in the evening during the month of Ramadan. Not only in Ramadan, puffed rice is used as breakfast food item round the year. But specially in winter season, consumption of puffed rice is higher than any other seasons. On the other hand, flattened rice is also a popular food item in our country. In rural areas of Bangladesh, flattened rice is consumed as breakfast food with curd. Therefore, a survey study was carried out to find out the popular varieties are used for puffed and flattened rice.

During the survey, Rangpur, Dinajpur, Barisal, Potuakhali, Jhalkhati and Bhola districts were selected and data were collected from different puffed and flattened rice commercial and handmade mills using predesigned questionnaire. Only few varieties are used for producing puffed rice. BR11, BR16, hybrid rice and Gutiswarna are more popular varieties. Among the varieties, BR16 covers more than 50% of total production of puffed rice followed by BR11 and Gutiswarna in Rangpur and Dinajpur regions. On the other hand, Barisal region is different from any other districts of Bangladesh. People of this region generally make bold types of puffed rice using traditional varieties because they produce rice only in Aman season. Among the varieties, Nachochimota covers more than 70% of total production of puffed rice in Barisal region compared to Mothamota 20% and Gigozdhan 10%. At present, over 1900 people belonging to 450 families from 11 villages, which are located on the southern bank of the Kirtonkhola-Sugandha rivers in Dapdapia have contributed towards making this area the hub of puffed rice production. What makes the puffed rice so special from Barisal region is the fact it is handmade in the age old way and they do not use chemicals such as urea to make its appearance better.

Twenty-one puffed rice, seven flattened and four auto rice mills were visited to collect data. It was shown that traditional methods are applied to produce puffed rice. There is no much variation in processing method from mill to mill. On average, every puffed rice producer use around 710 metric ton milled rice yearly that produces almost 625 metric ton puffed rice. On the other hand, every flattened rice producer uses around 650 metric ton rough rice yearly that produces almost 406 metric ton flattened rice. BR11, BR16, BRRI dhan28, BRRI dhan29, BRRI dhan49 and Gutiswarna are used for producing flattened rice. Among the varieties, BR16 and BRRI dhan28 are more popular for production of flattened rice. There are many auto rice mills, which produce special milled rice for using to produce puffed rice. In Rangpur and Dinajpur districts, average production of milled rice 1526 metric ton from four auto rice mills for producing puffed rice per year. Auto rice mills produce milled rice mainly from the variety BR16. If total number of puffed and flattened rice mills are estimated, percent of total production of milled rice is used for producing puffed rice could be calculated.

Therefore, it is needed to continue collecting data from auto rice mills along with puffed and flattened rice commercial mills in different districts of Bangladesh to draw a conclusion.

## NUTRITION QUALITY ASSESSMENT OF RICE

### Mineral profiling of HYV rice in Bangladesh

A total of 68 BRRI HYVs including Aus, Aman and Boro season grown rice varieties such as BR20, BR21, BR24, BR26, BRRI dhan27, BRRI dhan42, BRRI dhan43, BRRI dhan48, BRRI dhan65 for Aus season; BR4, BR5, BR10, BR11, BR22, BR23, BR25, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan38, 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, BRRI dhan66 for Aman season and BR1, BR2, BR3, BR6, BR7, BR8, BR9, BR12, BR14, BR15, BR16, BR17, BR18, BR19, BRRI dhan28, BRRI dhan29, BRRI dhan35, BRRI dhan36, BRRI dhan47, BRRI dhan50, BRRI dhan55, BRRI dhan58, BRRI dhan59, BRRI dhan60, BRRI dhan61, BRRI dhan63, BRRI dhan64, BRRI dhan67, BRRI dhan68 BRRI dhan69 for Boro season were selected in this study to evaluate their mineral profiling including zinc, iron, calcium, phosphate, phytic acid and molar ratio of phytate to respective minerals (PA/Zn, PA/Fe, PA/Ca and PA/P). Rough rice was collected from BRRI Genebank and unparboiled milled rice was analyzed for different mineral contents.

Rice samples were digested and estimatation of iron, zinc and calcium were carried out by the method of the Association of Official Agricultural Chemists. Estimation of phosphorus done by measuring calorimetrically the blue colour formed when the ash solution is treated with ammonium molybdate and the phosphomolybdate. Phytic acid present in rice samples were determined colorimetrically by Wheeler and Ferral method. The molar ratios of PA/Zn, PA/Fe, PA/Ca and PA/P were calculated as follows: the molar intake of phytate (molecular weight, 660) was divided by the molar intake of Zn (molecular weight, 65), molar intake of Fe (molecular weight, 56), molar intake of Ca (molecular weight, 40) and molar intake of P (molecular weight, 31) respectively.

In the present study of mineral profiling of Zn, Fe, Ca and P, the data revealed that there are variation of mineral content among HYVs including Aus, Aman and Boro seasons grown in Bangladesh. All HYVs were grown in West Byed field of BRRI, Gazipur during Aus, Aman and Boro season in 2015-16. BRRI recommended fertilizer dose was applied in field preparation (BRRI, 2015). Field soil was adequate in Zn and there was no symptoms of Zn deficiency in total duration of the experiment (BRRI, 2016).

A total of 30 BRRI Boro HYVs were studied in this experiment. Table 6 shows the mineral profiling data. The data revealed that both BR6 and BRRI dhan64 possesed the highest Zn content of 24 ppm ($mgkg^{-1}$) followed by BRRI dhan36 and BR7 at 23.7 and 22.7 ppm respectively at unparboiled milled rice condition. BR17 showed the highest content of Fe (17.5 ppm) followed by BRRI dhan35 (14.5 ppm), BRRI dhan64 (11.1 ppm), BRRI dhan58 (9.9 ppm) and BR12 (9.8 ppm). BR7 showed the highest content of Ca (48.1 ppm) followed by BR2 (42.1 ppm), BR1 (41.1 ppm), BRRI dhan28 (41.8 ppm) and BR19 (39.9 ppm). BRRI dhan64 showed the highest content of P (3.1 $gkg^{-1}$) followed by BR1 (2.7 $gkg^{-1}$) and BR6 (2.4 $gkg^{-1}$) in Boro season (Table 6).

A total of 10 BRRI Aus HYVs were studied in this experiment and all mineral profiling data are summarized in Table 7. The data reveals that BRRI dhan43 possessed the highest Zn content of 38.4 ppm ($mgkg^{-1}$) followed by BRRI dhan42 (27.0 ppm), BR21(22.1 ppm) and BR24 (20.7) at milled rice condition. BR20 showed the highest content of Fe (19.1 ppm) followed by BR21 (18 ppm) and BRRI dhan43 (17.0 ppm). BRRI dhan65 showed the highest content of Ca (86.0 ppm) followed by BRR1 dhan42 (85.0 ppm), BR26 (84.9 ppm), BRRI dhan48 (83.1 ppm), BR24 (82.0 ppm) and BR21 (76.0 ppm). BR26 showed the highest content of P (3.3 $gkg^{-1}$) followed by BR20 (3.1 $gkg^{-1}$) and BRRI dhan65 (2.8 $gkg^{-1}$) in Aus season (Table 7).

A total of 28 BRRI Aman HYVs were studied in this experiment. Table 8 shows the mineral profiling data. Our data reveal that BRRI dhan32 possessed the highest Zn content of 25.4 ppm ($mgkg^{-1}$) followed by BR25 (20.7 ppm) and BRRI dhan62 (20.0 ppm) at milled rice condition. BRRI dhan62 showed the highest content of Fe (21.0 ppm) followed by BRRI dhan38 (20 ppm), BRRI dhan34 (19.0 ppm), BR11 (19.0 ppm), BR22 (19.0 ppm), BRRI dhan37 (17.9 ppm), BR23 (17.6 ppm), BRRI dhan31 (17.3 ppm), BR4 (16.1 ppm), BRRI dhan53 (10.7 ppm) and BRRI dhan49 (10.6 ppm). BRRI dhan49 showed the highest content of Ca (86.9 ppm) followed by BRR1 dhan37 (86.0 ppm), BRR1 dhan52 (85.0 ppm), BRR1 dhan32 (83.0 ppm), BRR1 dhan31 (81.0 ppm), BRR1 dhan30 (81.0 ppm) and BR25 (81.0 ppm). BRRI dhan34 showed the highest content of P (3.6 $gkg^{-1}$) followed by BRRI dhan49 (3.3 $gkg^{-1}$), BRRI dhan53 (3.2 $gkg^{-1}$), BRRI dhan37 (3.2 $gkg^{-1}$) and BRRI dhan30 (3.0 $gkg^{-1}$) in Aman season (Table 8).

Phytic acid (PA) and molar ratios of phytate to respective minerals such as Zn, Fe, Ca and P were analyzed for 14 HYVs including Aus, Aman and Boro season. Zn content of all the selected HYVs was $\geq$ 20.0 ppm at milled rice condition. PA content, PA/Zn ratio, PA/Fe ratio, PA/Ca ratio and PA/P ratio were measured for those selected HYVs. In Aman season, BR25, BRRI dhan32 and BRRI dhan62 possessed higher Zn content ($\geq$20 ppm) and their PA values are 19.1, 19.9 and 19.1 $mgg^{-1}$ respectively. Molar ratio of PA/Zn, PA/Fe, PA/Ca and PA/P ranges from 7.7 to 9.4, 7.7 to 48.5, 1.4-8.3 and 33.2-56.6 respectively. Lower molar ratios of PA to respective minerals (Zn, Fe, Ca and P) indicate higher bioavailability of minerals (Table 9). In Aus season, BR21, BR24, BRRI dhan42 and BRRI dhan43 possessed higher Zn content ($\geq$20 ppm) and their PA values are 14.98, 19.07, 14.30 and 13.89 $mgg^{-1}$ respectively. Molar ratio of PA/Zn, PA/Fe, PA/Ca and PA/P ranges from 2.1 to 9.1, 6.9 to 30.8, 1.02-1.4 and 8.7-47.4 respectively. Lower molar ratio of PA to respective minerals (Zn, Fe, Ca and P) indicates to be higher bioavailability of minerals. Considering above parameters, BRRI dhan43 seemed to be

**Table 6. Mineral profiling of 30 Boro season grown BRRI HYVs.**

| HYV | Zn (mgkg$^{-1}$) | Fe (mgkg$^{-1}$) | Ca (mgkg$^{-1}$) | P (gkg$^{-1}$) |
|---|---|---|---|---|
| BR1 | 21.3 | 7.8 | 41.1 | 2.7 |
| BR2 | 19.9 | 8.6 | 42.1 | 2.0 |
| BR3 | 17.5 | 5.9 | 26.3 | 2.1 |
| BR6 | 24.0 | 9.5 | 34.2 | 2.4 |
| BR7 | 22.7 | 7.8 | 48.1 | 1.7 |
| BR8 | 19.6 | 6.1 | 37.6 | 1.5 |
| BR9 | 16.3 | 7.8 | 35.6 | 1.8 |
| BR12 | 19.8 | 9.8 | 26.7 | 2.3 |
| BR14 | 16.8 | 8.1 | 22.3 | 1.8 |
| BR15 | 17.6 | 7.3 | 33.7 | 2.3 |
| BR16 | 18.4 | 6.2 | 32.4 | 1.3 |
| BR17 | 19.8 | 17.5 | 37.2 | 1.9 |
| BR18 | 19.0 | 6.6 | 36.4 | 1.4 |
| BR19 | 18.2 | 9.6 | 39.9 | 2.0 |
| BRRI dhan28 | 18.8 | 7.8 | 41.8 | 2.0 |
| BRRI dhan29 | 18.8 | 8.2 | 30.3 | 1.8 |
| BRRI dhan35 | 21.6 | 14.5 | 26.8 | 2.4 |
| BRRI dhan36 | 23.6 | 9.6 | 35.1 | 1.8 |
| BRRI dhan47 | 21.3 | 8.9 | 34.8 | 1.4 |
| BRRI dhan50 | 19.6 | 8.7 | 33.2 | 2.2 |
| BRRI dhan55 | 18.1 | 8.0 | 28.1 | 1.9 |
| BRRI dhan58 | 17.8 | 9.9 | 31.9 | 2.1 |
| BRRI dhan59 | 16.3 | 7.5 | 25.7 | 1.8 |
| BRRI dhan60 | 19.6 | 8.7 | 33.2 | 2.2 |
| BRRI dhan61 | 19.1 | 8.0 | 30.2 | 1.3 |
| BRRI dhan63 | 18.8 | 7.3 | 37.3 | 1.7 |
| BRRI dhan64 | 24.0 | 11.1 | 18.7 | 3.1 |
| BRRI dhan67 | 18.0 | 8.9 | 35.3 | 1.3 |
| BRRI dhan68 | 16.7 | 9.6 | 18.0 | 2.1 |
| BRRI dhan69 | 18.2 | 9.1 | 32.4 | 1.7 |
| Mean | 19.4 | 8.8 | 32.9 | 1.9 |
| STDEV | 2.2 | 2.3 | 6.8 | 0.4 |
| Max | 24.0 | 17.5 | 48.1 | 3.1 |
| Min | 16.3 | 5.9 | 18.0 | 1.3 |
| Range | 16.3-24.0 | 5.9-17.5 | 18.0-48.0 | 1.3-3.1 |

**Table 7. Mineral profiling of 10 Aus season grown BRRI HYVs**

| HYV | Zn (mgkg$^{-1}$) | Fe (mgkg$^{-1}$) | Ca (mgkg$^{-1}$) | P (gksg$^{-1}$) |
|---|---|---|---|---|
| BR20 | 17.5 | 19.1 | 26.1 | 3.1 |
| BR21 | 22.1 | 18.0 | 76.0 | 2.2 |
| BR24 | 20.7 | 7.9 | 82.0 | 1.9 |
| BR26 | 18.7 | 10.7 | 84.9 | 3.3 |
| BRRI dhan27 | 16.1 | 7.8 | 32.2 | 1.6 |
| BRRI dhan27 | 16.1 | 7.8 | 32.2 | 1.6 |
| BRRI dhan42 | 27.0 | 3.9 | 85.0 | 2.5 |
| BRRI dhan43 | 38.4 | 17.0 | 68.1 | 2.5 |
| BRRI dhan48 | 13.2 | 8.5 | 83.1 | 2.7 |
| BRRI dhan65 | 17.1 | 15.4 | 86.0 | 2.8 |
| Mean | 20.7 | 11.6 | 65.6 | 2.4 |
| STDEV | 7.3 | 5.3 | 25.0 | 0.6 |
| Max | 38.4 | 19.1 | 86.0 | 3.3 |
| Min | 13.2 | 3.9 | 26.1 | 1.6 |
| Range | 13.2-38.4 | 3.9-19.1 | 26.1-86.0 | 1.6-3.3 |

**Table 8. Mineral profiling of 28 Aman season grown BRRI HYVs.**

| HYV | Zn (mgkg$^{-1}$) | Fe (mgkg$^{-1}$) | Ca (mgkg$^{-1}$) | P (gkg$^{-1}$) |
|---|---|---|---|---|
| BR4 | 12.0 | 16.1 | 17.8 | 2.7 |
| BR5 | 12.6 | 2.1 | 71.2 | 1.6 |
| BR10 | 14.0 | 4.1 | 56.0 | 1.7 |
| BR11 | 11.0 | 19.0 | 34.0 | 2.3 |
| BR22 | 11.0 | 19.0 | 66.0 | 1.9 |
| BR23 | 12.8 | 17.6 | 14.5 | 2.1 |
| BR25 | 20.7 | 3.8 | 81.0 | 1.7 |
| BRRI dhan30 | 14.4 | 9.9 | 81.0 | 3.0 |
| BRRI dhan31 | 11.0 | 17.3 | 81.0 | 2.9 |
| BRRI dhan32 | 25.4 | 3.5 | 83.0 | 1.7 |
| BRRI dhan33 | 18.1 | 3.0 | 74.9 | 2.4 |
| BRRI dhan34 | 17.4 | 19.0 | 38.1 | 3.6 |
| BRRI dhan37 | 13.1 | 17.9 | 86.0 | 3.2 |
| BRRI dhan38 | 11.0 | 20.0 | 25.4 | 2.8 |
| BRRI dhan39 | 11.0 | 9.8 | 69.0 | 2.5 |
| BRRI dhan40 | 11.4 | 2.6 | 74.0 | 2.4 |
| BRRI dhan41 | 12.0 | 21.0 | 17.3 | 2.2 |
| BRRI dhan44 | 11.6 | 16.2 | 9.8 | 2.4 |
| BRRI dhan46 | 14.4 | 5.3 | 78.6 | 4.3 |
| BRRI dhan49 | 12.5 | 10.6 | 86.9 | 3.3 |
| BRRI dhan51 | 10.5 | 8.4 | 67.0 | 2.7 |
| BRRI dhan52 | 12.7 | 5.0 | 85.0 | 2.1 |
| BRRI dhan53 | 12.0 | 10.7 | 59.6 | 3.2 |
| BRRI dhan54 | 12.7 | 6.9 | 13.4 | 2.5 |
| BRRI dhan56 | 14.3 | 3.8 | 79.0 | 2.5 |
| BRRI dhan57 | 11.0 | 6.1 | 22.9 | 2.4 |
| BRRI dhan62 | 20.0 | 21.0 | 14.0 | 2.7 |
| BRRI dhan66 | 16.8 | 4.5 | 62.0 | 1.6 |
| Mean | 13.8 | 10.9 | 55.3 | 2.5 |
| STDEV | 3.6 | 6.8 | 27.8 | 0.6 |
| Max | 25.4 | 21.0 | 86.9 | 4.3 |
| Min | 10.5 | 2.1 | 9.8 | 1.6 |
| Range | 10.5-25.4 | 2.1-21.0 | 9.8-86.9 | 1.6-4.3 |

the best micronutrient enriched HYV in Aus season in Bangladesh whose PA/Zn (3.56), PA/Fe (6.93), PA/Ca (1.24) and PA/P (25.69) values are also lowest among other HYVs. Lower molar ratios of PA to respective minerals (Zn, Fe, Ca and P) indicate higher bioavailability of minerals (Table 9). In Boro season BR1, BR6, BR7, BRRI dhan35, BRRI dhan36, BRRI dhan47 and BRRI dhan64 possessed higher Zn content (≥20 ppm) and their PA values are 20.4, 23.0, 28.6, 21.7, 15.0, 24.2 and 24.1 mgg$^{-1}$ respectively. Molar ratios of PA/Zn, PA/Fe, PA/Ca and PA/P ranges from 6.3 to 12.4, 12.7 to 31.1, 1.7-7.8 and 20.0-81.3 respectively. Lower molar ratios of PA to respective minerals (Zn, Fe, Ca and P) indicate higher bioavailability of minerals. Considering above parameters, BR7, BRRI dhan47 and BRRI dhan64 show better HYV for micronutrient enriched HYV in Boro season in Bangladesh. Lower molar ratio of PA to respective minerals (Zn, Fe, Ca and P) indicate higher bioavailability of minerals (Table 6). Both BRRI dhan62 and BRRI dhan64 were released as two high zinc enriched HYVs in Bangladesh in 2013 and 2014 for Aman and Boro season respectively.

Mineral profiling of these Zn, Fe, Ca and P for selected 68 BRRI HYVs is that potentially very important for maintaining database. The data revealed that 15 HYVs are having Zn content more than 20 ppm including BRRI dhan62 and BRRI dhan64. Interestingly the present study revealed that BRRI dhan43 possessed the highest Zn content (38.4 ppm) among all HYVs. BRRI dahn43 is a Aus season grown HYV and it shows lower phytate to mineral molar ratio such as PA/Zn (3.56), PA/Fe (6.93), PA/Ca (1.24) and PA/P (25.69) which implies that it may show higher bioavailability of minerals (Table 9).

BRRI has released four Zn enriched HYVs such as BRRI dhan62 and BRRI dhan72 for Aman season and BRRI dhan64 and BRRI dhan74 for Boro season in Bangladesh. Since there is no reported high Zn enriched HYV in Aus season yet, we would like to conclude that BRRI dhan43 has the highest Zn content (38.4 ppm≃ mg $kg^{-1}$) at Aus season in Bangladesh. BRRI dhan43 is also enriched with Fe (17 ppm≃ mg $kg^{-1}$), Ca (68.1 ppm≃ mg $kg^{-1}$) and P (2.5 $gkg^{-1}$). Since it's molar

**Table 9. Phytic acid (PA) content of 15 selected HYVs ( ≥ 20ppm Zn) and molar ratio of Phytate to minerals.**

| HYV | PA ($mgg^{-1}$) | PA/Zn | PA/Fe | PA/Ca | PA/P |
|---|---|---|---|---|---|
| | | Aman | | | |
| BR25 | 19.1 | 9.1 | 42.9 | 1.4 | 52.4 |
| BRRI dhan32 | 19.9 | 7.7 | 48.5 | 1.5 | 56.6 |
| BRRI dhan62 | 19.1 | 9.4 | 7.7 | 8.3 | 33.2 |
| Mean | 19.3 | 8.7 | 33.0 | 3.7 | 47.4 |
| STDEV | 0.4 | 0.7 | 18.1 | 3.2 | 10.2 |
| Range | 19.1-19.9 | 7.7-9.4 | 7.7-48.5 | 1.4-8.3 | 33.2-56.6 |
| | | Aus | | | |
| BR21 | 14.98 | 6.68 | 7.06 | 1.19 | 31.70 |
| BR24 | 19.07 | 9.06 | 20.42 | 1.41 | 47.39 |
| BRRI dhan42 | 14.30 | 5.21 | 30.81 | 1.02 | 26.76 |
| BRRI dhan43 | 13.89 | 3.56 | 6.93 | 1.24 | 25.69 |
| Mean | 15.56 | 6.13 | 16.31 | 1.22 | 32.89 |
| STDEV | 2.06 | 2.02 | 10.01 | 0.14 | 8.68 |
| Range | 13.9-19.1 | 3.6-9.1 | 6.9-30.8 | 1.2-1.4 | 25.7-47.4 |
| | | Boro | | | |
| BR1 | 20.4 | 9.5 | 22.2 | 3.0 | 35.6 |
| BR6 | 23.0 | 9.5 | 20.6 | 4.1 | 45.1 |
| BR7 | 28.6 | 12.4 | 31.1 | 3.6 | 79.0 |
| BRRI dhan35 | 21.7 | 9.9 | 12.7 | 4.9 | 42.4 |
| BRRI dhan36 | 15.0 | 6.3 | 13.2 | 2.6 | 39.1 |
| BRRI dhan47 | 24.2 | 11.2 | 23.1 | 4.2 | 81.3 |
| BRRI dhan64 | 24.1 | 9.9 | 18.4 | 7.8 | 36.5 |
| Mean | 22.4 | 9.8 | 20.2 | 4.3 | 51.3 |
| STDEV | 4.2 | 1.9 | 6.3 | 1.7 | 20.0 |
| Range | 15.0-28.6 | 6.3-12.4 | 12.7-31.1 | 2.6--7.8 | 35.6-81.3 |

ratios to Zn (PA/Zn); Fe (PA/Fe); Ca (PA/Ca) and P (PA/P) are lower among all 15 selected high Zn enriched HYVs by 3.56, 6.93,1.24 and 25.69 respectively. So essential micronutrients will be maximum bio available by human consumption of BRRI dhan43 in Bangladesh. BRRI dhan43 can be used as a potential parental source or donor for further micronutrient enriched rice specially zinc enriched rice breeding programme in Bangladesh.

# Hybrid Rice Division

SUMMARY

In T. Aman season 2016, a total of 184 test crosses and 261 (A × R) crosses were made from source nursery. One hundred fifty-two test crosses ($F_1$s) were evaluated for their pollen fertility status of which six entries have been found heterotic over check varieties. Pollen parents of those combinations were regarded as suspected restorers and selected for fertility restoration ability with other CMS lines in the next season. Two entries were found completely sterile and their corresponding male parents were regarded as suspected maintainer lines. All the backcross generations except one $BC_4$ generation was found unstable in terms of pollen sterility and hence discarded. Fifty-six CMS lines along with their respective maintainer lines were maintained by hand crossing. Six test crosses were made for disease resistant parental lines development. Matured seeds of $BC_2F_1$ populations from three combinations were collected and preserved for three combinations against bacterial blight disease.

A total of 140 test crosses and 319 (A × R) crosses were made using eight CMS lines in Boro season 2016-17. In total 128 test crosses ($F_1$s) were evaluated for their pollen fertility status. Among them two entries showed complete sterility and immediately backcrossed with their corresponding male parents for conversion. On the other hand, six entries have been selected for their high yielding ability compared to the check varieties. One $BC_5$ along with two $BC_1$ generations was found unstable in pollen sterility and hence discarded. Other entries were advanced to the next generations. Sixty-seven CMS lines along with their respective maintainer lines were maintained by hand crossing in CMS maintenance and evaluation nursery for their genetic purity.

In T. Aman, out of 126 test hybrids under observational trials four hybrid combinations were selected based on yield, duration and grain type and produced more than 16-44% yield advantage over check variety BR11, 9-36% over BRRI dhan49 and 3-25% over BRRI hybrid dhan4 with two to three week shorter growth duration. Out of 186 test hybrids six hybrid combinations were selected based on yield, duration and grain type and showed yield advantage ranging from 5-27% over BRRI hybrid dhan3, 37-67% over BRRI dhan28 and 16-42% over BRRI dhan29 in Boro 2016-17 with growth duration similar to BRRI dhan28 but one to two weeks earlier than BRRI dhan29. Under preliminary yield trials, ten hybrids out of 16 gave more than one ton yield advantage over BRRI dhan49 and three of them out yielded BRRI hybrid dhan4 and company hybrid Arize-4 by more than one ton in T. Aman 2016 and Boro 2016-17, Twenty-five hybrids were evaluated along with three checks and almost all the hybrids showed one ton yield advantage over BRRI dhan28 and nine hybrids showed yield advantage more than one ton over BRRI dhan29. Only two hybrid combinations had out yielded BRRI hybrid dhan3 by more than one ton. National hybrid rice yield trials were conducted through SCA in T. Aman 2016 and Boro 2016-17, which included 18 and 37 hybrids. Results were compiled by SCA. During the reporting year one new hybrid rice variety named as BRRI hybrid dhan5 has released all over Bangladesh for Boro season cultivation.

Seed yield of 80 kg/plot (1.7 t/ha), 95 kg/plot (1.8 t/ha) and 25 kg/plot (1.25 t/ha) were obtained from BRRI10A, BRRI11A line and IR58025A respectively in T. Aman season. On the other hand, in Boro 2016-17, CMS seed yield of 220 kg (2.2 t/ha), 120 kg (2.2 t/ha) and 90 kg (1.82 t/ha) were obtained from BRRI10A/B, BRRI11A/B and IR58025A/B respectively. A total of 100 kg (1.6 t/ha), 110 kg (1.65 t/ha) and 20 kg (1.2 t/ha) hybrid seeds were produced from BRRI11A/BRRI15R, BRRI10A/BRRI10R and IR58025A/BRRI10R respectively during T. Aman 2016. During Boro 2016-17, a total of 120 kg (2.6 t/ha) from BRRI hybrid dhan2, 200 kg (2.5 t/ha) from BRRI hybrid dhan3 and 400 kg (1.65 t/ha) seeds were obtained from BRRI hybrid dhan4. A total of 81, 350 kg $F_1$ seeds were produced during Boro 2016-17 with the technical assistance from BRRI under 13 seed companies and BRRI regional stations. In the reporting year, hybrid rice division supplied 3,395 kg of parental lines and $F_1$ seeds to 40 farmers, 13 seed companies, scientists and staffs of BRRI.

DEVELOPMENT OF PARENTAL MATERIALS

**Source nursery**

One hundred eighty-four test crosses and 261 (A × R) crosses were made using eight CMS lines in T. Aman 2016. One hundred forty test crosses and 319

(A × R) crosses were made using eight CMS lines in Boro season 2016-17.

**Test cross nursery**

In T. Aman 2016, out of 152 test crosses ($F_1$s) six entries have been found heterotic over check varieties expressing 19-26% yield advantage over check BR11 with two to three weeks earlier and two entries were found completely sterile. Pollen parents of heterotic combinations were regarded as suspected restorers and pollen parents of completely sterile combinations were regarded as suspected maintainer lines. In Boro 2016-17, out of 128 test crosses ($F_1$s), two tested entries showed complete sterility and they were immediately backcrossed with their corresponding male parents for conversion. On the other hand, six entries have been selected for their high yielding ability compared to the check variety.

**Back cross nursery**

In T. Aman 2016, all the backcross generations were stable in terms of pollen sterility and advanced for next generation except for one $BC_4$ generations. It was discarded due to fluctuation in pollen fertility. In Boro 2016-17, one $BC_5$ and two $BC_1$ generations were found unstable in pollen sterility and hence they were discarded. Other generations were advanced as $BC_6$, $BC_5$, $BC_4$, $BC_3$ and $BC_2$ generations (Table 1).

**Table 1. Performance of backcross entries during Boro seasons of 2016-2017.**

| BC gen | Designation | Sterility status | DFF | D50%F | DTM | Grain type | Base colour | Remark |
|---|---|---|---|---|---|---|---|---|
| $BC_5$ | BRRI60A/EL140 | CS | 109 | 112 | 138 | Slender | green | Advanced as $BC_6$ generation |
| $BC_5$ | BRRI28A/EL140 | CS | 108 | 111 | 137 | Slender | green | Advanced as $BC_6$ generation |
| $BC_5$ | BRRI60A/EL135 | CS | 94 | 97 | 124 | Medium | purple | Advanced as $BC_6$ generation |
| $BC_5$ | IR77803A/EL135 | CS | 97 | 100 | 127 | Medium bold | purple | Advanced as $BC_6$ generation |
| $BC_5$ | BRRI60A/EL110 | CS | 102 | 105 | 132 | Slender | purple | Advanced as $BC_6$ generation |
| $BC_5$ | PMS8A/EL30 | CS | 99 | 103 | 128 | Medium bold | purple | Advanced as $BC_6$ generation |
| $BC_5$ | BRRI7A/EL116 | CS | 114 | 117 | 142 | Slender | purple | Advanced as $BC_6$ gen, little awn |
| $BC_5$ | BRRI7A/EL125 | CS | 117 | 120 | 146 | Slender | purple | Advanced as $BC_6$ generation |
| $BC_5$ | BRRI7A/EL145 | CS | 111 | 114 | 140 | Slender | green | Advanced as $BC_6$ generation |
| $BC_5$ | BRRI28A/EL256 | CS | 107 | 110 | 137 | Slender | purple | Advanced as $BC_6$ generation |
| $BC_5$ | BRRI71A/EL70 | CS | 96 | 99 | 125 | Medium slender | purple | Advanced as $BC_6$ generation |
| $BC_5$ | BRRI7A/EL211 | S | 116 | 119 | 144 | Medium slender | purple | Discarded |
| $BC_5$ | BRRI7A/EL211 | CS | 118 | 121 | 147 | Medium | purple | Advanced as $BC_6$ generation |
| $BC_5$ | BRRI7A/EL207 | CS | 118 | 121 | 144 | Medium slender | green | Advanced as $BC_6$ generation |
| $BC_5$ | BRRI7A/EL196 | CS | 118 | 121 | 144 | Medium slender | green | Advanced as $BC_6$ generation |
| $BC_3$ | BRRI7A/EL50 | CS | 115 | 118 | 144 | Medium slender | purple | Advanced as $BC_6$ generation |

**Table 1. Continued.**

| BC gen | Designation | Sterility status | DFF | D50%F | DTM | Grain type | Base colour | Remark |
|---|---|---|---|---|---|---|---|---|
| $BC_5$ | BRRI7A/EL195 | CS | 118 | 121 | 148 | Medium slender | purple | Advanced as $BC_6$ generation |
| $BC_5$ | BRRI56A/EL23 | CS | 105 | 108 | 135 | Medium | purple | Advanced as $BC_6$ generation |
| $BC_5$ | BRRI32A/EL36 | CS | 107 | 110 | 138 | Medium slender | purple | Advanced as $BC_6$ generation |
| $BC_4$ | BRRI33A/EL29 | CS | 103 | 106 | 133 | Medium | purple | Advanced as $BC_5$ generation |
| $BC_4$ | BRRI7A/EL87 | CS | 111 | 114 | 141 | Medium | green | Advanced as $BC_5$ generation |
| $BC_4$ | BRRI7A/EL190 | CS | 114 | 117 | 144 | Slender | green | Advanced as $BC_5$ generation |
| $BC_4$ | BRRI36A/EL28 | CS | 99 | 102 | 129 | Slender | purple | Advanced as $BC_5$ generation |
| $BC_3$ | BRRI33A/CHH-44 | CS | 112 | 115 | 142 | Slender | purple | Advanced as $BC_4$ generation |
| $BC_3$ | BRRI33A/CDE-1 | CS | 112 | 115 | 142 | Slender | green | Advanced as $BC_4$ generation |
| $BC_2$ | BRRI30A/EL199 | CS | 112 | 115 | 142 | Slender | green | Advanced as $BC_3$ generation |
| $BC_2$ | BRRI28A/EL28 | CS | 109 | 112 | 139 | Bold | purple | Advanced as $BC_3$ generation |
| $BC_2$ | BRRI28A/EL26 | CS | 97 | 100 | 127 | Bold | purple | Advanced as $BC_3$ generation |
| $BC_2$ | BRRI13A/EL75 | CS | 116 | 119 | 146 | Medium | green | Advanced as $BC_3$ generation |
| $BC_2$ | IR75608A/EL71 | CS | 115 | 118 | 145 | Medium | purple | Advanced as $BC_3$ generation |
| $BC_1$ | IR75608A/EL197 | S | 103 | 107 | 134 | Slender | purple | Discarded |
| $BC_1$ | IR75608A/EL209 | S | 105 | 108 | 137 | Slender | purple | Discarded |

DS: $P_1$ = 2 Dec 2016; $P_2/F_1$= 5 Dec 2016 $P_3$ = 8 Dec 2016; DT: 6 Jan 2017; CS = completely sterile, S = sterile.

**CMS maintenance and evaluation nursery**

Fifty-six CMS lines were maintained by hand crossing for seed increase and genetic purity in T. Aman 2016 and in Boro 2016-17, 67 CMS lines were maintained through hand crossing for seed increase and genetic purity.

**Pedigree nursery for development of BB resistant parental lines of hybrid rice**

Six crosses were made in T. Aman season and matured $F_1$ seeds were properly collected and preserved and those would be grown in next season. Matured $BC_2F_1$ seeds were also collected and preserved. On the other hand, DNA extraction was done of each combination and molecular work is going on. In T. Aman 2016 and in Boro 2016-17 out of six testcrosses one entry (IR79156A/HRBB1) was found completely sterile against bacterial blight and immediately backcrossed for conversion and no entry was found heterotic over the check variety.

EVALUATION OF PARENTAL LINES AND HYBRIDS

In T. Aman 2016, out of 126 hybrids four hybrid combinations were selected based on yield, duration and grain type (Table 2). Around 16-44% yield advantage over check variety BR11, 9-36% over BRRI dhan49 and 3-25% over BRRI hybrid dhan4

Table 2. List of experimental hybrids found heterotic over check variety in T. Aman 2016.

| Hybrid | PHT (cm) | E/T | SF (%) | DTM | Yld (t/ha) | Grain type | Yld adv over cks | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ck-1 | Ck-2 | Ck-3 |
| BRRI13A/EL108R | 113.2 | 11 | 81.5 | 113 | 7.5 | S | 19.05 | 11.9 | 2.7 |
| BRRI32A/EL254R | 109 | 13 | 86.7 | 116 | 8.0 | S | 26.9 | 19.4 | 9.6 |
| BRRI28A/BAU521R | 106.6 | 8 | 82.3 | 108 | 7.3 | M | 15.9 | 9.0 | - |
| BRRI30A/ BR6839-41-5-1R | 113.2 | 13 | 92.5 | 120 | 9.1 | M | 44.4 | 35.8 | 24.6 |
| BR11 (ck 1) | 111.5 | 8.8 | 77.9 | 147 | 6.3 | B | - | - | - |
| BRRI dhan49 (ck 2) | 110 | 9 | 80.7 | 136 | 6.7 | MS | - | - | - |
| BRRI hybrid dhan4 (ck 3) | 102 | 10 | 89.6 | 118 | 7.3 | S | - | - | - |
| LSD (0.05) | 3.6 | 1.7 | 4.5 | 12.0 | 0.8 | | | | |
| CV% | 3.6 | 18.0 | 5.8 | 10.8 | 11.3 | | | | |

DS: 24 Jun 2016; DT: 24 Jul 2016 S= Slender, M= Medium, B = Bold, MS= Medium slender.

with two to three week shorter growth duration. Upon commercial seed production feasibility of these selected hybrid combinations and grain quality assessment it will be tested under preliminary yield trial (PYT) and multi-location yield trials (MLT). Upon satisfactory yield advantage over check variety it is subjected to registration under national hybrid rice yield trial (NHRYT) for releasing as new hybrid rice of BRRI. Out of 186 test hybrids six hybrid combinations (Table 3) were selected based on yield, duration and grain type as they showed yield advantage ranging from 5-27% over BRRI hybrid dhan3, 37-67% over BRRI dhan28 and 16-42% over BRRI dhan29 in Boro 2016-17 with growth duration similar to BRRI dhan28 but one to two weeks earlier than BRRI dhan29.

**Preliminary yield trials of promising hybrids**

In preliminary yield trials, out of sixteen, ten hybrids gave more than one ton yield advantage over BRRI dhan49 and three of them out yielded BRRI hybrid dhan4 and company hybrid Arize-4 (Table 4) by more than one ton in T. Aman 2016 and during Boro 2016-17, Twenty-five hybrids

Table 3. List of the hybrid combinations found heterotic from observational nursery in Boro 2016-17.

| Combination | Plant height (cm) | No. of effective tillers/hill | Spikelet fertility (%) | Grain type | Day to maturity | Grain yield (t/ha) | Yield advantage over check | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ck-1 | Ck-2 | Ck-3 |
| BRRI42A/IR509R | 95.6 | 13.8 | 92.6 | S | 143 | 10.6 | 20.5 | 58.2 | 34.2 |
| BRRI7A/EL255R | 103.8 | 13.0 | 92.0 | MS | 150 | 11.2 | 27.2 | 67.1 | 41.7 |
| IR75608A/CHH35R | 100.4 | 12.4 | 89.1 | S | 142 | 10.4 | 18.1 | 55.2 | 31.6 |
| BRRI32A/CHH32R | 105 | 11.6 | 87.1 | MS | 145 | 10.0 | 13.6 | 49.2 | 26.5 |
| BRRI32A/CHH56R | 102.2 | 10.0 | 90.1 | S | 142 | 9.8 | 11.3 | 46.2 | 24.0 |
| BRRI42A/EL224R | 97.3 | 10.2 | 93.8 | S | 140 | 9.2 | 4.5 | 37.3 | 16.4 |
| BRRI hybrid dhan3 | 107 | 8.8 | 90.5 | B | 148 | 8.8 | - | - | - |
| BRRI dhan28 | 105 | 11.7 | 88.5 | MS | 142 | 6.7 | - | - | - |
| BRRI dhan29 | 97 | 10.5 | 90.8 | MS | 159 | 7.9 | - | - | - |
| Mean | 101.4 | 11.3 | 90.5 | - | 146.0 | 9.4 | | | |
| LSD $_{(0.05\%)}$ | 3.5 | 1.3 | 1.8 | - | 4.9 | 1.3 | | | |
| CV (%) | 4.0 | 14.1 | 2.3 | - | 5.6 | 16.4 | | | |

DS: 10 Dec 2016; DT: 9 Jan 2017; S= Slender, M= Medium, B = Bold, MS= Medium slender.

were evaluated along with three checks and almost all the hybrids showed one ton yield advantage over BRRI dhan28 and nine hybrids showed yield advantage more than one ton over BRRI dhan29. Only two hybrid combinations had out yielded BRRI hybrid dhan3 by more than one ton (Table 5).

SEED PRODUCTION OF PARENTAL LINES AND HYBRIDS

**CMS line multiplication of released hybrids**

During T. Aman 2016, seed yield 80 kg/plot (1.7 t/ha), 95 kg/plot (1.8 t/ha) and 25 kg/plot (1.25

**Table 4. Results of preliminary yield trials in T. Aman 2016.**

| Combination | Day to maturity | Plant height (cm) | Effective tiller/m² | Spikelet fertility (%) | Grain type | Yield (t/ha) | Yield advantage over check (t/ha) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ck-1 | Ck-2 | Ck-3 |
| IR79156A/BRRI20R | 111 | 124.9 | 339 | 82 | S | 5.85 | 1.0 | | |
| IR79156A/PL-1 | 113 | 131.5 | 299 | 80 | S | 5.92 | 1.1 | | |
| IR75608A/BRRI31R | 108 | 113.9 | 332 | 82 | S | 6.65 | 1.8 | 1.0 | 1.4 |
| BRRI7A/BRRI31R | 110 | 114.6 | 249 | 86 | MS | 6.85 | 2.0 | 1.2 | 1.6 |
| BRRI33A/BRRI31R | 111 | 122.0 | 260 | 84 | MS | 6.70 | 1.9 | 1.1 | 1.5 |
| BRRI7A/EL262R | 110 | 114.9 | 304 | 80 | M | 5.67 | | | |
| BRRI7A/EL260R | 108 | 113.6 | 286 | 82 | M | 6.05 | 1.2 | | |
| BRRI7A/EL108R | 110 | 110.7 | 249 | 89 | M | 6.54 | 1.7 | | |
| BRRI28A/EL108R | 110 | 113.2 | 257 | 84 | MS | 6.03 | 1.2 | | |
| BRRI13A/EL108R | 106 | 118.1 | 262 | 82 | MS | 5.67 | | | |
| BRRI7A/EL253R | 106 | 107.5 | 244 | 85 | M | 6.20 | 1.4 | | |
| BRRI28A/EL253R | 107 | 122.4 | 257 | 78 | MS | 5.55 | | | |
| BRRI13A/EL253R | 105 | 113.6 | 246 | 79 | M | 5.25 | | | |
| BRRI7A/EL254R | 105 | 110.4 | 251 | 85 | M | 6.49 | 1.6 | | |
| BRRI28A/EL254R | 105 | 109.8 | 235 | 82 | MS | 5.73 | | | |
| BRRI13A/EL254R | 104 | 116.4 | 255 | 78 | MS | 5.2 | | | |
| BRRI dhan49 (Ck-1) | 128 | 114.8 | 290 | 80 | M | 4.85 | | | |
| BRRI hybrid dhan4 (ck-2) | 115 | 123.6 | 249 | 81 | S | 5.65 | | | |
| Arize-4 (ck-3) | 123 | 119.9 | 268 | 80 | S | 5.25 | | | |
| Mean | 110 | 117 | 270 | 82 | | 6 | | | |
| LSD (0.05) | 3.66 | 3.60 | 17.73 | 1.70 | | 0.33 | | | |
| CV (%) | 5.61 | 5.21 | 11.09 | 3.51 | | 9.58 | | | |

DS: 11 Jul 2016; DT: 31 Jul 2016; Unit plot =30 m² S= Slender, M= Medium, B = Bold, MS= Medium slender.

**Table 5. Results of preliminary yield trials in Boro 2016-17.**

| Combination | DTM | PHT (cm) | ET/m² | SF (%) | Yield (t/ha) | Yield advantage over Ck (t/ha) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Ck-1 | Ck-2 | Ck-3 |
| IR79156A/BRRI20R | 151 | 107.4 | 299.2 | 83 | 10.58 | 4.5 | 1.97 | 1.11 |
| IR75608A/BRRI31R | 146 | 99.6 | 264.0 | 91 | 9.51 | 3.4 | 0.9 | 0.04 |
| BRRI7A/BRRI31R | 149 | 103.2 | 270.6 | 80 | 9.67 | 3.6 | 1.06 | 0.20 |
| BRRI33A/BRRI31R | 151 | 108.0 | 271.7 | 82 | 9.70 | 3.6 | 1.09 | 0.23 |
| BRRI7A/EL108R | 146 | 87.8 | 290.4 | 86 | 9.68 | 3.6 | 1.07 | 0.21 |
| BRRI13A/EL108R | 144 | 104.9 | 267.9 | 84 | 10.53 | 4.4 | 1.92 | 1.06 |

**Table 5. Continued.**

| Combination | DTM | PHT (cm) | ET/m² | SF (%) | Yield (t/ha) | Yield advantage over Ck (t/ha) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Ck-1 | Ck-2 | Ck-3 |
| BRRI28A/EL108R | 145 | 105.7 | 262.9 | 86 | 9.84 | 3.7 | 1.23 | 0.37 |
| BRRI32A/EL108R | 146 | 101.7 | 283.8 | 88 | 9.62 | 3.5 | 1.01 | 0.15 |
| BRRI33A/EL108R | 146 | 97.4 | 262.4 | 79 | 9.59 | 3.5 | 0.98 | 0.12 |
| BRRI35A/EL108R | 150 | 102.6 | 239.8 | 85 | 10.18 | 4.1 | 1.57 | 0.71 |
| BRRI48A/EL108R | 147 | 102.0 | 286.6 | 81 | 9.08 | 2.9 | 0.47 | - |
| BRRI7A/EL253R | 145 | 96.7 | 250.8 | 80 | 8.56 | 2.5 | - | - |
| BRRI13A/EL253R | 151 | 107.0 | 290.4 | 91 | 9.13 | 3.02 | 0.52 | - |
| BRRI28A/EL253R | 147 | 94.9 | 275.0 | 84 | 8.14 | 2.03 | - | - |
| BRRI32A/EL253R | 145 | 98.1 | 321.2 | 87 | 8.44 | 2.33 | - | - |
| BRRI33A/EL253R | 147 | 105.3 | 259.6 | 89 | 8.67 | 2.56 | 0.06 | - |
| BRRI35A/EL253R | 153 | 103.8 | 272.8 | 89 | 10.28 | 4.17 | 1.67 | 0.81 |
| BRRI48A/EL253R | 152 | 103.8 | 259.6 | 78 | 9.56 | 3.45 | 0.95 | - |
| BRRI7A/EL254R | 147 | 99.8 | 257.4 | 76 | 8.47 | 2.36 | - | - |
| BRRI13A/EL254R | 147 | 108.3 | 241.5 | 77 | 6.73 | 0.6 | - | - |
| BRRI28A/EL254R | 145 | 103.5 | 286.0 | 78 | 8.26 | 2.15 | - | - |
| BRRI32A/EL254R | 144 | 97.2 | 242.0 | 64 | 5.70 | - | - | - |
| BRRI33A/EL254R | 144 | 88.3 | 246.7 | 78 | 4.83 | - | - | - |
| BRRI35A/EL254R | 147 | 108.9 | 255.2 | 82 | 9.98 | 3.87 | 1.37 | 0.51 |
| BRRI48A/EL254R | 146 | 103.7 | 256.9 | 78 | 8.74 | 2.63 | 0.13 | - |
| BRRI dhan28 (ck-1) | 140 | 110.8 | 240.0 | 79 | 6.11 | | | |
| BRRIdhan29 (ck-2) | 155 | 104.4 | 325.6 | 90 | 8.61 | | | |
| BRRI hybrid dhan3(ck-3) | 149 | 108.0 | 326.2 | 80 | 9.47 | | | |
| Mean | 147 | 102 | 272 | 79 | 8.85 | | | |
| LSD (0.05) | 1.58 | 2.78 | 12.04 | 4.14 | 0.84 | | | |
| CV (%) | 2.12 | 5.65 | 10.16 | 3.05 | 8.85 | | | |

DS: 5 Dec 2016, DT: 5 Jan 2017; DTM=Days to maturity, PHT=Plant height, ET/m²=Effective tillers meter$^{-2}$, SF (%)=Spikelet fertility

t/ha) were obtained from BRRI10A, BRRI11A and IR58025A, respectively (Table 6). In Boro 2016-17, seed yield of 220 kg (2.2 t/ha), 120 kg (2.20 t/ha) and 90 kg (1.82 t/ha) were obtained from BRRI10A/B, BRRI11A/B and IR58025A/B respectively (Table 7).

**Table 6. CMS multiplication of BRRI10A, BRRI11A and IR58025A lines in T. Aman 2016.**

| Combination | Plant height (cm) | | 50% flowering (day) | | PER (%) | OCR (%) | Yield | |
|---|---|---|---|---|---|---|---|---|
| | A line | B line | A line | B line | A line | A line | (kg/plot) | (t/ha) |
| BRRI10A/B | 81 | 86 | 71 | 70 | 70 | 35 | 80 | 1.7 |
| BRRI11A/B | 82 | 83 | 73 | 71 | 73 | 36 | 95 | 1.8 |
| IR58025A/B | 85 | 90 | 77 | 77 | 69 | 32 | 25 | 1.25 |

DS: $B_1$= 6 Jul 2016 A/$B_2$= 9 Jul 2016; $B_3$=12 Jul 2016; DT: A/B = 29 Jul 2016. DS: $B_1$= 8 Jul 2016, A/$B_2$=11 Jul 2016, $B_3$=14 Jul 2016; DT: A/B=31 Jul 2016. DS: $B_1$= 5 Jul 2016 A/$B_2$= 8 Jul 2016; $B_3$=11 Jul 2016; DT: A/B = 30 Jul 2016. PER=Panicle exertion rate, OCR= Out crossing rate.

**Table 7. CMS multiplication of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan4 in Boro 2016-17.**

| Combination | Plant height (cm) | | 50% flowering (day) | | PER (%) (kg/ plot) | OCR (%) (kg /ha) | Yield | | Location |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | (kg/ plot) | (kg/ ha) | |
| | A line | B line | A line | B line | A line | A line | A line | | |
| BRRI10 A/B | 83 | 84 | 122 | 123 | 85 | 44 | 220 | 2200 | |
| BRRI11A/B | 85 | 86 | 125 | 126 | 84 | 46 | 120 | 2200 | Gazipur |
| IR58025A/B | 87 | 89 | 122 | 121 | 80 | 39 | 90 | 1820 | |

DS: $B_1$= 29 Nov 2016, A/$B_2$ = 2 Dec 2016, $B_3$= 05 Dec 2016; DT: A/B=31 Dec 2016. DS: $B_1$= 1 Dec 2016, A/$B_2$ = 4 Dec 2016, $B_3$=7 Dec 2016; DT: A/B=4 Jan 2017. DS: $B_1$= 3 Dec 2016, A/$B_2$ = 6 Dec 2016, $B_3$=9 Dec 2016; DT: A/B=5 Jan 2017. PER=Panicle Exertion Rate, OCR= Out Crossing Rate.

## $F_1$ hybrid seed production of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan4 in T. Aman 2016 and Boro 2016-17

During T. Aman 2016, seed yield were obtained 100 kg (1600 kg/ha) from BRRI10A/BRRI10R, 110 kg (1650 kg/ha) from BRRI11A/BRRI15R and 20 kg (1200 kg/ha) from IR58025A/BRRI10R (Table 8).

In Boro 2016-17, seed yield obtained 120 kg (2.6 t/ha), 200 kg (2.5 t/ha) and 400 kg (1.65 t/ha) respectively from BRRI10A/BRRI10R, BRRI11A/BRRI15R and IR58025A/BRRI10R respectively (Table 9).

**Table 8. $F_1$ seed production of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan4 in T. Aman 2016.**

| Combination | PHT (cm) | | Days to 50% flowering | | PER (%) | OCR (%) | Yield/ plot (kg) | Yield (kg/ ha) |
|---|---|---|---|---|---|---|---|---|
| | A line | R line | A line | R line | A line | A line | | |
| BRRI hybrid dhan2 (BRRI10A/ BRRI10R) | 76 | 101 | 87 | 85 | 74 | 43 | 100 | 1600 |
| BRRI hybrid dhan3 (BRRI11A/ BRRI15R) | 82 | 88 | 76 | 73 | 73 | 36 | 110 | 1650 |
| BRRI hybrid dhan4 (IR58025A/ BRRI10R) | 77 | 108 | 128 | 131 | 75 | 38 | 20 | 1200 |

DS: $R_1$=8 Jul 2016, A=11 July 2016, $R_2$=14 Jul 2016, DT R/A=1 Aug 2016, DS: $R_1$=8 Jul 2016, A=12 Jul 2016, $R_2$=16 Jul 2016, DT R/A= 3 Aug 2016, PER=Panicle exertion rate, OCR= Out crossing rate.

**Table 9. $F_1$ seed production of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan4 in Boro 2016-17.**

| Combination | Plant height (cm) | | 50% flowering (day) | | PER (%) (kg /plot) | OCR (%) (kg /ha) | Yield | | Location |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | (kg/ plot) | (kg/ ha) | |
| | A line | R line | A line | R line | A line | A line | $F_1$ Seed | | |
| BRRI10A/ BRRI10R | 82 | 89 | 120 | 122 | 86 | 49 | 120 | 2600 | BRRI Gazipur |
| BRRI11 A /BRRI15R | 84 | 91 | 122 | 123 | 88 | 50 | 200 | 2500 | BRRI Gazipur |
| IR58025 A /BRRI10R | 86 | 90 | 121 | 122 | 88 | 42 | 400 | 1.650 | BRRI Gazipur |

DS: $R_1$=27 Nov 2016, A= 30 Nov 2016, $R_2$=3 Dec 2016, DT: A/R=30 Dec 2016. DS: $R_1$=3 Dec 2016, A= 7 Dec 2016, $R_2$=11Dec 2016 DT: A/R=6 Jan 2017. DS: $R_1$=01 Dec 2016, A= 4 Dec 2016, $R_2$=7 Dec 2016, DT: A/R=3 Jan 2017. PER=Panicle exertion rate, OCR= Out crossing rate.

**Seed production of promising CMS lines and hybrids**

Seed yield 30 kg/plot (1.0 t/ha), 12 kg/plot (1.2 t/ha), 5 kg/plot (0.5 t/ha), 7 kg/plot (0.7 t/ha), 12 kg/plot (1.2 t/ha), 3.0 kg/plot (0.3 t/ha) and 80 kg/plot (2.0 t/ha) were obtained from BRRI13A, BRRI21A, BRRI28A, BRRI32A, BRRI33A, BRRI42A and BRRI48A/B, respectively during T. Aman 2016 (Table 10). From 12 promising hybrid combinations seed yield were obtained ranging from 2.3 to 7 kg /plot equivalent to 0.46 to 1.4 t/ha (Table 11).

**Table 10. Seed amount obtained from selected promising CMS lines in T. Aman 2016.**

| Designation | Plant height (cm) | | D50% flowering | | PER (%) | OCR (%) | Plot area ($m^2$) | Yield (kg/ plot) | Seed yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|
| | A line | B line | A line | B line | | | | | |
| BRRI13A/B | 102 | 102.5 | 107 | 105 | 72.3 | 52.2 | 300 | 30 | 1.0 |
| BRRI21A/B | 107 | 107.3 | 121 | 118 | 68.3 | 48.3 | 100 | 12 | 1.2 |
| BRRI28A/B | 104 | 104.2 | 116 | 113 | 68.1 | 45.5 | 100 | 5.0 | 0.5 |
| BRRI32A/B | 93.5 | 94 | 111 | 109 | 71.3 | 51 | 100 | 7.0 | 0.7 |
| BRRI33A/B | 87 | 87.7 | 110 | 107 | 69.3 | 48.3 | 100 | 12 | 1.2 |
| BRRI42A/B | 96 | 96.2 | 118 | 116 | 66 | 44.6 | 100 | 3.0 | 0.3 |
| BRRI48A/B | 99.3 | 99.8 | 118 | 115 | 73.5 | 52.6 | 400 | 80 | 2.0 |
| Average | 98.4 | 98.81 | 114.43 | 111.86 | 69.83 | 48.93 | 171.43 | 21.29 | 0.99 |
| $Lsd_{(0.05)}$ | 6.65 | 6.53 | 5.00 | 4.79 | 2.58 | 3.08 | 122.24 | 26.70 | 0.55 |
| CV (%) | 6.93 | 6.78 | 4.48 | 4.39 | 3.79 | 6.45 | 73.12 | 128.65 | 57.22 |

DS: $B_1$= 6 Jul 2016; $B_2$/A = 9 Jul 2016; $B_3$=12 Jul 2016; DT: 1 Aug 2016; PER (%) = Panicle exertion rate, OCR (%) = Out crossing rate.

**Table 11. Seed amount obtained from promising hybrid rice combinations in T. Aman 2016.**

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

DS: $R_1$= 7 Jul 2016, $R_2$=10 Jul 2016, $R_3$= 13 Jul 2016, A=10 Jul 2016 ; DT : R/A= 3 Aug 2016.

During Boro 2016-17, seed yield 30 kg/plot (1.0 t/ha), 12 kg/plot (1.2 t/ha), 5 kg/plot (1.0 t/ha), 6 kg/plot (1.0 t/ha), 12 kg/plot (1.2 t/ha), 0.2 kg/plot (0.6 t/ha), 80 kg/plot (2.0 t/ha) and 4 kg/plot (0.8 t/ha) were obtained from promising CMS lines BRRI7A, BRRI13A, BRRI21A, BRRI30A, BRRI32A, BRRI35A, IR75608A and IR79156A respectively (Table 12). Seed yield were obtained 210 kg (2.1 t/ha), 230 kg (2.3 t/ha), 30 kg (1.5 t/ha) respectively from BRRI7A/BRRI31R, IR79156A/BRRI20R and IR79156A/PL-1R respectively in Boro 2016-17 (Table 13).

**Table 12. Seed amount obtained from selected promising CMS lines in Boro 2016-17.**

| Designation | Plant height (cm) | | D50% flowering | | PER (%) | OCR (%) | Plot area ($m^2$) | Yield (kg/ plot) | Seed yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|
| | A line | B line | A line | B line | | | | | |
| BRRI7A/B | 100 | 101.3 | 117 | 115 | 70.0 | 51.3 | 300 | 30.0 | 1.0 |
| BRRI13A/B | 105 | 105.3 | 121 | 118 | 72.3 | 53.2 | 100 | 12.0 | 1.2 |
| BRRI21A/B | 103 | 104 | 116 | 113 | 68.5 | 46.3 | 50 | 5.0 | 1.0 |
| BRRI30A/B | 89.6 | 91.4 | 125 | 122 | 70.2 | 50.2 | 60 | 6.0 | 1.0 |
| BRRI32A/B | 86.0 | 86.5 | 113 | 112 | 76.0 | 50.5 | 100 | 12.0 | 1.2 |
| BRRI35A/B | 93.0 | 94.2 | 118 | 116 | 66.7 | 44.3 | 30 | 0.2 | 0.6 |
| IR75608A/B | 89.0 | 90.3 | 127 | 124 | 71.6 | 51.2 | 50 | 4.0 | 0.8 |
| IR79156A/B | 81.0 | 81.0 | 120 | 117 | 67.4 | 45.4 | 400 | 80.0 | 2.0 |
| Average | 93.3 | 94.3 | 119.6 | 117.1 | 70.3 | 49.1 | 136.3 | 18.7 | 1.1 |
| Lsd $_{(0.05)}$ | 7.8 | 7.9 | 4.2 | 3.8 | 2.7 | 3.0 | | 24.1 | 0.4 |
| CV (%) | 9.2 | 9.2 | 3.9 | 3.5 | 4.3 | 6.6 | | 141.6 | 37.6 |

DS: $B_1$= 3 Dec 2016; $B_2$/A = 6 Dec 2016; $B_3$= 9 Dec 2016; DT: 7 Jan 2017; PER (%) = Panicle exertion rate, OCR (%) = Out crossing rate.

**Table 13. Seed amount obtained from promising hybrid rice combinations in Boro 2016-17.**

| Designation | PHT (cm) | | D50%F | | PER (%) | OCR (%) | Plot area ($m^2$) | Yield (kg/plot) | Seed yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|
| | A line | R line | A line | R line | | | | | |
| BRRI7A/BRRI31R | 95.5 | 101.3 | 128 | 128 | 73.3 | 45.2 | 1000 | 210 kg | 2.1 |
| IR79156A/ BRRI20R | 96.4 | 102.0 | 127 | 129 | 74.2 | 47.2 | 1000 | 230 kg | 2.3 |
| IR79156A/PL-1R | 98.4 | 106.5 | 126 | 129 | 68.0 | 46.0 | 200 | 30 kg | 1.5 |

DS: $R_1$= 7 Dec 2016, $R_2$=14 Dec 2016, $R_3$= 24 Dec 2016, A=10 Dec 2016; DT : R/A=17 Jan, 17/20 Jan 2017; DS: $R_1$= 7 Dec 2016, A=10 Dec 2016, $R_2$=13 Dec 2016; DT: A/R=15 Jan 2017. DS: $R_1$= 7 Dec 2016, A=10 Dec 2016, $R_2$=13 Dec 2016; DT: A/R=13 Jan 2017. PER (%) = panicle exertion rate, OCR (%) = Out crossing rate.

**Dissemination of hybrid rice technology**

In the reporting year, Hybrid Rice Division supplied 3,395.0 kg of parental lines and $F_1$ seeds to 12 seed companies along with farmers, BRRI staffs, BRRI RSs and different projects (Table 14). A total of 81,350 kg $F_1$ seed was produced in Boro 2016-17 with the technical assistance from BRRI under thirteen seed companies and regional station of BRRI (Table 15).

**Table 14. Amount of parental line and hybrid seeds supplied to different organization.**

| Recipient | Nos. | $F_1$ (kg) | A line (kg) | B line (kg) | R line (kg) |
|---|---|---|---|---|---|
| Seed companies | 13 | 300.0 | 750.00 | - | 250.00 |
| Farmers | 40 | 600.0 | 70.00 | - | 25.00 |
| BRRI scientists + staffs | 12 | 150.00 | - | - | - |
| BRRI, R/S (2) + PGB+ CSISA | 5 | 1250 | - | - | - |
| Total | 70 | 2300.00 | 820.00 | 0.00 | 275.00 |
| Grand total | | | 3395.00 | | |

**Table 15. Seed production activities of BRRI developed hybrids in Boro seasons of 2016-17 both at private and public sectors.**

| Name of the organization/person | Location | Variety | Area (acre) | Seed yield (ton) | Remark |
|---|---|---|---|---|---|
| Radical Enterprise | Sherpur | BHD3 | 3.0 | 3 | Experienced |
| Rangpur BRRI RS | Rangpur | BHD3 | 0.33 | 0.3 | Experienced |
| Modina Seed Company, Mymensingh | Tangail | BHD3 | 3.0 | 3.5 | Experienced |
| | | BHD2 | 5.0 | 6.0 | |
| | | BHD4 | 4.0 | 3.5 | |
| Bhai Bhai Traders, | Lalmonirhat | BHD3 | 1.0 | 1.0 | Experimental |
| M/S Hoque Enterprise | Gaibandha | BHD2 | 10 | 10 | Experienced |
| Nayan Seed | Shibganj, Bogra | BHD2 | 15 | 18 | Experienced |
| | | BHD3 | 12 | 15 | |
| | | BHD4 | 2 | 1.5 | |
| SR Seeds | Rangpur | BHD3 | 3 | 3 | Experienced |
| Sumaiya Seed | Kurigram | BHD3 | 2 | 1.8 | Experimental |
| MS Hasina and Sons | Chuadanga | BHD2 | 4 | 4 | Experienced |
| Aftab Bhumukhi Farms Ltd | Kishoreganj | BHD3 | 1 | 1 | Experienced |
| Janani Biz Vander | Rangpur | BHD3 | 0.33 | 0.3 | Experimental |
| Jalal Akand, Contract grower Hybrid Rice Division, BRRI | Barisal | BHD2 | 2 | 1.5 | Experienced |
| | | BHD3 | 2 | 1.8 | |
| | | BHD4 | 2 | 1.25 | |
| | | BHD5 | 1 | 0.8 | |
| Barisal BRRI RS | Barisal | BHD3 | 1 | 1 | Experienced |
| Asha Agro | Nilphamari | BHD3 | 0.33 | 0.3 | Experimental |
| Sonali Biz Vander | Meherpur | BHD3 | 0.33 | 0.3 | Experimental |
| Modina Green Tech | Tangail | BHD3 | 1 | 1.2 | Experienced |
| | | BHD4 | 1 | 0.8 | |
| Bhanga RS BRRI | Bhanga | BHD4 | 0.33 | 0.2 | Experimental |
| Molseuddin SAAO | Comilla | BHD3 | 0.33 | 0.3 | Experimental |
| Total= | | | 76.98 | 81.35 | |

Legend: BHD2 = BRRI hybrid dhan2, BHD3 = BRRI hybrid dhan3, BHD4 = BRRI hybrid dhan4.

# Agronomy Division

SUMMARY

Salicylic acid @ 250 µM produced good quality seedling under cold prone area in respect to shoot length, number of seedling per unit area and seedling strength when sprayed at 15 and 30 DAS, respectively. In DS Aus, BI dhan5 gave more than 1.90 t $ha^{-1}$ grain yield at late seeding situation (4 May) than the check variety BRRI dhan42 with five days earlier. In T. Aman, BR(Bio)9786-BC2-119-1-1 and BR(Bio)9786-BC2-132-1-3 gave about 1.00 and 0.57 t $ha^{-1}$ higher yield respectively over check variety BRRI dhan49 in 30 August planting with similar growth duration. In Boro, PQR line, BR7372-18-2-1-HR1-HR6(Com) gave about 1.50 and 1.0 t $ha^{-1}$ more yield than BRRI dham50 than BRRI dhan63 in 19 January and 3 February planting. CTR entry, BR7812-19-1-6-1-P2 produced higher grain yield over check variety, BRRI dhan36 in 6 February planting but statistically similar. Short duration entry, BR(Bio)9787-BC2-173-1-3 gave about 5.30 t $ha^{-1}$ yield at late planting situation (22 February). Copper and Boron had positive effect on increasing spikelet fertility of CN6 in T. Aman season but Boron and Magnesium had positive effects in Boro season. BRRI recommended dose (N-P-K-S-Zn = 117-19-58-15-3.5 kg $ha^{-1}$) with 20 × 15 cm spacing gave higher grain yield (> 6.20 t $ha^{-1}$) of BRRI dhan69, which is statistically similar with 75% of BRRI Rec. dose + 2.5 t $ha^{-1}$ decomposed PL with 25 × 15 cm spacing. At 16 August planting, Monibandobi produced about 5.30 t $ha^{-1}$ grain yield with fertilizer combination of $N_{56}$ $P_7$ $K_{38}$ kg $ha^{-1.}$ With the use of recommended rate of herbicide, all bacterial and fungal population reduced of 3DAHA (day after herbicide application) and the population increased at 7-20 DAHA. *Cyperus difformis* and *Scirpus maritimus* were effectively controlled by Pretilachlor + Pyrazosulfuran ethyl + 1 HW, whereas Bispyribac sodium +1HW effectively controlled *Cyperus difformis*, *Scirpus maritimus* and *Echinochloa crus-galli* in wet direct seeded Aus rice. Pretilachlor + Trisulfuron, Bensulfuran methyl + Bispyribac sodium and 2,4-D Amine effectively controlled most of the sedges and grasses in direct seeded rice in Aman season. Basal application of N (19 kg $ha^{-1}$) is effective for early recovery and faster tillering of inbred Boro rice and about 10% spikelet fertility could be increased with scheduling of N and K in CN6. Farmers got about 3.00 t $ha^{-1}$ yield advantage of BRRI dhan66 over local variety Shishumoti in Rabi-Jute-T. Aman copping patter of Gopalganj district.

SEEDS AND SEEDLINGS

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

The study was carried out at BRRI RS, Rangpur during Boro 2016-17. The experiment was laid out in RCB design and replicated thrice. The conventional seed bed was prepared using 80 g seed per $m^{-2}$. BRRI dhan29 was used as planting material. Seeds were sown in seed bed on 30 November. The treatments (SA) were: $T_1$= 250 µM, $T_2$= 500 µM, $T_3$= 750µM, $T_4$= No SA (control). SA sprayed at 15 and 30 days after seeding (DAS). Sampling was done at 40 DAS from 10 × 10 $cm^2$ area per treatment. Seedling strength was calculated as: Shoot dry weight (mg)/Shoot length (cm). SA @ 250 µM produced good quality seedlings under cold prone area in respect to shoot length, number of seedling per unit area and seedling strength when sprayed at 15 and 30 DAS, respectively (Table 1).

**Table 1. Effect of salicylic acid on rice seedling quality in Boro 2016-17, BRRI, RS, Rangpur.**

| Treatment | Shoot length (cm) | No. of seedlings/100 $cm^2$ | Seedling strength (mg $cm^{-1}$) |
|---|---|---|---|
| $T_1$ | 15.9 | 193 | 3.05 |
| $T_2$ | 15.3 | 148 | 2.17 |
| $T_3$ | 15.2 | 131 | 1.88 |
| $T_4$ | 14.7 | 119 | 1.82 |
| CV (%) | 2.04 | 5.17 | 12.19 |
| $Lsd_{0.05}$ | 0.62 | 18.4 | 0.53 |

$T_1$= 250 µM, $T_2$= 500 µM, $T_3$= 750µM, $T_4$= No SA.

PLANTING PRACTICES

### Effect of seeding time on yield of advanced lines in Aus season

The trial was conducted at BRRI HQ farm, Gazipur in Aus, 2016 with advanced lines: BI dhan5, BRH11-9-14-6-7B, IR92240-40-2-2-1 and BR7178-2B-19 including check BRRI dhan42. Dry seeds were directly sown in line to the well prepared main field from 18 April to 4 May with eight days intervals. The treatments were distributed in a split-plot design, where placing seeding date in the main plots and lines/varieties in the sub-plots with three replications. All genotypes produced higher yield on 18 April seeding and then gradually decreased with advancement of seeding time. Advanced line, BI dhan5 gave statistically similar grain yield with check variety, BRRI dhan42 up to 26 April seeding but it gave more than 1.90 t $ha^{-1}$ grain yield at late seeding situation (4 May) than check variety with five days earlier (Table 2).

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

Five field trials were conducted at BRRI farm, Gazipur in T. Aman 2016 to find out suitable planting time for higher yield. MER lines- 1. BR7528-2R-HR16-12-3-P1, 2. BR7528-2R-HR16-12-23-P1, 3. IR84750-213-2-2-3-1, 4. BR7895-4-3-3-2-3, 5. BR8445-54-6-6 including check BRRI dhan72, BRRI dhan39 and BRRI dhan49. RLR lines- RLR-1 (IR70213-10-CPA4-2-2-2, BR8214-19-3-4-1 and BR8214-23-1-3-1 including check BRRI dhan39), RLR-2 (BR8210-10-3-1-2 1 and check BRRI dhan49 and Lal Swarna), RLR-3 (Sumon Swarna, Ranjit Swarna, Nepali Swarna, Swarna5 and Guti Swarna including check BR11 and BRRI dhan49). Advanced lines BR(Bio)9786-BC2-119-1-1 and BR(Bio)9786-BC2-132-1-3 including check BRRI dhan49. Twenty five-day-old seedling was transplanted with 20 × 20 cm spacing. The trial was conducted in spilt-plot design, where planting date was in main plots and the advanced lines were in sub-plots. MER line, BR7528-2R-HR16-12-3-P1, BR7895-4-3-3-2-3 and BR7528-2R-HR16-12-23-P1 gave statistically similar grain yield with check BRRI dhan72 up to 14 August planting with 4-6 days earlier. IR84750-213-2-2-3-1 gave similar yield with check BRRI dhan72 up to 29 August transplanting. All RLR-1 tested entries gave significantly the highest yield than check BRRI dhan39 at all planting dates but about 10 days later than the check variety (Table 3). BR8210-10-3-1-2 (RLR-2) gave lower yield than check varieties, BRRI dhan49 and Lal Swarna at all plantings. All Swarna cultivars (RLR-3) gave statistically similar grain yield with check variety BRRI dhan49 with similar growth duration (Table 4). The advanced lines, BR(Bio)9786-BC2-119-1-1 and BR(Bio)9786-BC2-132-1-3 produced significantly higher grain yield than the check variety BRRI dhan49 at all planting dates. Also, these lines gave about 1.00 and 0.57 t $ha^{-1}$ higher yield, respectively over check variety up to 30 August planting with similar growth duration (Table 5).

**Table 2. Effect of seeding date on yield and growth duration (in parenthesis) of advanced lines in Aus 2016, BRRI, Gazipur.**

| Advanced line/variety | Grain yield (t $ha^{-1}$) | | |
|---|---|---|---|
| | 18 April | 26 April | 4 May |
| BI dhan5 | 3.65 (95) | 3.47 (96) | 3.34 (94) |
| BRH11-9-14-6-7B | 2.76 (97) | 2.65 (95) | 2.58 (96) |
| IR92240-40-2-2-1 | 2.94 (95) | 2.70 (96) | 2.60 (96) |
| BR7178-2B-19 | 3.20 (98) | 3.15 (98) | 3.10 (96) |
| BRRI dhan42 (ck) | 3.83 (100) | 3.73 (101) | 1.40 (100) |
| CV (%) | | 2.06 | |
| $Lsd_{0.05}$ | | 0.58 | |

**Table 3. Effect of planting time on yield and growth duration (in the parenthesis) of advanced lines (RLR-1) in T. Aman, 2016, BRRI, Gazipur.**

| Advanced line | Grain yield (t ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | 17 Jul | 1 Aug | 16 Aug | 31 Aug | 16 Sep |
| IR70213-10-CPA4-2-2-2 | 5.70(130) | 4.72(120) | 4.93(125) | 4.80(115) | 4.00(130) |
| BR8214-19-3-4-1 | 4.90(128) | 5.92(122) | 4.18(127) | 4.06(113) | 3.85(128) |
| BR8214-23-1-3-1 | 6.00(132) | 5.98(120) | 4.83(124) | 4.09(115) | 4.45(131) |
| BRRI dhan39 (ck) | 4.82(121) | 4.21(123) | 4.22(127) | 4.00(129) | 3.80(131) |
| CV(%) | | | 3.18 | | |
| $Lsd_{0.05}$ | | | 0.25 | | |

**Table 4. Effect of planting time on yield and growth duration (in the parenthesis) of advanced lines (RLR-3) in T. Aman, 2016, BRRI, Gazipur.**

| Advanced line | Grain yield (t ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | 17 Jul | 1 Aug | 16 Aug | 31 Aug | 16 Sep |
| Sumon Swarna (Rajshahi) | 5.41(138) | 5.37(136) | 5.05(134) | 4.70(133) | 3.00(139) |
| Ranjit Swarna (Rajshahi) | 5.34(136) | 5.21(134) | 5.16(131) | 4.97(130) | 3.10(138) |
| Nepali Swarna (Rangpur) | 5.54(136) | 5.64(136) | 5.52(131) | 5.38(130) | 3.55(138) |
| Swarna5 | 5.81(137) | 5.83(134) | 4.90(131) | 4.79(130) | 3.65(133) |
| Guti Swarna | 5.71(135) | 5.47(136) | 5.01(131) | 4.77(130) | 3.61(137) |
| BR11 (ck) | 6.23(147) | 6.11(144) | 6.08(147) | 5.72(146) | 3.81(149) |
| BRRI dhan49 (ck) | 5.96(136) | 5.84(136) | 5.29(134) | 5.08(136) | 3.75(138) |
| CV(%) | | | 4.94 | | |
| $Lsd_{0.05}$ | | | 0.62 | | |

**Table 5. Effect of planting time on yield and growth duration (in the parenthesis) of Biotec. advanced lines in Aman, 2016, BRRI, Gazipur.**

| Advanced line | Grain yield (t ha$^{-1}$) | | | |
|---|---|---|---|---|
| | 1 Aug | 16 Aug | 31 Aug | 16 Sep |
| BR(Bio)9786-BC2-119-1-1 | 6.63 (134) | 6.40 (131) | 6.00 (130) | 3.77 (140) |
| BR(Bio)9786-BC2-132-1-3 | 6.02 (133) | 6.00 (134) | 5.75 (132) | 3.66 (141) |
| BRRI dhan49 (ck) | 5.45 (136) | 5.44 (135) | 5.08 (130) | 3.75 (146) |
| CV (%) | | 2.86 | | |
| $Lsd_{0.05}$ | | 0.26 | | |

## Effect of planting time on yield of advanced lines in Boro season

Six trials were conducted at BRRI farm, Gazipur in Boro 2016-17. The long duration (ALART-2) promising lines were: BR(Bio)9786-BC2-122-1-3, BR(Bio)9786-BC2-49-1-2,BR(Bio)9786-BC2-59-1-2, BR(Bio)9786-BC2-124-1-1 including the check, BRRI dhan29 and favourable Boro (FBR) lines were: BR8338-34-3-4, BR8340-16-2-1 and including the check BRRI dhan58; PQR lines were: BR8076-1-2-2-3, BR7372-18-2-1-HR1-HR6(Com) and including the check BRRI dhan50 and BRRI dhan63. Short duration (ALART-1) lines were- BR(Bio)9787-BC2-63-2-2, BR(Bio)9787-BC2-63-2-4, BR(Bio)9787-BC2-173-1-3 including the check BRRI dhan28; MER lines were- BR7831-59-1-1-4-5-1-9-P1, BR7831-59-1-1-4-9-1-2-P3 including the check BRRI dhan62 and BRRI dhan28; Cold tolerant (CTR) line was- BR7812-19-1-6-1-P2 including the check BRRI dhan28 and BRRI dhan36. Thirty-five-day-old seedlings were transplanted at 20 × 20 cm spacing using single seedling per hill. The treatments were distributed in a split-plot design where placing planting date in the main plot and varieties in the sub-plot with three replications. Fertilizers were applied @ 124-20-82-27-3.5 kg $ha^{-1}$ N-P-K-S-Zn, respectively. Nitrogen was applied equal splits at 20, 35 and 50 DAT (days after transplanting). Long duration entry BR(Bio)9786-BC2-122-1-3 produced about 6.50 t $ha^{-1}$ yield from 19 January to 3 February planting. PQR line, BR7372-18-2-1-HR1-HR6(Com) gave about 1.50 and 1.0 t $ha^{-1}$ more yield than BRRI dhan50 than BRRI dhan63 on 19 January and 3 February planting (Table 6). None of the promising lines from FBR gave higher yield than the check variety BRRI dhan58 and MER than the check variety BRRI dhan62 CTR entry, BR7812-19-1-6-1-P2 produced higher grain yield over the check variety BRRI dhan36 up to 6 February planting which was statistically similar (Table 7). Short duration entry BR(Bio)9787-BC2-173-1-3 produced higher grain yield than the check variety at all planting dates with similar growth duration. This line also gave about 5.30 t $ha^{-1}$ yield at late planting situation (22 February) (Table 8).

## FERTILIZER MANAGEMENT

**Role of micronutrients supplementation on increasing spikelet fertility of advanced line CN6**

The experiment was conducted in T. Aman 2016 and Boro 2016-17 at BRRI, Gazipur to find out appropriate micronutrient (s) that effective for increasing spikelet fertility. CN6 was tested under five different treatments ($T_1 = T_5$ + MgO (@ 0.05%), $T_2 = T_5$ + 80% S (@ 0.006%) + $ZnSO_4$ (@ 0.025%), $T_3 = T_5$ + Boron (@ 5 ppm), $T_4 = T_5$ + Copper (@ 5 ppm) and $T_5$ = BRRI recommended fertilizer dose. In Boro, 2016-17, treatment $T_2$ was replaced with $T_5$+ 60 g Mop + 60 g elemental S (80% wp) + 20 g $ZnSO_4$. In T. Aman, BRRI recommended fertilizer

**Table 6. Effect of planting date on grain yield and growth duration (in parenthesis) of PQR lines in Boro, 2016-17, BRRI, Gazipur.**

| Advanced line | Grain yield (t $ha^{-1}$) | | | |
|---|---|---|---|---|
| | *4 Jan | 19 Jan | 3 Feb | 16 Feb |
| **BR8076-1-2-2-3 | 3.75 (148) | 5.40 (147) | 4.75 (143) | 3.11 (133) |
| **BR7372-18-2-1-HR1- HR6(Com) | 4.97 (148) | 6.15 (147) | 6.18 (143) | 3.38 (133) |
| BRRI dhan50 (ck) | 4.46 (147) | 4.67 (148) | 4.94 (144) | 3.42 (134) |
| BRRI dhan63 (ck) | 4.70 (147) | 5.09 (146) | 5.24 (143) | 3.81 (132) |
| CV (%) | 11.8 | | | |
| $Lsd_{0.05}$ | 1.039 | | | |

*Early harvesting (70% maturity) because of lodging caused by heavy rainfall, **Irregular flowering.

**Table 7. Effect of planting time on yield and growth duration of advanced lines (CTR) in Boro, 2016-17, BRRI, Gazipur.**

| Advanced lines | Grain yield (t $ha^{-1}$) | | | |
|---|---|---|---|---|
| | 06 Jan | 22 Jan | 6 Feb | 22 Feb |
| *BR7812-19-1-6-1-P2 | 6.11 (148) | 5.40 (145) | 5.27 (142) | 3.99 (139) |
| BRRI dhan28 (ck.) | 5.74 (138) | 5.02 (133) | 4.77 (130) | 4.97 (126) |
| BRRI dhan36 (ck.) | 5.65 (142) | 5.12 (137) | 4.84 (132) | 4.82 (129) |
| CV (%) | 6.2 | | | |
| $Lsd_{0.05}$ | 0.55 | | | |

* Growth duration higher due to irregular flowering.

**Table 8. Effect of planting time on yield and growth duration of advanced lines (short duration) in Boro, 2016-17, BRRI, Gazipur.**

| Advanced line | Grain yield (t ha$^{-1}$) | | | |
|---|---|---|---|---|
| | 6 Jan | 22 Jan | 6 Feb | 22 Feb |
| BR (Bio)9787-BC2-63-2-2 | 5.25 (138) | 5.14 (133) | 5.16 (130) | 4.62 (126) |
| BR (Bio)9787-BC2-63-2-4 | 5.26 (137) | 5.17 (132) | 4.87 (130) | 4.34 (127) |
| BR (Bio)9787-BC2-173-1-3 | 6.11 (141) | 5.61 (133) | 5.54 (131) | 5.27 (127) |
| BRRI dhan28 (ck) | 5.74 (138) | 5.02 (133) | 4.77 (130) | 4.97 (126) |
| CV (%) | 7.7 | | | |
| $Lsd_{0.05}$ | 0.66 | | | |

dose was: N-P-K-S @ 93-13-42-10 kg ha$^{-1}$ and N was splitted as 1/3 as basal + 1/3 at 10 DAT + 1/3 at 20 DAT and N-P-K-S-Zn @ 120-19-60-20-3.5 Kg ha$^{-1}$ in Boro season. N was splitted as 1/3 at 20 DAT + 1/3 at 35 DAT + 1/3 at 56 DAT. The experiment was conducted in RCB design with three replications. All the micronutrients were sprayed at booting stage in Aman and PI and soft dough stage in Boro. In T. Aman, treatment $T_3$ ($T_5$ + Boron (@5 ppm) and $T_1$= ($T_5$ + MgO @ 0.05%) produced about 17 and 15% higher number of grains over BRRI recommended fertilizer dose ($T_5$). In Boro 2016-17, similar result was found. Treatments $T_1$, $T_2$, $T_3$ and $T_4$ had about 10.3, 17.4, 20.0 and 19.0% lower sterility, respectively than $T_5$ in T. Aman 2016 and it was 8.8, 7.3, 13.7 and 3.8% in Boro 2016-17 (Fig. 1). In T. Aman, higher yield was recorded in $T_4$ which was similar with $T_2$ and in Boro 2016-17, Treatment $T_3$ ($T_5$+ Boron @ 5ppm) and $T_1$ ($T_5$+ MgO @ 0.05%) produced higher grain yield compared with control $T_5$ (Table 9). Copper and Boron had positive effects on increasing spikelet fertility in T. Aman season. But Boron and Mg had positive effects on increasing spikelet fertility in Boro season.

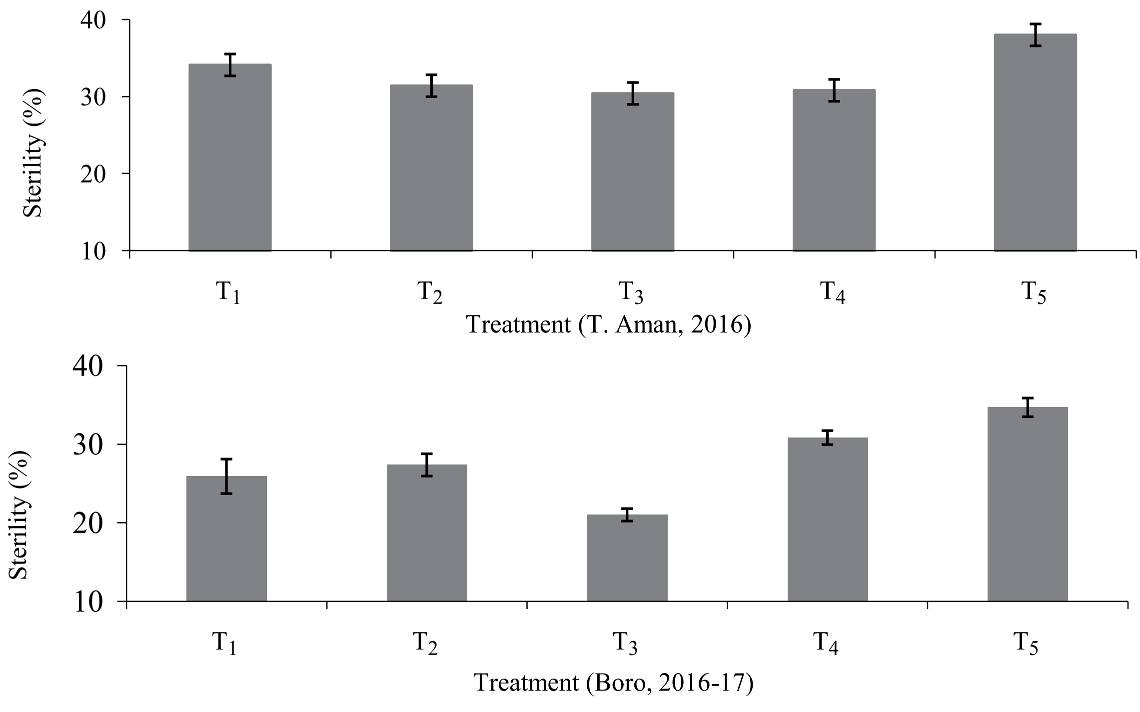



Fig. 1. Sterility (%) of CN6 as influenced by different micronutrient supplementation, BRRI, Gazipur.

**Table 9. Effect of micronutrient supplementation on spikelet fertility of advanced line CN6, BRRI, Gazipur.**

| Treatment | Grain panicle$^{-1}$ | TGW (g) | Grain yield (t ha$^{-1}$) |
|---|---|---|---|
| *T. Aman, 2016* | | | |
| $T_1 = T_5$ + MgO @ 0.05% | 186 | 17.5 | 3.57 |
| $T_2 = T_5$ + 80% S (@ 0.006%) + $ZnSO_4$ (@ 0.025% | 172 | 17.6 | 3.70 |
| $T_3 = T_5$ + Boron (@ 5 ppm | 194 | 17.5 | 3.57 |
| $T_4 = T_5$ + Copper (@ 5 ppm | 167 | 17.9 | 3.98 |
| $T_5$ = BRRI recommended fertilizer dose (ck.) | 161 | 17.7 | 3.29 |
| $Lsd_{0.05}$ | 13.04 | ns | 0.363 |
| *Boro, 2016-17* | | | |
| $T_1= T_5$+ MgO @ 0.05% | 186 | 17.8 | 5.14 |
| $T_2= T_5$+ 60 g Mop + 60 g elemental S (80% wp) + 20 g $ZnSO_4$ | 169 | 17.2 | 4.27 |
| $T_3= T_5$+ Boron @ 5ppm | 201 | 17.7 | 5.60 |
| $T_4= T_5$+Copper @ 5ppm | 167 | 17.6 | 4.72 |
| $T_5$= BRRI recommended fertilizer dose (ck) | 161 | 17.7 | 4.76 |
| $Lsd_{0.05}$ | 11.59 | ns | 0.89 |

D/S: 15 July, D/TP: 04 August, D/MA: 31 October, Growth duration = 109 days. D/S: 09 Dec., D/TP: 19 January, D/MA: 11 May, Growth duration= 154 days, TGW = 1000 grain weight.

**Influence of integrated nutrient and spacing on growth and yield of BRRI dhan69**

The experiment was conducted in Boro 2016-17 at BRRI, Gazipur to find out suitable fertilizer management and spacing for higher yield of BRRI dhan69. The experiment was laid out in split plot design with three replications, the main plot treatments were nutrient management: $T_1$= BRRI recommended dose (N-P-K-S-Zn = 117-19-58-15-3.5 kg ha$^{-1}$), $T_2$= 75% of $T_1$, $T_3$= 75% of $T_1$+ PL (2.5 t ha$^{-1}$) and $T_4$= No fertilizer. The sub plot treatments were: spacing ($S_1$= 20 × 20 cm, $S_2$= 20 × 15 cm and $S_3$= 25 × 15 cm). Thirty-nine-day-old seedling was transplanted using one seedling per hill on 17$^{th}$ January 2017. The full dose of PKSZn and poultry litter (PL) were applied during final land preparation and N was top dressed at 15, 30 and 45 DAT. Tiller number was counted from 35 DAT and continued up to maturity. The highest LAI was found in BRRI recommended dose with 20 × 15 cm spacing ($N_1S_2$) which is statistically similar with 75% of BRRI recommended dose + 2.5 tha$^{-1}$ PL with 20 × 15 cm spacing ($N_3S_2$) (Fig. 2) . At 35 DAT, treatment $N_3S_2$ showed the highest tiller number but it was higher in $N_1S_2$ at 50 DAT and continued till maturity. Treatment $N_1S_2$ gave the higher grain yield due to higher number of panicles and also higher LAI. 75% of BRRI recommended dose + 2.5 t ha$^{-1}$ PL with 25 × 15 cm spacing ($N_3S_3$) gave statistically similar yield (Table 10).

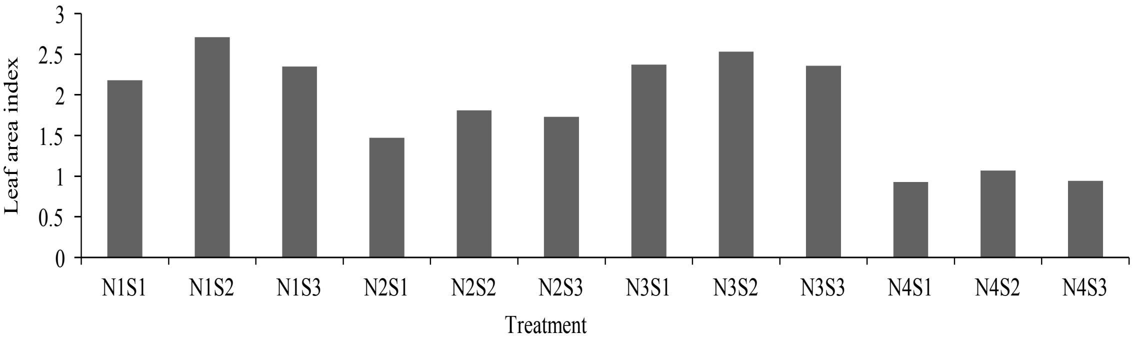



Fig. 2. Effect of integrated nutrient management and spacing on LAI of BRRI dhan69, Boro 2016-17, BRRI, Gazipur.

**Table 10. Effect of integrated nutrient management and spacing on yield and yield characters of BRRI dhan69, Boro 2016-17, BRRI, Gazipur.**

| Treatment | Panicle $m^{-2}$ | Grain $panicle^{-1}$ | TGW (g) | Yield ($t\ ha^{-1}$) |
|---|---|---|---|---|
| $N_1S_1$ | 208 | 117 | 23.7 | 5.52 |
| $N_1S_2$ | 212 | 147 | 23.5 | 6.21 |
| $N_1S_3$ | 203 | 135 | 23.4 | 5.80 |
| $N_2S_1$ | 188 | 128 | 23.2 | 5.68 |
| $N_2S_2$ | 195 | 104 | 23.5 | 5.34 |
| $N_2S_3$ | 205 | 105 | 23.5 | 5.46 |
| $N_3S_1$ | 183 | 138 | 23.7 | 5.41 |
| $N_3S_2$ | 187 | 140 | 23.8 | 5.87 |
| $N_3S_3$ | 196 | 144 | 23.7 | 6.08 |
| $N_4S_1$ | 118 | 138 | 23.7 | 3.34 |
| $N_4S_2$ | 115 | 117 | 23.8 | 2.96 |
| $N_4S_3$ | 121 | 128 | 23.5 | 3.18 |
| CV% | 3.04 | 4.98 | 1.10 | 2.01 |
| $Lsd_{0.05}$ | 9.24 | 10.96 | ns | 0.18 |

$T_1$= BRRI recommended dose (N-P-K-S-Z = 117-19-58-15-3.5 kg $ha^{-1}$), $T_2$ 75% of $T_1$, $T_3$= 75% of $T_1$ + PL (2.5 t $ha^{-1}$) and $T_4$= No fertilizer; $S_1$= 20 × 20 cm, $S_2$= 20 × 15 cm and $S_3$= 25 × 15 cm.

**Performance of Swarna cultivars to different fertilizer management options**

This experiment was conducted in T. Aman 2016 at BRRI Gazipur to investigate which Swarna cultivar possesses acceptable characters that will be helpful to develop a variety. Five SWARNA cultivars (Swarna5, Lalgooty Swarna, Nepali Swarna, Gooty Swarna, Sumon Swarna were tested under four fertilizer management options (NPK, PK, NK and NP). Fertilizer rate was (N-P-K @ 56-07-38 kg $ha^{-1}$and N was splitted as 1/3 at 10 DAT + 1/3 at 25 DAT + 1/3 at 40 DAT. The experiment was conducted in split plot design (main plot- fertilizer management option and sub plot- genotypes) with three replications. Swarna5 and Lalgooty Swarna produced statistically higher number of panicles with fertilizer combination of $N_{56} K_{38}$ (-P) and $N_{56} P_7 K_{38}$ respectively but Gooty Swarna was $N_{56} K_{38}$ (-P). Swarna5 produced significantly more number of grains than other Swarna cultivars with fertilizer combination of $N_{56} P_7 K_{38}$. Swarna5 and Gooty Swarna produced more than 5.6 $tha^{-1}$ grain yield with all fertilizer combinations (Table 11).

**Table 11. Yield of Swarna cultivars as influenced by fertilizer management options, T. Aman 2016, BRRI, Gazipur.**

| Treatment | Yield ($t\ ha^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Swarna5 | Gooty Swarna | Nepali Swarna | Lalgooty Swarna | Sumon Swarna |
| $N_{56}P_7K_{38}$ | 5.82 | 5.12 | 5.64 | 5.66 | 4.53 |
| $P_7K_{38}$ (-N) | 5.61 | 5.74 | 5.44 | 5.46 | 5.31 |
| $N_{56}K_{38}$ (-P) | 5.72 | 5.74 | 5.19 | 5.58 | 5.12 |
| $N_{56}P_7$ (-K) | 5.58 | 5.77 | 5.14 | 5.40 | 4.33 |
| Mean | 5.69 | 5.59 | 5.35 | 5.53 | 4.82 |
| CV (%) | | | 4.78 | | |
| $Lsd_{0.05}$ | | | 0.674 | | |

D/Sk: 4 Jul, D/TP: 31 Jul, D/F: 20 Oct, D/M: 16 Nov.

**Performance of Monibandobi to different fertilizer management options**

This experiment was conducted in T. Aman 2016 at BRRI farm Gazipur to investigate its yield potential that will be helpful to develop a variety. Monibandobi was tested under four fertilizer management options (NPK, PK, NK and NP). Fertilizer rate was (N-P-K @ 56-07-38 kg $ha^{-1}$ and N was splitted as 1/3 at 10 DAT + 1/3 at 25 DAT + 1/3 at 40 DAT. The experiment was conducted in RCB design with three replications. On average higher number of panicles was observed on 16 August planting than 31 July planting irrespective of fertilizer management options. At 31 July planting, treatments, $N_{56}P_7$ (-K) produced higher number of panicles over other treatments. $P_7K_{38}$ (-N) produced higher number of panicles than $N_{56}P_7K_{38}$ due to lodging. But in 16 August planting, $N_{56}P_7K_{38}$ produced higher number of panicles and consequently higher grain yield (Table 12).

WEED MANAGEMENT

**Comparative study of BRRI multi row power weeder and BRRI weeder**

The experiment was conducted at BRRI, Gazipur in T. Aman 2016 to compare BRRI multi-row power weeder and BRRI weeder. The treatments were: 1. BRRI developed multi row power weeder, 2. BRRI developed multi row power weeder + 1 HW, 3. BRRI weeder +1 HW, 4. Manual weeding (2 HW), 5. Weed free and 6. Control (no weeding). BRRI dhan56 was used as variety. Twenty-five-day-old seedlings were transplanted on 4th August 2016. The experiment was conducted in RCB design with three replications. BRRI multi row power weeder and BRRI weeder were operated at 15 DAT. Hand weeding at 15 and 38 DAT. The highest WCE (%) was observed in 2 HW treatments followed by BW+1 HW. Higher number of weed was found in MRPW after operation which leads to lowest WCE (Table 13). The highest yield was achieved from weed free plot which is similar to 2 HW treatment and BW + 1 HW (Table 14).

**Table 12. Yield and ancillary characters of Monibandobi under different fertilizer combinations, T. Aman 2016, Gazipur.**

| Treatment | 31 July planting | | | | 16 August planting | | | |
|---|---|---|---|---|---|---|---|---|
| | Panicle $m^{-2}$ | Grain $panicle^{-1}$ | TGW (g) | Yield (t $ha^{-1}$) | Panicle $m^{-2}$ | Grain $panicle^{-1}$ | TGW (g) | Yield (t $ha^{-1}$) |
| $N_{56}P_7K_{38}$ | 180 | 74 | 25.1 | 4.29 | 218 | 72 | 25.2 | 5.24 |
| $P_7K_{38}$ (-N) | 184 | 114 | 25.4 | 4.70 | 174 | 116 | 25.1 | 4.68 |
| $N_{56}K_{38}$ (-P) | 170 | 80 | 25.1 | 4.25 | 196 | 78 | 25.3 | 4.57 |
| $N_{56}P_7$ (-K) | 198 | 112 | 25.8 | 4.75 | 173 | 116 | 25.5 | 4.67 |
| Mean | 182 | 95 | 25.4 | 4.50 | 190 | 96 | 25.3 | 4.80 |
| $Lsd_{0.05}$ | 19.09 | 3.11 | 0.31 | ns | 29.83 | 3.31 | 0.301 | 0.2332 |

D/Sk: 4 July, D/TP: 31 July, D/F: 30 October, D/M: 27 Nov. D/Sk: 25 July, D/TP: 16 August, D/F: 5 November, D/M: 5 Dec, TGW= 1000 grain wight.

**Table 13. Weed infestation and weed control efficiency of different weeding treatments, T. Aman 2016, BRRI, Gazipur.**

| Treatment | 16 DAT | | | 35 DAT | | |
|---|---|---|---|---|---|---|
| | Weed no. ($m^{-2}$) | Weed dry weight (g $m^{-2}$) | WCE (%) | Weed no. ($m^{-2}$) | Weed dry weight (g $m^{-2}$) | WCE (%) |
| MRPW | 65 | 20.1 | 60 | 86 | 27.9 | 63 |
| MRPW+1HW | 32 | 12.5 | 75 | 45 | 16.8 | 78 |
| BW+1HW | 24 | 8.0 | 84 | 13 | 6.8 | 91 |
| 2 HW | 18 | 6.5 | 87 | 10 | 5.8 | 92 |
| Weed free | 0 | - | - | 0 | 0 | - |
| Control | 193 | 50.5 | - | 221 | 76.3 | - |

**Table 14. Yield and ancillary characters of BRRI dhan56 under different weed control treatments, T. Aman 2016, BRRI, Gazipur.**

| Treatment | Panicle $m^{-2}$ | Grains $panicle^{-1}$ | TGW (g) | Grain yield (t $ha^{-1}$) |
|---|---|---|---|---|
| MRPW | 201 | 81 | 25.1 | 3.17 |
| MRPW+1HW | 204 | 82 | 25.4 | 3.96 |
| BW+1HW | 214 | 83 | 25.8 | 4.45 |
| 2HW | 218 | 88 | 25.8 | 4.56 |
| Weed free | 223 | 90 | 26.0 | 4.60 |
| Control | 169 | 72 | 25.0 | 1.80 |
| CV(%) | 3.6 | 4.3 | 1.6 | 7.2 |
| $Lsd_{0.05}$ | 13.53 | 6.5 | 0.72 | 0.49 |

MRPW= Multi row power weeder, BW= BRRI weeder, TGW = 100 grain weight.

**Effect of herbicides on soil microorganisms in transplanted rice**

The experiment was conducted in Agronomy field and microbiology laboratory, BRRI, Gazipur during T. Aman 2016 and Boro 2016-17 to study the effect of herbicides on soil microorganisms in transplanted rice. The experiment was conducted in RCB design with three replications in field and CRD in laboratory condition. In T. Aman 2016, bensulfuron methyl+ acetachlor (66 g $bigha^{-1}$), bispyribac sodium+ bensulfuron methyl (19 g $bigha^{-1}$), pyrazosulfuron ethyl+ pretilachlor (107 g $bigha^{-1}$) and in Boro 2016-17, bispyribac sodium (13.2 and 27.0 g $bigha^{-1}$) were used. Soil samples (0-60 cm) were collected from herbicide treated plot at 3, 7, 10, 15, 20, 30 and 60 days after herbicide application (DAHA) for determination of soil microorganisms. The effect of four commonly used herbicides on non-target soil micro flora was investigated over a period of nine weeks. Herbicide treatments at both recommended rates resulted in decreases in microbial counts up to 20 DAHA. Higher concentrations of herbicide treatments resulted in much lower microbial counts compared to soils treated with recommended herbicide doses. But in general, after herbicide application all bacterial and fungal population reduced 3 DAHA and the population increased 7-20 DAHA and thereafter microbial population fluctuated over time. So application of herbicide in soil reduced soil microorganisms in a certain time and after 7-20 days it increased more than before and fluctuated over time.

**Effect of weed control methods on productivity of wet direct seeded Aus rice**

The experiment was conducted at BRRI farm, Gazipur, in Aus 2016 to determine effective weed control methods in wet direct seeding rice. Sprouted seeds of BRRI dhan43 were sown in line on 10 April. Line to line distance was 20 cm and seeds were sown continuous in a line. The treatments were; i) Pre-emergence herbicide + 1 HW, ii) Post-emergence herbicide + 1 HW, iii) 3 HW and iv) no weeding. Pre-emergence herbicide: Pretilachlor+ Pyrazosulfuran ethyl applied @ 800 $gha^{-1}$ at 4 DAS. Post-emergence herbicide: Bispyribac sodium applied @ 150 g $ha^{-1}$ at 7 DAS. The treatments were distributed in RCB design with three replications. The BRRI recommended fertilizers (N-P-K-S= 62-11-42 kg $ha^{-1}$) were used. Weed sampling was done at 30 DAS. *Echinochloa crus-galli* was effectively controlled (81%) by Bispyribac sodium+1 HW. But both the herbicides effectively control *Cyperusdifformis* and *Scirpusmaritimus* (>80%) (Table 15). The highest $paniclem^{-2}$, $grainspanicle^{-1}$ and yield was observed in both herbicide treated and 3 HW plot but they are statistically similar (Table 16).

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

The experiment was conducted at BRRI, Gazipur, in Aman 2016 and Boro 2016-17 to determine efficiency of new herbicides to control weeds in wet direct seeded rice cultivation. In Aman, sprouted seeds of BRRI dhan56 were directly sown in line

**Table 15. Effect of weed management options on weed control efficiency in direct wet seeded rice in Aus 2016, BRRI, Gazipur.**

| Treat | Weed control efficiency (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | *E. crus-galli* | *C. dactylon* | *P. comersoni* | *C. difformis* | *S. maritimus* | *F. miliaceae* | *M. vaginalis* |
| $T_1$ | 75.4 | 42.4 | 48.6 | 81.2 | 81.9 | 70.3 | 50.9 |
| $T_2$ | 81.4 | 48.6 | 50.8 | 80.4 | 82.2 | 73.4 | 58.2 |
| $T_3$ | 84.6 | 58.4 | 61.5 | 85.4 | 81.5 | 77.5 | 80.6 |

$T_1$ = Pretilachlor + Pyrazosulfuran ethyl + 1HW, $T_2$ = Bispyribac sodium+ 1HW, $T_3$ = 3HW.

**Table 16. Effect of weed management optionson yield and ancillary characters of direct wet seeded rice in Aus 2016, BRRI, Gazipur.**

| Treatment | Panicle $m^{-2}$ | Grains $panicle^{-1}$ | Yield (t $ha^{-1}$) |
|---|---|---|---|
| (Pretilachlor + Pyrazosulfuran ethyl ) + 1 HW | 235 | 72 | 3.08 |
| Bispyribac sodium + 1 HW | 239 | 71 | 3.13 |
| Three hand weeding (3 HW) | 249 | 73 | 3.21 |
| Control | 144 | 57 | 1.73 |
| CV (%) | 3.40 | 5.35 | 4.57 |
| $Lsd_{(0.05}$ | 14.75 | 7.30 | 0.25 |

(line distance 20 cm) and 25-day-old seedling of same variety was transplanted on 30 July and in Boro, 35-day-old seedling of BRRI dhan58 was transplanted and direct seeding was also done by the same variety. The treatments were; i) Pre planting (Sulfentrazone- 200 ml $ha^{-1}$) + 1 HW, ii) Pre emergence herbicide (Bensulfuron methyl + Acetachlor-750 g $ha^{-1}$) + 1 HW, iii) Early post emergence herbicide (Pretilachlor + Trisulfuron-750 g $ha^{-1}$) + 1 HW, iv) Post emergence herbicide (Metsulfuron methyl+Chlorimuron ethyl-20 g $ha^{-1}$) + 1 HW, v) Post emergence herbicide (Bensulfuran methyl + Bispyribac sodium-144 g $ha^{-1}$) + 1HW, vi) Post emergence herbicide (2,4-D Amine -1.0 L $ha^{-1}$) + 1HW, vii) Three hand weeding (3 HW) and viii) control (no weeding). Pre-planting herbicide was applied at 4 days before seeding and transplanting; Pre-emergence herbicide at 4 days after seeding (DAS) in direct seeding and at 4 DAT in transplanting method; Early post herbicide at 8 DAS in direct seeding and at 8 DAT in transplanting method; Post-emergence herbicide at 11 DAS in direct seeding and at 11 DAT in transplanting method. The treatments were distributed in RCB design with three replications. BRRI recommended fertilizers (Aman: N-P-K-S= 68-11-41-10 kg $ha^{-1}$ and Boro: N-P-K-S-Zn= 137-19-82-20-3.5 kg $ha^{-1}$) were applied. Weed sampling was done at 30 DAS and 30 DAT. *Echinochloa crus-galli*, *Cyperus difformis* and *Scirpus maritimus* were effectively controlled by Sulfentrazone and Bensulfuron methyl + Acetachlorwith 1 HW more than 80%, whereas, *Echinochloa crus-galli*, *Cyperus difformis, Scirpus maritimus* and *Monochoria vaginalis* were effectively controlled by Pretilachlor + Trisulfuron, Metsulfuron methyl + Chlorimuron ethyl and Bensulfuran methyl + Bispyribac sodium in transplanted field (Table 17). In direct seeding field, weed control efficiency of pre-planting herbicide, Sulfentrazone for *Echinochloa crus-galli*, *Cyperus difformis* and *Scirpus maritimus* were more than 80% (Table 18) in both Aman and Boro seasons. Consequently, Pretilachlor + Trisulfuron, Bensulfuran methyl + Bispyribac sodium and 2,4-D Amine also effectively controlled most of sedges and grasses in direct seeded rice.

### Effect of continuous application of herbicide on weed species shifting and resistance

The study was conducted at BRRI, Gazpurin Boro 2016-17 to know the effect of long-term use of herbicides in rice on weed shifting and sustainability of rice yield. The experiment was laid out in RCB design with three replications. The treatments were: 1. pre-emergence herbicide (pretilachlor), 2. Post-emergence herbicide

**Table 17. Effect of herbicide on weed control efficiency in transplanted rice, 2016-17 at BRRI, Gazipur.**

| Weed | Weed control efficiency (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | W1 | W2 | W3 | W4 | W5 | W6 | W7 |
| | | | | *Aman 2016* | | | |
| *Cynodondactylon* | 35.6 | 34.7 | 43.6 | 50.4 | 45.8 | 48.6 | 58.9 |
| *Echinochloa crus-galli* | 80.4 | 81.5 | 84.3 | 80.8 | 83.5 | 75.4 | 85.7 |
| *Cyperusdifformis* | 81.3 | 83.2 | 82.5 | 80.9 | 80.5 | 70.7 | 85.5 |
| *Scirpusmaritimus* | 80.8 | 80.4 | 82.9 | 80.7 | 81.5 | 67.4 | 83.7 |
| *Monochoriavaginalis* | 75.8 | 74.9 | 81.7 | 81.3 | 80.4 | 69.8 | 84.8 |
| *Marsileaminuta* | 64.7 | 72.4 | 75.7 | 70.6 | 74.4 | 73.9 | 82.5 |
| | | | | *Boro 2016-17* | | | |
| *Cynodondactylon* | 37.2 | 38.5 | 41.2 | 56.5 | 42.6 | 50.9 | 69.5 |
| *Echinochloa crus-galli* | 82.6 | 80.4 | 81.5 | 80.7 | 85.5 | 74.3 | 87.5 |
| *Cyperusdifformis* | 80.5 | 81.7 | 83.3 | 80.4 | 82.4 | 72.0 | 84.6 |
| *Scirpusmaritimus* | 81.5 | 80.7 | 83.1 | 81.3 | 83.7 | 69.9 | 86.4 |
| *Monochoriavaginalis* | 72.3 | 71.5 | 80.5 | 80.6 | 81.5 | 72.1 | 85.7 |
| *Marsileaminuta* | 68.9 | 70.9 | 76.4 | 74.3 | 75.4 | 71.5 | 80.7 |

**Table 18. Effect of herbicide on weed control efficiency in wet direct seeded rice, 2016-17 at BRRI, Gazipur.**

| Weed | Weed control efficiency (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | W1 | W2 | W3 | W4 | W5 | W6 | W7 |
| | | | | *Aman 2016* | | | |
| *Cynodondactylon* | 32.8 | 31.7 | 40.5 | 48.5 | 47.6 | 49.7 | 56.7 |
| *Echinochloa crus-galli* | 80.9 | 76.6 | 82.6 | 76.4 | 81.6 | 82.5 | 83.4 |
| *Cyperusdifformis* | 80.8 | 72.9 | 81.2 | 70.8 | 83.6 | 80.8 | 84.0 |
| *Scirpusmaritimus* | 81.6 | 70.5 | 81.5 | 72.4 | 81.2 | 81.4 | 84.3 |
| *Monochoriavaginalis* | 71.5 | 70.8 | 80.7 | 73.6 | 80.6 | 76.5 | 82.3 |
| *Marsileaminuta* | 57.9 | 64.2 | 74.8 | 70.5 | 75.4 | 68.6 | 80.6 |
| | | | | *Boro 2016-17* | | | |
| *Cynodondactylon* | 38.7 | 33.5 | 42.8 | 45.6 | 48.1 | 46.4 | 53.5 |
| *Echinochloa crus-galli* | 82.4 | 80.1 | 84.3 | 75.4 | 82.7 | 84.2 | 86.5 |
| *Cyperusdifformis* | 81.6 | 75.4 | 80.1 | 73.3 | 84.2 | 84.7 | 87.3 |
| *Scirpusmaritimus* | 82.0 | 76.6 | 82.5 | 75.2 | 83.1 | 85.4 | 85.7 |
| *Monochoriavaginalis* | 70.4 | 68.3 | 81.2 | 72.9 | 81.3 | 73.5 | 84.5 |
| *Marsileaminuta* | 62.4 | 60.8 | 71.5 | 76.5 | 72.6 | 64.6 | 82.7 |

W1=Sulfentrazone + 1 HW, W2= Bensulfuron methyl + Acetachlor + 1 HW, W3= Pretilachlor + Trisulfuron + 1 HW, W4= Metsulfuron methyl +Chlorimuron ethyl + 1 HW, W5= Bensulfuran methyl + Bispyribac sodium + 1 HW, W6=2,4-D Amine + 1 HW, W7= Three hand weeding (3HW).

(Pyrozosulfron ethyl) 3. Combination of pre and post (Pretilachlor + Pyrozosulfron ethyl) and 4. Control (no herbicide). Pre-emergence herbicide was applied at 4 DAT while the post-emergence was applied at 2-3 leaf stage of weed. Forty-day-old seedlings of BRRI dhan28 were transplanted on 13th January 2017 at 20 × 20 cm spacing with two seedlings hill$^{-1}$. Weed sampling was done at 45 DAT. Weed control efficiency (WCE) was measured as: Weed dry weight in control plot/ Weed dry weight in weedy check × 100. Amrul (*Oxalis europea*) and Shama (*Echinochloa* crusgalli) were predominant in Pretilachlor treated plot; Shama (*Echinochloa crusgalli)* and Chesra (*Scirpus maritimus)* were in Pyrazosulfuran ethyl and Pretilachlor + Pyrazosulfuran ethyl treated plot (Table 19). Pre-emergence herbicide showed the maximum (99%) control efficiency in case of Chesra followed by Shama (71%). The post emergence herbicide controlled Chesra (98%) and Amrul (70%) respectively and followed by combination of pre and post emergence herbicide (Table 20). Pretilachlorand combination of pre and post emergence herbicide treated plot produced higher number of panicles, more grains per panicle and consequently higher grain yield (Table 21).

**Screening of crop residues for weed control efficiency in rice**

The study was conducted at BRRI, Gazipur in T. Aman 2016. The experiment was laid out in CRD design with three replications. The pot size was 1.0 × 1.0 $m^2$. The treatments were: $T_1$ = Sorghum residues, $T_2$ = Soyabeanresidues, $T_3$ = Mungbean residues, $T_4$ = Rice straw, $T_5$ = Pre-emergence herbicide (Butachlor) and $T_6$ = control. Crop residue was incorporated at 3 DAT @ 5.0 t $ha^{-1}$. BRRI dhan72 was used as a test variety. Thirty-day-old seedling was transplanted with 20 × 20 cm spacing on 15$^{th}$ June 2016. Weed data were taken at 30 DAT from 50 × 50 cm area. Minimum number of weed and maximum weed reduction (75.5%) was observed in pre-emergence herbicide treated plot followed by rice straw treated plot. Sorghum residue also suppressed the weed density (69.5%) (Table 22). The highest yield was recorded in pre emergence herbicide followed by rice straw.

**Table 19. Effect of herbicide application on the number of individual weed species during Boro 2016-17, BRRI, Gazipur.**

| Treatment | Number of weed species ($m^{-2}$) | | | | | |
|---|---|---|---|---|---|---|
| | Shama | Chesra | Amrul | Durba | Panikachu | Huldaemutha |
| $T_1$ | 14 | 6 | 14 | 5 | - | - |
| $T_2$ | 37 | 21 | 2 | 4 | - | - |
| $T_3$ | 17 | 19 | 1 | 2 | - | - |
| $T_4$ | 40 | 473 | 13 | 11 | 2 | 1 |

**Table 20. Effect of herbicide on weed control efficiency (%) of individual species during Boro 2016-17, BRRI, Gazipur.**

| Treat | Weed control efficiency (%) | | | | | |
|---|---|---|---|---|---|---|
| | *E crus-galli* | *S. maritimus* | *O. europea* | *C. dactylon* | *M. aginalis* | *C. difformis* |
| $T_1$ | 71 | 99 | 19 | 39 | - | - |
| $T_2$ | 54 | 98 | 70 | 60 | - | - |
| $T_3$ | 65 | 98 | 90 | 76 | - | - |
| $T_4$ | - | - | - | - | - | - |

**Table 21. Effect of different weed control option on yield and ancillary characters of BRRI dhan28 during Boro 2016-17, BRRI, Gazipur.**

| Treatment | Panicle ($m^{-2}$) | Grain $panicle^{-1}$ | TGW (g) | Yield (t $ha^{-1}$) |
|---|---|---|---|---|
| $T_1$ | 270 | 100 | 23.1 | 5.03 |
| $T_2$ | 242 | 99 | 23.0 | 4.26 |
| $T_3$ | 256 | 102 | 22.5 | 5.12 |
| $T_4$ | 107 | 80 | 23.9 | 1.30 |
| CV (%) | 12.7 | 16.6 | 3.0 | 13.6 |
| $LSD_{0.05}$ | 55.54 | ns | ns | 1.09 |

$T_1$= Pretilachlor, $T_2$= Pyrazosulfuran ethyl, $T_3$= Pretilachlor+Pyrazosulfuran ethyl, $T_4$= Control (no weeding).

**Table 22. Weed density, total dry matter and WCE as influenced by different management practices in Aman 2016, BRRI, Gazipur.**

| Treatment | Weed density ($m^{-2}$) | Total dry weight (g $m^{-2}$) | Weed control efficiency (%) |
|---|---|---|---|
| $T_1$ | 34 | 7.9 | 69.6 |
| $T_2$ | 51 | 9.5 | 63.4 |
| $T_3$ | 56 | 10.9 | 58.0 |
| $T_4$ | 27 | 7.2 | 73.1 |
| $T_5$ | 25 | 6.48 | 75.5 |
| $T_6$ | 100 | 26.0 | - |

$T_1$= residue of sorghum, $T_2$= residue of soyabean[1], $T_3$= residue of mungbean$^{-1}$, $T_4$= residue of rice straw, $T_5$= pre emergence herbicide (butachlor), $T_6$= control.

## YIELD MAXIMIZATION

### Nutrient management for yield maximization of hybrid and fine rice

An experiment was conducted at BRRI farm, Gazipur during Boro 2016-17 to obtain maximum grain yield of hybrid and fine rice. The nutrient management for hybrid rice was: $T_1$= BRRI recommended fertilizer dose (115-20-60-12-2.6 kg $ha^{-1}$ N, P, K, S and Zn), $T_2$= 20% over $T_1$, $T_3$= $T_1$ but USG instead of prilled urea, $T_4$= 70% of $T_1$+ 1.5 t $ha^{-1}$ organic manure (CD/PL/VC) and $T_5$= STB fertilizer dose (Control). The hybrid varieties were: $V_1$= BRRI hybrid dhan3 and $V_2$= BRRI hybrid dhan5. Nutrient management for fine rice was: $T_1$= BRRI recommended fertilizer dose (92-14-50-8-2.3 kg $ha^{-1}$ N, P, K, S and Zn), $T_2$= 20% over $T_1$, $T_3$= $T_1$ but USG instead of prilled urea, $T_4$= 70% of $T_1$ + 1.5 t $ha^{-1}$ organic manure (CD/PL/VC) and $T_5$= STB fertilizer dose (Control). The fine rice varieties were: $V_1$= BRRI dhan50 and $V_2$= BRRI dhan63. Treatments were distributed in split plot design; while different nutrient management was in main plot and variety in sub plot. One t $ha^{-1}$ higher grain yield was observed in BRRI hybrid dhan3 compared to BRRI hybrid dhan5 due to higher number of panicles and more grains per panicle (Table 23). Irrespective of fine rice variety, the lowest grain yield was observed in $N_4$. Irrespective of nutrient management, fine rice varieties showed significant differences in panicle $m^{-2}$, grain panicle$^{-1}$, TGW and HI. Higher panicle $m^{-2}$ was observed in BRRI dhan50 but higher grain panicle$^{-1}$ and TGW were observed in BRRI dhan63. Statistically similar grain yield was observed in both the varieties (Table 24).

**Table 23. Effect of hybrid rice variety and nutrient management on yield and yield components in Boro 2016-17, BRRI, Gazipur.**

| Variety | Panicle $m^{-2}$ | Grain panicle$^{-1}$ | TGW (g) | GY (t $ha^{-1}$) |
|---|---|---|---|---|
| $V_1$ | 297 | 92 | 26.9 | 9.07 |
| $V_2$ | 260 | 84 | 25.7 | 8.06 |
| CV % | 2.84 | 4.09 | 1.7 | 4.32 |
| $Lsd_{0.05}$ | 6.43 | 2.93 | 0.37 | 0.30 |
| $N_1$ | 283 | 95 | 26.18 | 8.92 |
| $N_2$ | 275 | 91 | 26.41 | 8.61 |
| N3 | 288 | 90 | 26.28 | 8.88 |
| N4 | 275 | 83 | 26.12 | 8.36 |
| N5 | 271 | 82 | 26.49 | 8.04 |
| CV % | 4.02 | 7.65 | 2.96 | 4.14 |
| $Lsd_{0.05}$ | ns | ns | ns | 0.47 |

### Effect of organic and inorganic fertilizer management on growth and yield of BRRI dhan58

The experiments were conducted at BRRI farm, Gazipur in Boro 2016-2017 seasons to maximize yield of Boro rice. The experiment was carried out

**Table 24. Effect of fine rice variety and nutrient management on yield and yield components in Boro 2016-17, BRRI Gazipur.**

| Variety | Panicle $m^{-2}$ | Grain panicle$^{-1}$ | TGW (g) | GY (t $ha^{-1}$) |
|---|---|---|---|---|
| $V_1$ | 325 | 73 | 21.3 | 5.12 |
| $V_2$ | 275 | 79 | 23.0 | 5.10 |
| CV % | 9.62 | 7.61 | 1.93 | 7.07 |
| $Lsd_{0.05}$ | 49.28 | 4.69 | 0.35 | ns |
| $N_1$ | 296 | 72 | 22.39 | 5.09 |
| $N_2$ | 300 | 78 | 22.37 | 5.04 |
| $N_3$ | 317 | 78 | 22.04 | 5.29 |
| $N_4$ | 296 | 72 | 21.82 | 4.79 |
| $N_5$ | 292 | 78 | 22.20 | 5.36 |
| CV % | 12.34 | 7.91 | 1.57 | 5.39 |
| $Lsd_{0.05}$ | ns | ns | ns | 0.37 |

$T_1$= BRRI recommended fertilizer dose (92-14-50-8-2.3 kg $ha^{-1}$ N, P, K, S and Zn), $T_2$= 20% over $T_1$, $T_3$= $T_1$ but USG instead of prilled urea, $T_4$= 70% of $T_1$ + 1.5 t $ha^{-1}$ organic manure (CD/PL/VC) and $T_5$= STB fertilizer dose (Control). The fine rice varieties were: $V_1$= BRRI dhan50 and $V_2$= BRRI dhan63.

with six different splittings of N and other fertilizers and two OM. The N fertilizer splitting was: 1. $N_0$ (No nitrogen) + PKSZn, 2. $N_1$ (30% basal + 35% AT + 35% PI) + PKSZn, 3. $N_2$ (33.3% 15 DAT + 33.3% AT + 33.3% PI) + PKSZn, 4. $N_3$ (30% 15 DAT + 35% AT + 35% PI) + PSZn + 50% K as basal + 50% K at PI, 5. $N_4$ (15% basal + 45% AT + 30% PI+ 10% heading) + PKSZn. Fertilizer from OM was: 1. Cowdung@ 5.0 t $ha^{-1}$ and 2. Decomposed poultry manure @ 2.5 $tha^{-1}$. All treatments were laid out in a split plot design with three replications. Nitrogen fertilizer was in main plot and OM was in subplot. Forty-one-day-oldseedling was transplanted on 5 January 2017 at 20 × 20 cm spacing with two seedlings $hill^{-1}$. Number of tiller $m^{-2}$ in different N and OM management increased significantly over time and peaked at 60 DAT and then declined steady. At 60 DAT, the highest tiller was produced from N4 and PL treated plots**.** The treatments $N_1$ produced the highest dry weight compared to the others. The rapid increase of dry matter was observed between 60-90 DAT. PM produced highest DM up to 90 DAT. The highest LAI was observed in $N_1$ followed by $N_4$ treatment. Regression analysis showed that, LAI at booting stage was significantly correlated with grain yield (Fig. 3). Treatment $N_1$ produced the highest grain yield followed by $N_4$ treatment. Higher grain yield of $N_1$ treatment was associated with higher panicle $m^{-2}$, grains $panicle^{-1}$ and TGW. Cowdung applied treatments produced the highest grain yieldbut the difference was significant with poultry manure (Table 25).

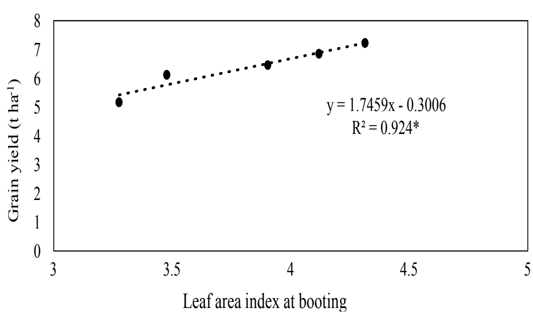



Fig. 3. Relationship between grain yield with LAI of BRRI dhan58.

**Table 25. Yield and yield characters of BRRI dhan58 as affected by nitrogen and OM management Boro 2016-17, BRRI, Gazipur.**

| Treatment | Panicle $m^{-2}$ | Grains $panicle^{-1}$ | TGW (g) | Grain yield (t $ha^{-1}$) |
|---|---|---|---|---|
| *N management* | | | | |
| $N_0$ | 214 | 122 | 21.87 | 5.16 |
| $N_1$ | 284 | 155 | 22.56 | 7.23 |
| $N_2$ | 264 | 137 | 21.57 | 6.12 |
| $N_3$ | 272 | 139 | 21.34 | 6.46 |
| $N_4$ | 277 | 149 | 22.45 | 6.85 |
| $Lsd_{0.05}$ | 22.20 | 16.90 | 1.37 | 0.61 |
| *OM Mmanagement* | | | | |
| CD | 267 | 154 | 21.94 | 6.75 |
| PM | 257 | 127 | 21.97 | 5.98 |
| CV (%) | 6.6 | 9.3 | 4.9 | 7.5 |
| $Lsd_{0.05}$ | ns | 10.69 | ns | 0.39 |

$N_0$ = (No nitrogen) + others fertilizers, $N_1$= (30% basal+ 35% AT + 35% PI) + PKZnS(Basal), $N_2$ = (33.3% 15 DAT+33.3% AT+33.3% PI)+PKZnS(Basal), $N_3$= (30% 15 DAT+35% AT+35% PI)+ PZnS (Basal) + K 50% at basal + K 50% at PI, $N_4$ = (15% basal+45% AT+30% PI+ 10% heading )+PKZnS (Basal), CD= cowdung @ 5.0 t $ha^{-1}$, PM= poultry manure @ 2.5 t $ha^{-1}$.

### Yield maximization of Boro rice through adjustment of N ratio and K splitting

This experiment was conducted in Boro 2016-17 at BRRI farm, Gazipur to maximize and sustain Boro rice yield. Three rice genotypes (BRRI dhan62, BRRI hybrid dhan5 and CN6) were tested under five N splitting techniques (Table 26). The experiment was conducted in split plot design (main plot- N splitting and sub plot- genotypes) with three replications. Thirty-day-old seedling (from soaking -transplanting) was transplanted on 1 January with one seedling per hill at 20 × 20 cm spacing. Tiller count was started from 20 DAT up to 110 DAT. All inbred genotypes positively response to basal N application ($YM_4$) and produce faster and higher number of tillers at all sampling dates. But hybrid rice responded on $YM_1$ and $YM_2$ where 1st top dress of urea was 78 and 104 $kgha^{-1}$ respectively (Fig. 4). CN6 and BRRI hybrid dhan5 produced more panicles when application of 10% higher N and K than BRRI fertilizer rate and management. Grain number increases with splitting of N and K in CN6 and BRRI hybrid dhan5 but not in BRRI

Table 26. Fertilizers scheduling for each treatment, Boro 2016-17, BRRI, Gazipur.

| Treatment | Basal ($kgha^{-1}$) | | | | | | Top dress ($kg\ ha^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | VC | N | P | K | S | Zn | $1^{st}N$ | $2^{nd}N$ + K | | $3^{rd}N$ |
| BRRI | - | - | 18 | 75 | 38 | 3.5 | 40 | 40 | - | 40 |
| $YM_1$ | - | - | 18 | 37.5 | 38 | 3.5 | 36 | 60 | 45 | 36 |
| $YM_2$ | - | - | 18 | 37.5 | 38 | 3.5 | 48 | 48 | 45 | 36 |
| $YM_3$ | 1.5 $tha^{-1}$ | - | 10.6 | 34.5 | 33.5 | 3.5 | 27 | 45 | 41.5 | 27.2 |
| $YM_4$ | - | 18.5 | 18 | 37.5 | 38 | 3.5 | 30 | 48 | 45 | 36 |

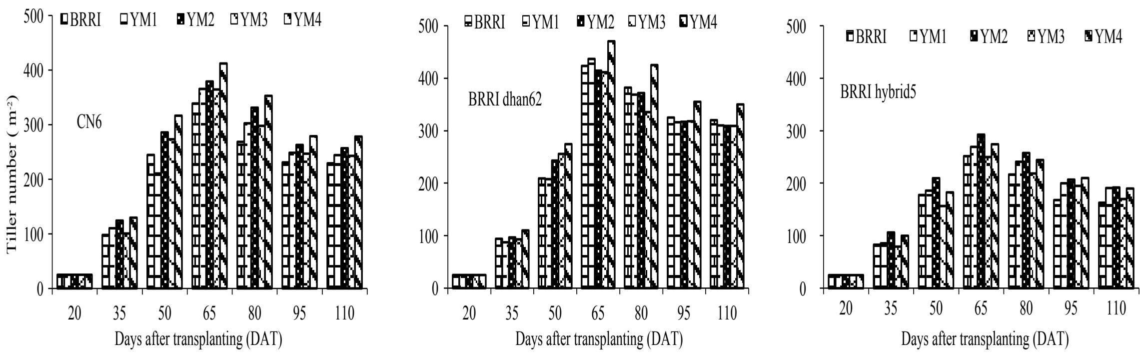



Fig 4. Tillering pattern of tested genotypes with N splitting techniques, Boro 2016-17, BRRI, Gazipur

dhan62. TGW of CN6, BRRI dhan62 and BRRI hybrid dhan5 was 15.6, 24.3 and 31.5 g irrespective of N management techniques. CN6 produced significantly higher grain yield with $YM_2$ and $YM_4$ over BRRI management, BRRI dhan62 was higher with $YM_4$ and BRRI hybrid dhan5 was higher with $YM_1$ due to higher panicle number, more number of grains per panicle and TGW over other management (Table 27). Higher sterility was observed in CN6 and lower in BRRI dhan62 and BRRI hybrid dhan5. CN6 showed higher sterility (39.0%) with BRRI management and about 10% lower sterility was observed in $YM_1$ – $YM_4$ (Fig. 5).

PROJECT ACTIVITY

**Performance of balanced fertilization, weed management technologies and validation of modern varieties at Pirojpur-Gopalganj and Bagerhat district**

In T. Aman 2016 and, Boro 2016-17, about 175 and 300 demonstrations were done in the farmers field of Pirojpur, Gopalganj and Bagerhat districts respectively. BRRI released T. Aman, Boro and BRRI hybrid varieties were used to popularize in different locations. Weed management treatments were: Herbicide + 1 HW, BRRI, Weeder + 1 HW which were compared with farmers practice. Each experimental area was about 33 decimal. Herbicide + 1 HW and BRRI weeder + 1 HW produced more grain yield compared to farmer's practice (2 HW) over variety, locations and seasons. About 61% cost was reduced due to herbicide use whereas, 49% cost was reduced when used BRRI weeder +1 HW for weed management of rice (Table 28). Average yield improvement was 13% in herbicide + 1 HW and BRRI weeder + 1 HW was 5% over farmers practice. About 61% cost could be reduced by using herbicide + 1 HW whereas, 49% cost was in BRRI weeder +1 HW. In T. Aman 2016 and Boro 2016-17, a total of 155 demonstration were conducted with BRRI varieties. In T. Aman 2016, BRRI hybrid dhan4 produced higher grain yield followed by BRRI dhan66 in Gopalganj. In Bagerhat, BRRI dhan56 produced higher grain yield followed by BRRI dhan73 but in Pirojpur, BRRI dhan53 produced higher grain yield in selected location. In Boro, BRRI hybrid dhan3 produced higher grain

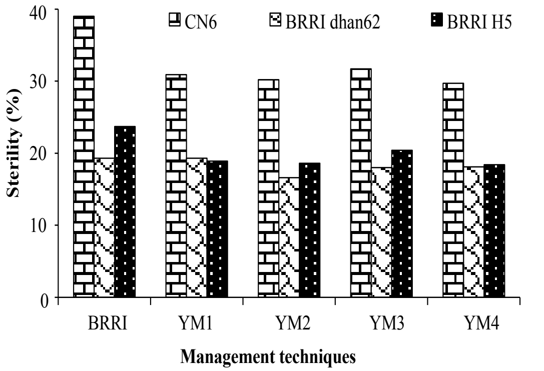



Fig. 5. Sterility (%) of tested genotypes with N splitting techniques, Boro 2016-17, BRRI, Gazipur.

yield followed by BRRI hybrid dhan2 in Gopalganj area. In Bagerhat, BRRI hybrid dhan3 produced higher grain yield followed by BRRI dhan58 and BRRI dhan67. But in Pirojpur, BRRI hybrid dhan2 produced higher grain yield in selected location.

Farmers prefer to cultivate BRRI dhan67 instead of BRRI dhan28 and BRRI dhan47 with similar growth duration but higher grain yield (Table 29-30).

**Improvement of relay cropping of Aman with jute in Gopalganj**

In Gopalgonj, Pirojpur and Bagerhat, major cropping pattern is Rabi-Jute-T. Aman.In this pattern, Aman rice seeds (BRRI dhan28, BRRI dhan33, BRRI dhan39 and local varieties) are direct seeded as relay crop. Farmers fertilized their field after Jute harvest. However, there are many other short duration photo-insensitive Aman varieties and their performance is not yet known. This experiment was undertaken to find out the best Aman rice for this pattern.Jute variety OM-9897 seeded on 20-25 March, 2016. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan66 and local variety, Shishumoti were broadcasted. The fertilizers were applied 2-3 weeks after direct seeding of rice. The highest number of panicle and yield was observed in BRRI dhan66 and lower number of panicle and yield was in local variety Shishumoti. Farmers got about 3.0 tha$^{-1}$ yield advantages to cultivate BRRI dhan66 (Table 31).

**Optimization of P fertilizer in peat soil at Gopalganj area**

The experiment was carried out in three farmers' field of KotaliparaTungipara of Gopalganj district in Boro, 2016-17 to find out optimum P dose in peat

**Table 27. Yield and yield components of tested genotypes under five N management techniques, Boro, 2016-17, BRRI, Gazipur.**

| Treatment | Panicles m$^{-2}$ | | | Grain panicle$^{-1}$ | | | TGW g) | | | Grain yield (t ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CN6 | BR62 | BH5 | CN6 | BR62 | BH5 | CN6 | BR62 | BH5 | CN6 | BR62 | BH5 |
| BRRI Mgn. | 226 | 318 | 161 | 156 | 98 | 121 | 15.6 | 24.3 | 31.5 | 5.22 | 5.39 | 6.30 |
| $YM_1$ | 240 | 308 | 188 | 172 | 101 | 149 | 15.9 | 24.2 | 31.7 | 5.54 | 5.48 | 6.57 |
| $YM_2$ | 248 | 306 | 188 | 163 | 96 | 126 | 15.8 | 24.8 | 31.2 | 5.90 | 5.36 | 6.07 |
| $YM_3$ | 242 | 305 | 161 | 169 | 90 | 135 | 15.3 | 24.3 | 31.6 | 5.47 | 5.24 | 6.04 |
| $YM_4$ | 275 | 346 | 182 | 177 | 91 | 130 | 15.6 | 24.0 | 31.3 | 6.03 | 5.75 | 5.93 |
| CV (%) | | 5.12 | | | 8.56 | | | 2.99 | | | 4.44 | |
| $Lsd_{0.05}$ | | 31.357 | | | 16.758 | | | 0.9938 | | | 0.2511 | |

**Table 28. Comparative study of weed management cost in Aman and Boro season at different locations, 2016-17.**

| Weed management option | Grain yield (t ha$^{-1}$) | | Yield advantage over FP (%) | | Weed management cost (Tk ha$^{-1}$) | | Cost reduced over FP (%) | |
|---|---|---|---|---|---|---|---|---|
| | Aman | Boro | Aman | Boro | Aman | Boro | Aman | Boro |
| Farmers practice (2 HW) | 4.95 | 6.50 | - | - | 12600 | 14400 | - | - |
| Herbicide + 1 HW | 5.24 | 6.95 | 6 | 7 | 4750 | 5550 | 62 | 61 |
| BRRI weeder + 1 HW | 5.10 | 6.64 | 3 | 2 | 6450 | 7250 | 49 | 50 |

**Table 29. Performance of BRRI varieties in respect to yield and growth duration under different locations, T. Aman, 2016.**

| Variety | Grain yield (t/ha) | Growth duration (day) |
|---|---|---|
| | *Gopalganj (No. of farmers: 40)* | |
| BRRI dhan52 | 5.04 | 142 |
| BRRI dhan56 | 4.95 | 109 |
| BRRI dhan62 | 4.33-5.2 | 101-105 |
| BRRI dhan66 | 5.06-5.67 | 113 |
| BRRI hybrid dhan4 | 6.08-6.25 | 112-114 |
| | *Bagerhat* | |
| BRRI dhan53 | 4.53-4.78 | 122-124 |
| BRRI dhan56 | 4.52-5.36 | 105-109 |
| BRRI dhan62 | 4.57 | 102 |
| BRRI dhan73 | 4.57-4.86 | 121-122 |
| | *Pirojpur (No. of farmers: 25)* | |
| BRRI dhan53 | 5.32 | 121 |
| BRRI dhan54 | 4.51-5.37 | 131-134 |

**Table 30. Performance of BRRI varieties in respect to yield and growth duration under different locations, Boro 2016-17.**

| Variety | Grain yield (t/ha) | Growth duration (day) |
|---|---|---|
| | *Gopalganj (No. of farmers: 50)* | |
| BRRI dhan58 | 7.17-7.87 | 145-152 |
| BRRI dhan63 | 6.54-6.86 | 145-150 |
| BRRI hybrid dhan2 | 8.85 | 145 |
| BRRI hybrid dhan3 | 9.77-10.19 | 140-145 |
| BRRI hybrid dhan5 | 8.41-8.65 | 142-145 |
| | *Bagerhat* | |
| BRRI dhan58 | 6.9-7.29 | 145-152 |
| BRRI dhan67 | 6.8 | 140 |
| BRRI hybrid dhan3 | 9.04-10.1 | 140-145 |
| | *Pirojpur (No. of farmers: 40)* | |
| BRRI dhan67 | 6.51-6.94 | 138-142 |
| BRRI hybrid dhan2 | 8.5-8.82 | 140-145 |

soil. The treatments were; 0, 30, 45, 60 kg P $ha^{-1}$ and farmer's practice. The tested variety was BRRI hybrid dhan3 in both locations. The unit plot size was 140 $m^2$ and each plot was separated by well-prepared levee. The seedlings were transplanted at 20 × 20 cm spacing. Urea applied in three equal splits. In Kotalipara, the highest grain yield was obtained from farmer practice plot followed by P @ 30 kg $ha^{-1}$. The crop yield in phosphorus omission plot was lower compared to other treatments. However, in Tongipara, the highest grain yield was obtained from farmer practice plot followed by 30 kg P $ha^{-1}$ and lowest in without application of P fertilizer plot. In both places farmers practice plots produced higher grain yield (Table 32).

**Table 31. Performance of different Aman rice varieties used as relay crop with jute inAman season 2016, Mukshudpur, Gopalganj.**

| Variety | Date of seeding | No. of farmers | Growth duration (day) | Panicle $m^{-2}$ | Grain yield (t $ha^{-1}$) |
|---|---|---|---|---|---|
| BRRI dhan56 | 7-9 Jul | 4 | 107 | 260 | 5.01 |
| BRRI dhan57 | 8 Jul | 3 | 104 | 250 | 4.73 |
| BRRI dhan62 | 8 Sep | 3 | 102 | 240 | 4.25 |
| BRRI dhan66 | 6 Aug | 4 | 109 | 300 | 6.20 |
| BRRI dhan49 | 8 Sep | 2 | 130 | 255 | 4.66 |
| BRRI dhan52 | 7 July | 3 | 140 | 265 | 5.04 |
| Shishumoti | 24 June | 1 | 149 | 180 | 3.14 |

**Table 32. Yield and yield components of BRRI hybrid dhan3 influenced by different P in Boro 2016-17.**

| Treatment | Tiller $m^{-2}$ | Panicle $m^{-2}$ | Grains $panicle^{-1}$ | Sterility (%) | Grain yield (t $ha^{-1}$) |
|---|---|---|---|---|---|
| | | | *Kotalipara, Gopalganj* | | |
| 30 kg P/ha | 319 | 269 | 127 | 21.4 | 6.83 |
| 45 kg P/ha | 317 | 266 | 123 | 22.9 | 6.63 |
| 60 kg P/ha | 314 | 263 | 126 | 24.1 | 6.48 |
| No P fertilizer | 277 | 235 | 122 | 25.3 | 6.43 |
| FP | 336 | 277 | 141 | 14.2 | 7.44 |
| $Lsd_{0.05}$ | 48.68 | 42.2 | 9.24 | 5.41 | 0.55 |
| | | | *Tongipara, Gopalganj* | | |
| 30 kg P/ha | 406 | 345 | 152 | 12.6 | 8.12 |
| 45 kg P/ha | 375 | 340 | 153 | 15.8 | 8.04 |
| 60 kg P/ha | 334 | 307 | 143 | 19.7 | 7.58 |
| No P fertilizer | 317 | 296 | 133 | 23.4 | 7.08 |
| FP | 391 | 361 | 159 | 16.2 | 8.39 |
| $Lsd_{0.05}$ | 34.97 | 23.84 | 7.47 | 4.0 | 0.38 |

# Soil Science Division

SUMMARY

In T. Aman, BR7895-4-3-3-2-3 (MER) gave 5.15 t $ha^{-1}$ grain yields with 54-11-26 kg $ha^{-1}$ of N-P-K and it was 98-21-53 kg $ha^{-1}$ of N-P-K for IR70213-10-CPA4-2-2-2 (RLR-1). BR8210-10-3-1-2 (RLR-2) produced similar grain yield (5.43 t $ha^{-1}$) with BRRI dhan49 at 88-17-28 kg $ha^{-1}$ of N-K-P. Suman swarna (Rajshahi) produced the highest grain yield (5.61 t $ha^{-1}$) with 78-12-38 kg $ha^{-1}$ of N-P-K.Nutrient requirement of BR(Bio)9786-BC2-132-1-3 was 91-13-35 kg $ha^{-1}$ of N-P-K for producing 5.01 t $ha^{-1}$ grain yields. In Boro, nutrient requirements for BR(BIO)9787-BC2-63-2-2 (Biotech-1), BR(BIO)9786-BC2-124-1-1 (Biotech-2), BR8340-16-2-1 (FBR) and BR7812-19-1-6-1-P2 (CTR) were 105-18-92, 109-19-96, 139-25-123 and116-20-102 kg $ha^{-1}$ of N-P-K, respectively.

A combination of 50 kg K and 50 kg N $ha^{-1}$ for BRRI dhan49 and 50 kg K and 120 kg N $ha^{-1}$ for BRRI dhan29 cultivation were suitable for grey terrace soil. The highest K uptake (184 kg $ha^{-1}$) was obtained in combination of 50 kg N and 200 kg K $ha^{-1}$. Under AWD, grain yield of BRRI dhan65 could be increased with 25% more N and K rates than the recommended dose. In Boro, the recommended dose was enough for different rice genotypes grown under AWD.

Grain yield increase with Zn spraying was about 2-10% for BRRI dhan58 and about 6-18% for BRRI dhan74 compared to the control. Brown rice Zn content with BRRI dhan74 varied from 22.02-23.78 m $g^{-1}$ under control condition, which increased to 24.25-25.79 m $g^{-1}$ after Zn spraying. Grain polishing by 9-12% reduced Zn content by about 20-29%.

Intensive rice cultivation without fertilizer application gave 1.17-2.22 t $ha^{-1}$ rice yields. The performance of T. Aman rice genotypes under P deficient condition was in the order of BRRI dhan49>Kasalat>Gainja; while the performance of Boro rice genotypes was in the order of BR(Bio)9786-BC2-161-1-2>BRRI dhan58=BRRI dhan60 both in P fertilized and unfertilized conditions. BRRI dhan49 produced higher grain yield than the other rice genotypes under P deficient conditions.

In double rice cropping pattern, STB dose gave 9.66 t $ha^{-1}$ $yr^{-1}$ grain yields but 50% STB + MM resulted in 12.51 t $ha^{-1}$ $yr^{-1}$ under triple rice cropping pattern. Long-term omission of N, P and K adversely affected rice yield. Rice grain yield was higher when 0.5 t $ha^{-1}$ vermicompost was used with full dose of chemical fertilizers during T. Aman and Boro seasons. The INM practice was superior over balanced chemical fertilization to maintain soil carbon stock. Mean weight diameter of water stable (MWDw) aggregates and crop yields were positively correlated with SOC.

Deep placement of urea briquettes (UB) and UB+IPNS with PL significantly increased rice yield and NUE irrespective of season and water management. Deep placement of UB and IPNS based organic amendments significantly reduced floodwater $NH_4^+$-N and $NH_3$ volatilization. NO fluxes were small compared to $N_2O$ fluxes.

Onion-Jute-Fallow, Jute-Rice-Fallow, Wheat-Mungbean-Rice and Maize-Fallow-Rice patterns are relatively more suitable for reducing GHG emission. Potato-Boro-T. Aman and Mustard-Boro-T. Aman cropping pattern showed the highest total rice equivalent yield (REY) and low global warming potential (GWP) than Boro-T. Aman-Fallow cropping pattern.Intermittent drainage for growing dry season irrigated rice under Potato-Boro-T. Aman and Mustard-Boro-T.Aman patterns can be adopted to reduce about 24-26% of total GHG emissions than continuous flooding. On average, 1.56 Tg $year^{-1}$ $CH_4$ emissions took place from paddy fields in Bangladesh during 2012-2015. Methane emission was more in wet season. About 50% of recommended fertilizer dose can be reduced for Boro rice cultivation if mustard crop is grown under standard fertilizer practices.

Different elements are depositing through fog and dust in Bangladesh. Fog water $NH_4^+$-N content was the highest (about 36 ppm) in Gazipur district and the lowest in Sylhet district. This indicates that industrialization is influencing wet and dry deposition in Bangladesh.

Bio-organic fertilizer at 2 $tha^{-1}$ with 25% less chemical N and 100% omission of TSP fertilizer produced statistically similar grain yield with complete fertilization. Long-term study proved that application of cow dung or poultry manure as IPNS improves soil biology and maintained nutrient dynamics as well as soil health and crop productivity.

**Determination of N, P and K fertilizer doses**. Nutrient requirements vary depending on genotypes, season and growing conditions. So, it is necessary to determine the requirement of these primary nutrients before releasing a new variety. Trials were conducted at BRRI farm, Gazipur (AEZ 28) in T. Aman and Boro seasons of 2016-17. Fertilizer requirements of advanced rice genotypes were determined in comparison to standard varieties following site specific nutrient management (SSNM) technique. Fertilizers used were: $T_1$= NPK (AEZ - basis), $T_2$= N omission, $T_3$= P omission and $T_4$= K omission. Fertilizer treatments were imposed in the main plots and rice genotypes in the subplots and repeated three times. Sulphur was applied as blanket dose. NPKS @ 160-25-65-10 kgha$^{-1}$ in Boro and 92-12-60-8 kgha$^{-1}$ in T. Aman were used.

**T. Aman season.** BR7895-4-3-3-2-3 produced the highest grain yield (5.15 t ha$^{-1}$), which was statistically similar with BRRI dhan72 (5.20 t ha$^{-1}$). Nutrient requirement of BR7895-4-3-3-2-3 is 54-11-26 kg ha$^{-1}$ of N-P-K. IR70213-10-CPA4-2-2-2 produced the highest grain (5.86 t ha$^{-1}$) followed by BR8214-19-3-4-1 (5.25 t ha$^{-1}$). Nutrient requirement of IR70213-10-CPA4-2-2-2 is 98-21-53 kg ha$^{-1}$ of N-P-K for satisfactory grain yield. Suman swarna (Rajshahi) produced the highest grain yield (5.61 t ha$^{-1}$) with 78-12-38 kg ha$^{-1}$ of N-P-K. BR(Bio)9786-BC2-132-1-3 produced the highest grain yield (5.01 t ha$^{-1}$) with 91-13-35 kg ha$^{-1}$ of N-P-K.

**Boro season.** BR(BIO)9787-BC2-63-2-2 produced the highest grain yield (6.15 t ha$^{-1}$) with 105-18-92 kg ha$^{-1}$ N-P-K and BR(BIO)9786-BC2-124-1-1 gave 6.39 t ha$^{-1}$ with 109-19-96 kg ha$^{-1}$ N-P-K. BRRI dhan63 produced the highest grain yield (7.02 t ha$^{-1}$) followed by BR7372-18-2-1-HR1-HR6(COM) (5.86 t ha$^{-1}$). BR8340-16-2-1 produced the highest grain yield (8.20 t ha$^{-1}$) with139-25-123 kg ha$^{-1}$ N-P-K and BR7812-19-1-6-1-P2 (cold tolerance) produced 6.80 t ha$^{-1}$ with 116-20-102 kg ha$^{-1}$ N-P-K.

**Influence of N and Krates**. The objectives of this study were to find out suitable N and K ratio for MV rice cultivation and to study their dynamics in soil-and plant systems.Three years studyfrom T. Aman 2014 to Boro 2017 was conducted at BRRI farm, Gazipur (AEZ 28). Potassium @ 0, 50, 100, 150 and 200 kg ha$^{-1}$ in the main plots and N (0, 50, 75 and 100 kg ha$^{-1}$ in T. Aman and 0, 100, 120 and 140 kg ha$^{-1}$ in Boro) in the sub-plots were tested with BRRI dhan49 and BRRI dhan29, respectively. Phosphorus and S was applied as blanket dose. Split-plot design was used with three replications.

**Grain yield.** In T. Aman 2014-16 under K deficient condition,N rates significantly decreased grain yield. In N deficient condition, K rate up to 50 kg ha$^{-1}$was responsible for increased grain yield (Table 1). Application of N beyond 50 kg ha$^{-1}$ at any levels of K and K doses beyond 50 kg ha$^{-1}$ at any levels of N could not bring significant grain yield advantage. So, 50 kg K and 50 kg N ha$^{-1}$ combination was suitable for BRRI dhan49. In Boro 2015-17 under K deficient condition, application of N @ 100 kg ha$^{-1}$ significantly increased grain yield. In N deficient condition, K rates were not responsible for increased grain yield (Table 2). Application of N @ 120 kg ha$^{-1}$ with 50 kg K ha$^{-1}$ produced 6.12 t ha$^{-1}$ rice grains, which was statistically identical with the highest grain yield of 6.39 t ha$^{-1}$ achieved with a combination of 140 kg N and 100 kg K ha$^{-1}$.

**Table 1. Effect of N and K rates on grain yield of BRRI dhan49, BRRI farm, Gazipur, T. Aman 2014-16.**

| K dose (kg ha$^{-1}$) | N dose (kg ha$^{-1}$) | | | |
|---|---|---|---|---|
| | 0 | 50 | 75 | 100 |
| 0 | 3.18bA | 2.74bB | 2.69bB | 2.92bAB |
| 50 | 4.15aB | 4.91aA | 4.89aA | 4.78aA |
| 100 | 4.05aB | 4.89aA | 4.88aA | 4.93aA |
| 150 | 4.05aB | 5.02aA | 5.00aA | 5.20aA |
| 200 | 4.14aB | 5.11aA | 5.03aA | 5.01aA |
| CV (%) | | 8.19 | | |

Small letters in a column and uppercase letters in a row compare means at the 5% level of probability.

**Table 2. Effect of N and K rates on grain yield of BRRI dhan29, BRRI farm, Gazipur, Boro 2015-17.**

| K dose (kg $ha^{-1}$) | N dose (kg $ha^{-1}$) | | | |
|---|---|---|---|---|
| | 0 | 100 | 120 | 140 |
| 0 | 2.96aB | 3.85bA | 3.46cA | 3.62cA |
| 50 | 3.23aB | 5.84aA | 6.12abA | 5.82abA |
| 100 | 3.20aC | 5.86aB | 6.16abAB | 6.39aA |
| 150 | 3.48aC | 5.75aA | 5.59bAB | 5.22bB |
| 200 | 3.04aB | 5.93aA | 6.23aA | 5.84abA |
| CV (%) | 9.93 | | | |

Small letters in a column and uppercase letters in a row compare means at the 5% level of probability.

So, 50 kg K and 120 kg N combination is suitable for BRRI dhan29 rice cultivation to get satisfactory grain yield.

**Uptake of N, P, K, Mn and Zn.** In T. Aman, grain N uptake of 45.9 kg $ha^{-1}$ was recorded with 50 kg K and 50 kg N $ha^{-1}$. Total K uptake significantly increased with the increase of K rates at different levels of N doses. Under K deficient condition, increased N dose reduced total K uptake. In N deficient condition, K uptake increased with increasing K levels. The highest K uptake (184 kg $ha^{-1}$) was obtained in combination of 50 kg N and 200 kg K $ha^{-1}$. At K deficient condition, total P uptake declined with increasing N dose but at K fertilized condition increasing N level acted synergistically for increased P uptake. At K and N deficient condition, Zn uptake increased with increasing N and K doses, respectively. The highest Zn uptake (0.66 kg $ha^{-1}$) was found with 150 kg K $ha^{-1}$ and 100 kg N $ha^{-1}$.

**Nitrogen and K dose for rice under AWD situations**. The AWD plays an important role in saving irrigation water requirement, but little information is available on nutrient requirement under such conditions. So, the objective of the study was to find out optimum N and K dose with standard P and S rates under AWD situations for saving 10-20% water for rice cultivation. BRRI dhan56, BRRI dhan57, BRRI dhan65 and BRRI dhan66 in T. Aman and IR83140-B-36-B-B and IR83142-B-71-B-B, BRRI dhan28 and BRRI dhan29 in Boro were tested with five fertilizer management options at BRRI farm, Gazipur for two years. Treatment combinations were: Control (Native nutrients), standard dose of NPKS, 25% more NK + standard dose of PS, 50% more NK + standard dose of PS and 75% more NK + standard dose PS. Standard dose of NPKS for Boro and T. Aman seasons were @ 138-18-64-11 and 92-12-42-9 kg $ha^{-1}$, respectively. Experiment was laid out in a split-plot design with three replications. Fertilizer management options were in the main plots and rice genotypes were in the sub-plots. Irrigation water was applied following AWD technique. In T. Aman, no AWD technique was followed. All plots were surrounded by 30 cm soil levee. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis.

**Grain yield.** In T. Aman, grain yield with no added fertilizers varied from 2.93 to 3.01 t $ha^{-1}$, being the highest in BRRI dhan66 (4.52 t $ha^{-1}$). Significant increase in grain yield was observed with all rice genotypes due to application of recommended fertilizer dose. Application of 25% additional NK significantly increased grain yield only in BRRI dhan65 (3.98 t $ha^{-1}$) compared to standard dose. In Boro, grain yield at native nutrient conditions varied from 2.68 to 3.40 t $ha^{-1}$, being the highest in BRRI dhan29 (3.49 t $ha^{-1}$). Irrespective of variety, significant increase in grain yield was observed due to use of recommended fertilizer dose (Table 3). Additional NK application failed to improve grain yield of Boro rice.

**Agronomic and geneticbio-fortification with zinc**. The present investigation was undertaken to find out the effectiveness of combining agronomic and genetic bio-fortification of Zn content in rice grains grown under two ecological conditions of Bangladesh.

The experiments were conducted in BRRI RS, Comilla and Rajshahi during Boro 2016-17. Available Zn content in initial soils of Comilla and Rashahi were 5.72 and 0.33 ppm, respectively. Wuxal Zinc and Antracol were tested with BRRI dhan58 and BRRI dhan74 and compared with no spraying conditions. The treatments were assigned

**Table 3. Grain yield (t ha$^{-1}$) of rice genotypes as influenced by fertilizer management options, Boro 2015-2016, BRRI, Gazipur.**

| | Genotype | | | | Mean |
|---|---|---|---|---|---|
| | IR83140-B-36-B-B | IR83142-B-71-B-B | BRRI dhan28 | BRRI dhan29 | |
| Control | 2.68 | 2.65 | 2.47 | 3.40 | 2.8b |
| Std. NPKS* | 5.63 | 5.37 | 5.67 | 5.99 | 5.66a |
| 25% more NK + Std. PS | 5.94 | 5.27 | 5.83 | 6.08 | 5.78a |
| 50% more NK + Std. PS | 6.05 | 5.53 | 5.81 | 6.13 | 5.88a |
| 75% more NK + Std. PS | 5.91 | 5.57 | 5.76 | 5.76 | 5.75a |
| Mean | 5.24ab | 4.88c | 5.11bc | 5.47a | |
| CV (%) | | 8.99 | | | |

Similar letters in a column and in a row are not significantly different at the 5% level of probability. *Std.=Standard dose for Boro season

in a factorial randomized complete block design with three replications. Unit plot size was 6- × 5-m. Spraying rate of Wuxal Zinc was 3,000 ml ha$^{-1}$ and Antracol at 1.5 kg ha$^{-1}$. Table 4 shows spray schedules and other agronomic practices. Two to three 35-40-day-old seedlings were transplanted at 20 × 20 cm spacing. No insecticide was used in the field;irrigation and weed control were done when necessary. Outer husks of unparboiled dried paddy were removed by Satake Testing Husker (Model THU-35B, Satake Corporation, Hiroshima, Japan) with rubber rollers coated with polyvinyl chloride compound to avoid mineral contamination. The dehusked brown rice was milled using a Grainman tester mill (Model 60-220-50-DT, Grain Machinery Manufacturing Corporation, Miami, FL, USA). Three different degrees of milling were tested: 0, 10, and 12%, where 10% represents well-milled, polished rice. Primary analysis for these

**Table 4. Agronomic operation schedules for Zn trial, Boro 2016-17.**

| Parameter | Comilla | Rajshahi |
|---|---|---|
| Seeding date | 10-12-2016 | 15-12-2016 |
| Transplanting date | 19-01-2017 | 22-01-2017 |
| Plot size (m) | 6 × 5 | 6 × 5 |
| Spacing (cm) | 20 × 20 | 20 × 20 |
| Seedlings hill$^{-1}$ | 2-3 | 2-3 |
| N-P-K-S-Zn kg ha$^{-1}$ | 120-28-67-14-3.5 | 120-20-70-20-0 |
| *Urea application* | | |
| First split | 04-02-2017 | 09-02-2017 |
| Second split | 25-02-2017 | 24-02-2017 |
| Third split | 14-03-2017 | 20-03-2017 |
| *Wuxal Zn + Antracol* | | |
| First spray | 25-02-2017 | 16-02-2017 |
| Second spray | 14-03-2017 | 15-03-2017 |
| Third spray with Wuxal Zn | 10-04-2017 | 24-04-2017 |

samples was performed using atomic absorption spectrophotometry (AAS; Shimadzu Model AA-6800, Shimadzu Corporation, Tokyo, Japan).

**Grain and straw yields.** Grain and straw yields varied largely because of locations (Table 5). Zinc spraying resulting in 0.87-1.31 t ha$^{-1}$ grain yield increase in Comilla site; but it was 0.12-0.33 t ha$^{-1}$ in Rajshahi site. Grain yield increase with Zn spraying was about 2-10% for BRRI dhan58 and about 6-18% for BRRI dhan74 compared to control.

**Grain Zn content**. In both the locations, grain Zn content increased with Wuxal spraying that decreased greatly with polishing (Table 6). Grain Zn content in brown rice of BRRI dhan58 under control condition was about 17 m g$^{-1}$ that increased to about 19 m g$^{-1}$ through spraying treatment. Brown rice Zn content of BRRI dhan74 varied from 22.02-23.78 m g$^{-1}$ under control condition, which increased to 24.25-25.79 m g$^{-1}$ after Zn spraying. Grain polishing by 9-12% reduced Zn content by about 20-29%.

## MANAGEMENT OF NUTRITIONAL DISORDERS IN RICE

**Intensive wetland rice cropping and grain yield**. This experiment was designed to harvest three rice crops in a year and to evaluate the consequences of intensive cropping on soil fertility over time. The experiment was initiated in 1971 in a permanent layout with NPK fertilizer application. After several modifications of treatments in 1982, 1984 and 1991, six treatments viz. control, reverse control (NPKSZnCu), NPK, NPKS, NPKSZn and

**Table 5. Some plant parameters as influenced by Zn spraying in two locations.**

| Variety | Grain yield (t $ha^{-1}$) | | Straw yield (t $ha^{-1}$) | |
|---|---|---|---|---|
| | Control | Zn Spray | Control | Zn Spray |
| *Comilla* | | | | |
| BRRI dhan58 | 7.95 | 8.82 | 9.06 | 9.08 |
| BRRI dhan74 | 7.47 | 8.78 | 8.10 | 9.03 |
| LSD (Trt) | 0.67 | | 0.97 | |
| *Rajshahi* | | | | |
| BRRI dhan58 | 5.68 | 5.80 | 6.73 | 6.97 |
| BRRI dhan74 | 5.18 | 5.51 | 6.45 | 6.75 |
| LSD (Var) | 0.45 | | NS | |

LSD at the 5% level of probability.

**Table 6. Zinc content (ppm) in rice grain as influenced by biofortification and polishing of rice in two locations.**

| | Brown rice | | 9-10% polished | | 11-12% polished | |
|---|---|---|---|---|---|---|
| | Control | Zn spray | Control | Zn spray | Control | Zn spray |
| *BRRI RS, Comilla* | | | | | | |
| BRRI dhan58 | 16.49 | 18.88 | 13.66 | 14.61 | 12.35 | 13.03 |
| BRRI dhan74 | 23.78 | 25.79 | 20.01 | 20.78 | 18.30 | 18.80 |
| LSD (Var*Trt) | 0.43 | | NS | | NS | |
| LSD (Var) | - | | 1.93 | | 2.09 | |
| *BRRI RS, Rajshahi* | | | | | | |
| BRRI dhan58 | 16.84 | 19.57 | 14.24 | 15.26 | 12.51 | 13.10 |
| BRRI dhan74 | 22.02 | 24.25 | 17.61 | 18.41 | 15.72 | 16.25 |
| LSD (Var) | 1.92 | | 0.55 | | 0.58 | |

LSD at the 5% level of probability.

NPKSZnCu were imposed in 2000. Recently tested varieties in T. Aus, T. Aman and Boro seasons were BRRI dhan48, BRRI dhan46 and BRRI dhan50, respectively. The NPK doses used were 140-25-80, 60-15-80 and 60-10-60 kg $ha^{-1}$ for Boro, T. Aman and T. Aus, respectively. Sulfur, Zn and Cu were applied at 10, 4 and 1 kg $ha^{-1}$ in Boro season only.

**Rice production trend**. Annual rice production is in decreasing trend because of continuous rice cultivation without fertilizer application (Fig. 1). In 2016, grain yield in control plot was 1.17-2.22 t $ha^{-1}$ irrespective of season. When NPKSZnCu fertilizers were used as reverse treatment, total rice production jumped to 13.31 t $ha^{-1}$ against 5.09 t $ha^{-1}$ that is even higher than complete fertilization (12.59 t $ha^{-1}$ $yr^{-1}$).

**Annual nutrient removal.** The highest N (261.87 kg $ha^{-1}$ $yr^{-1}$), P (57.69 kg $ha^{-1}$ $yr^{-1}$) and K (258.77 kg $ha^{-1}yr^{-1}$) removal was found with reverse management treatment.

**Performance of rice varieties under phosphorus deficit conditions.** The performance of rice varieties under P deficient condition was evaluated at BRRI farm, Gazipur during 2016-17. Experimental designs used were split-plot and split-split-plot for T. Aman and Boro, respectively with three replications. In T. Aman, four soil available P (1.80-2.50, 2.51-3.20, 3.21-3.90 and 3.91-4.60 mg $kg^{-1}$) were considered as main plot treatments and BRRI dhan49, Kasalat and Gainja as sub-plot treatments. In Boro, soil available P (1.70-2.30, 2.31-2.90, 2.91-3.50 and 3.51-4.10 mg $kg^{-1}$) were in the main plots, fertilizer P (0 and 20 kg $ha^{-1}$) in the sub-plots and BRRI dhan58, BRRI dhan69 and BR(Bio)9786-BC2-161-1-2 were assigned in the sub-sub plots. Grain yields were adjusted at 14% moisture content.

**Grain and straw yields.** In T. Aman,grain and straw yields increased significantly with greater soil available P levels. BRRI dhan49 produced the highest grain and straw yields compared to other genotypes irrespective of soil available P. The performance of tested rice genotypes were in the order of BRRI dhan49>Kasalat>Gainja and BRRI dhan49>Gainja> Kasalat in terms of yield and straw yields (Table 7). In Boro, grain yield in fertilizer-P control plot progressively increased with greater soil P levels. Soil P levels had no effect on grain yield under fertilizer-P applied plots (Table 8). Phosphorus application significantly increased grain yield compared to fertilizer-P control plots at all levels of soil P. Under fertilizer-P control plot, all Boro rice genotypes performed equally. But under P fertilized plot, BR(Bio)9786-BC2-161-1-2 line produced the highest grain yield (6.66 t $ha^{-1}$) compared to other genotypes (Table 8). BRRI dhan58 and BRRI dhan69 performed equally both under P fertilized and unfertilized plots. The highest straw yield (4.79 t $ha^{-1}$) was recorded with the greatest soil P (3.51-4.10 mg $kg^{-1}$), which was statistically similar with 2.91-3.50mg $kg^{-1}$ soil available P.

**Phosphorus nutrition.** Total P uptake by BRRI dhan49 was 7.23 kg $ha^{-1}$ at 1.80-2.50 soil P that increased to 16.57 kg $ha^{-1}$ at 3.91-4.60 soil P (Table 9). Similar trends were observed with Kasalat and Gainja. The highest P requirement (2.74 kg) was observed with maximum soil P level. Kasalat required the lowest amount of P (1.84 kg) for one ton grain production, while BRRI dhan49 and Gainja had the same P requirement.

## INTEGRATED NUTRIENT MANAGEMENT

**Integrated nutrient management for double and triple rice cropping.** 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 BRRI dhan46 were included as test variety. Fertilizers used were: Control, STB dose (NPKS @ 160-25-60-20 kg $ha^{-1}$ for Boro, 70-12-48-10 kg $ha^{-1}$ for T. Aus and 84-15-54-14 kg $ha^{-1}$ for T. Aman), STB (50%) + MM (CD @ 2 t $ha^{-1}$ + ash @ 1 t $ha^{-1}$ oven dried), FP (NPKS @ 80-10-20-10 kg $ha^{-1}$ for Boro, 70-10-15-0 kg $ha^{-1}$ for T. Aus and 70-10-15-0 kg $ha^{-1}$ for T. Aman). The experiment was laid out in RCB design with three replications. Grain yields were adjusted at the 5% moisture content.

**Grain yield.** In Boro under double cropping pattern, 100% STB and 50% STB + MM fertilizer dose produced statistically similar grain yield but under triple cropping pattern, 50% STB + MM fertilizer dose gave statistically higher grain yield than 100% STB dose (Table 10). In T. Aus, the highest grain yield of BRRI dhan43 was found in 50% STB + MM treatment, which was statistically higher than STB dose. In T. Aman under double and

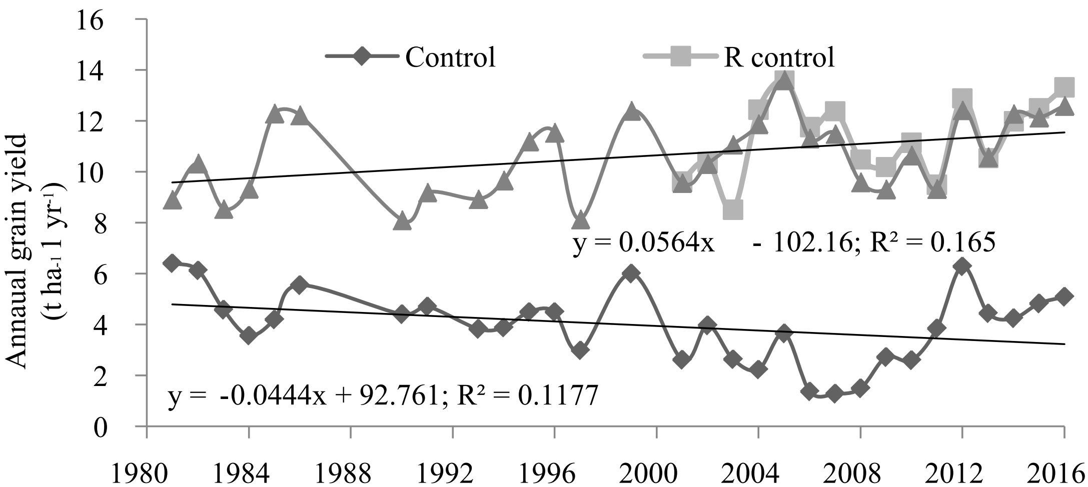



Fig. 1. Changes in annual rice production under wetland conditions over 37 years.

**Table 7. Effect of soil P and variety on yield of T. Aman rice, BRRI farm, Gazipur, 2016.**

| Soil P level (mg kg$^{-1}$) | Variety | | | | | | Mean | |
|---|---|---|---|---|---|---|---|---|
| | Grain yield (t ha$^{-1}$) | | | Straw yield (t ha$^{-1}$) | | | | |
| | BRRI dhan49 | Kasalat | Gainja | BRRI dhan49 | Kasalat | Gainja | Grain | Straw |
| 1.80-2.50 | 4.51 | 3.35 | 2.35 | 5.14 | 4.32 | 4.39 | 3.40 d | 4.62 b |
| 2.51-3.20 | 4.83 | 3.52 | 2.78 | 5.16 | 4.54 | 4.61 | 3.71 c | 4.77 b |
| 3.21-3.90 | 5.22 | 3.65 | 2.99 | 5.41 | 4.49 | 5.00 | 3.95 b | 4.97 ab |
| 3.91-4.60 | 5.80 | 4.18 | 3.16 | 6.12 | 4.61 | 5.14 | 4.38 a | 5.29 a |
| Mean | 5.09 a | 3.67 b | 2.82 c | 5.46 a | 4.49 c | 4.79 b | | |
| CV (%) | | | | | | | 5.09 | 5.72 |

Similar letters in a column or row of respective parameters are not significantly different at the 5% level of probability.

**Table 8. Effects of soil and fertilizer P on grain yield (t ha$^{-1}$) of Boro rice, BRRI farm, Gazipur, 2017.**

| Soil P (SP) (mg kg$^{-1}$) | Fertilizer P (FP) (kg ha$^{-1}$) | |
|---|---|---|
| | 0 | 20 |
| 1.70-2.30 | 1.92dB | 5.86aA |
| 2.31-2.90 | 3.06cB | 6.03aA |
| 2.91-3.50 | 3.70bB | 6.07aA |
| 3.51-4.10 | 4.63aB | 6.14aA |
| Variety | | |
| BRRI dhan58 | 3.20aB | 5.75bA |
| BRRI dhan69 | 3.32aB | 5.65bA |
| BR(Bio)9786-BC2-161-1-2 | 3.46aB | 6.66aA |
| CV (%) | 9.62 | |

Small letters in a column and uppercase letters in a row compare means at the 5% level of probability.

triple cropping pattern, 100% STB and 50% STB + MM fertilizer dose produced statistically similar grain yields. Cumulative yield of triple cropping was always higher than double rice cropping irrespective of treatments (Table 10). In Boro 2016-17 under double and triple cropping pattern, 100% STB and 50% STB + MM fertilizer treatments produced statistically similar grain yields but significantly higher than FP (Table 11).

**Long-term use of organic and inorganic nutrients in lowland rice.** Long-term missing element trial provides plant growth behaviour under deficit conditions and thus opportunity to take corrective measures. A long-term experiment was initiated on a permanent layout at BRRI farm Gazipur in 1985 Boro season having 12 treatments (see BRRI 2016) assigned in RCB design with four replications. In Boro 2000, each plot was divided into two to include a reverse treatment and additional varieties BRRI dhan29 and BRRI dhan31 to evaluate the reverse trends of missing elements. In Boro, NPKSZn was used @ 120-25-35-20-5 kg ha$^{-1}$, but in T. Aman it was 100-25-35-20-5 kg ha$^{-1}$. After 47$^{th}$ crop, treatments were modified with omission of Zn because of its sufficiency in the soil. The STB doses

**Table 9. Effect of soil P levels on P uptake and P requirement for different rice genotypes, T. Aman, BRRI, Gazipur.**

| Soil P level (mg kg$^{-1}$) | Variety | | | | | | Mean | |
|---|---|---|---|---|---|---|---|---|
| | P uptake (kg ha$^{-1}$) | | | P requirement (kg t$^{-1}$) | | | | |
| | BRRI dhan49 | Kasalat | Gainja | BRRI dhan49 | Kasalat | Gainja | P uptake (kg ha$^{-1}$) | P req. (kg t$^{-1}$) |
| 1.80-2.50 | 7.23cA | 4.30cB | 3.87cB | 1.60 | 1.27 | 1.63 | 5.13 | 1.50 b |
| 2.51-3.20 | 7.60cA | 5.33cB | 4.40cB | 1.60 | 1.53 | 1.57 | 5.78 | 1.57 b |
| 3.21-3.90 | 14.30bA | 8.03bB | 7.43bB | 2.73 | 2.20 | 2.50 | 9.92 | 2.48 a |
| 3.91-4.60 | 16.57aA | 9.93aB | 9.40aB | 2.87 | 2.37 | 3.00 | 11.97 | 2.74 a |
| Mean | 11.43 | 6.90 | 6.28 | 2.20 a | 1.84 b | 2.17 a | | |
| CV (%) | | | | | | | 10.09 | 7.65 |

Small letters in a column and uppercase letters in a row compare means at the 5% level of probability. In case of P requirement same letters within a column or row are not significantly different at the 5% level of probability.

**Table 10. Annual grain production (t ha$^{-1}$) under double and triple cropping patterns, BRRI, Gazipur, 2015-16.**

| Treatment | Double cropping | | | |
|---|---|---|---|---|
| | Boro 2015-16 (BRRI dhan29) | Fallow | T. Aman 2016 (BRRI dhan49) | Annual yield (t ha$^{-1}$) |
| $T_1$ = Control | 2.07 | - | 3.17 | 5.24 |
| $T_2$ = STB | 5.69 | - | 3.97 | 9.66 |
| $T_3$ = 50% STB+MM | 5.17 | - | 4.11 | 9.28 |
| $T_4$ = FP | 4.20 | - | 3.67 | 7.87 |
| $LSD_{0.05}$ | 0.57 | - | 0.50 | |
| | *Triple cropping* | | | |
| | Boro 2015-16 (BRRI dhan29) | T. Aus 2016 (BRRI dhan43) | T. Aman 2016 (BRRI dhan46) | Annual yield (t ha$^{-1}$) |
| $T_1$ = Control | 2.16 | 2.34 | 2.26 | 6.76 |
| $T_2$ = STB | 4.46 | 3.10 | 3.61 | 11.17 |
| $T_3$ = 50% STB+MM | 5.15 | 3.81 | 3.55 | 12.51 |
| $T_4$ = FP | 4.48 | 3.02 | 3.05 | 10.55 |
| $LSD_{0.05}$ | 0.57 | 0.16 | 0.41 | |

**Table 11. Yield scenarios of Boro rice under different treatments of double and triple cropping pattern, BRRI, Gazipur, 2016-17.**

| Treatment | Yield (t ha$^{-1}$) | | | |
|---|---|---|---|---|
| | Double cropping 2015-16 (15th crop, BRRI dhan29) | Double cropping 2016-17 (17th crop, BRRI dhan58) | Triple cropping 2015-16 (22th crop, BRRI dhan29) | Triple cropping 2016-17 (25th crop BRRI dhan74) |
| Control | 2.07 | 1.87 | 2.16 | 1.57 |
| STB | 5.69 | 5.20 | 4.46 | 5.00 |
| STB (50%)+MM | 5.17 | 5.18 | 5.15 | 4.75 |
| Farmer practice | 4.20 | 4.45 | 4.48 | 3.84 |
| $LSD_{0.05}$ | 0.57 | 0.65 | 0.57 | 0.70 |

of NPKS were 138-10-80-5 kg ha$^{-1}$ and 100-10-80-5 kg ha$^{-1}$ for Boro and T. Aman, respectively after 47th crop (BARC, 2005). Higher levels of available S in control plot compared to initial condition might be due to industrial deposition and thus S dose was reduced. Urea N was applied in three equal splits at final land preparation, at active tillering and at 5-7 days before PI. The rest of the fertilizers were applied at final land preparation. In Boro 2009-10, organic materials were used as third modification in $T_5$, $T_8$, $T_9$, $T_{10}$ and $T_{11}$ treatments. Oil cake (OC, 2 t ha$^{-1}$), saw dust (SD, 3 tha$^{-1}$), cow dung (CD, 3 t ha$^{-1}$), mixed manure, MM (CD: PM: SD: OC = 1:1:1:0.5) and PM @ 2 t ha$^{-1}$) in $T_{10}$, $T_9$, $T_5$, $T_{11}$ and $T_8$ treatments. Only N @ 138 kg ha$^{-1}$ was applied as top dress with organic amended treatments. Both missing elements and reverse management plots were merged for making 12 treatments. In T. Aman 2011-12, $T_9$ and $T_{11}$ treatments were changed to accommodate 60 and 40 kg K ha$^{-1}$, respectively. NPKSZn @ 100-7-80-3-5 kg ha$^{-1}$ was used in T. Aman 2013 and it was 138-7-80-3-5 kg ha$^{-1}$ in Boro 2013-2014. CD (3 t ha$^{-1}$), PM (2 t ha$^{-1}$) and mustard OC (2 t ha$^{-1}$) were used in $T_5$, $T_8$ and $T_{10}$ treatments. From T. Aman 2015, vermicompost (VC) was used in place of mustard OC with same rate. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis.

**Grain and straw yields.** In T. Aman, omission of N, P and K reduced rice yield than complete fertilization (Table 12). Among organic materials, CD and PM treated plot had the highest grain yield (4.91 and 4.86 t ha$^{-1}$) followed by VC (4.73 t ha$^{-1}$). The highest rice yield (4.65 t ha$^{-1}$) was obtained with 80 kg K ha$^{-1}$ and the lowest (4.01 t ha$^{-1}$) with 40 kg K ha$^{-1}$.

Table 12. Effect of organic and inorganic nutrients on rice grain and straw yields of BRRI dhan49, T. Aman 2016 and BRRI dhan29, Boro 2017, BRRI, Gazipur.

| Treatment | T. Aman | | Boro | |
|---|---|---|---|---|
| | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) |
| NPKSZn@100-7-80-3-5 $kgha^{-1}$ | 4.65 | 6.60 | 6.11 | 6.80 |
| NPSZn (-K) | 4.10 | 5.26 | 4.28 | 5.24 |
| NKSZn (-P) | 4.22 | 5.75 | 1.76 | 4.14 |
| PKSZn (-N) | 4.17 | 5.49 | 2.66 | 3.15 |
| CD (3 $tha^{-1}$) + IPNS | 4.91 | 6.23 | 6.59 | 7.36 |
| NPKS (-Zn) | 4.48 | 5.98 | 6.04 | 7.18 |
| NPKZn (-S) | 4.51 | 5.58 | 6.06 | 6.89 |
| PM (2$tha^{-1}$) + IPNS | 4.86 | 5.96 | 6.57 | 7.26 |
| NPKSZn@100-7-60-3-5 $kgha^{-1}$ | 4.37 | 5.64 | 5.56 | 6.09 |
| VC (2 $tha^{-1}$) + IPNS | 4.73 | 6.37 | 6.56 | 7.20 |
| NPKSZn@100-7-40-3-5 $kgha^{-1}$ | 4.01 | 6.09 | 5.55 | 6.25 |
| Control | 3.25 | 4.17 | 1.67 | 2.48 |
| $LSD_{0.05}$ | 0.35 | 0.84 | 0.34 | 0.59 |
| CV (%) | 5.58 | 10.22 | 4.73 | 7.00 |

In Boro,grain yield decreased due to omission of nutrients. Complete fertilization treatment gave 6.11 $tha^{-1}$ grain yields, which decreased significantly to 2.66, 1.76, and 4.28 t $ha^{-1}$ due to omission of all nutrients, N, P and K, respectively. However, the decrease in grain yield due to S and Zn omission was insignificant (Table 12). Application of PM @ 2 t $ha^{-1}$ CD @ 3 t $ha^{-1}$ and VC @ 2 t $ha^{-1}$ with IPNS based fertilization gave the highest grain yields (6.59, 6.57 and 6.56 t $ha^{-1}$), which was significantly higher than complete fertilizer treatment. Reduced dose of K @ 60 kg K $ha^{-1}$ produced significantly lower grain yield than complete fertilization, but K @ 40 kg $ha^{-1}$ and K @ 60 kg $ha^{-1}$ produced similar grain yield of BRRI dhan29. Straw yield in CD @ 3 t $ha^{-1}$ with IPNS fertilizer treatment was the highest (7.36 t $ha^{-1}$) followed by PM + IPNS and VC+IPNS based fertilization (7.26 and 7.20 t $ha^{-1}$). All inorganic treatments resulted in reduced straw yields followed by organic amendment.

**Annual rice production.** Long-term application of organic materials with IPNS based fertilizers showed increasing trend of rice yield, while inorganic fertilizer alone showed almost yield plateau during 2010-2016 (Fig. 2).

**Vermicompost and poultry manure for rice cultivation.** Long-term rice culture shows declining yield trends. Poor soil OM and imbalanced nutrient management were the main factors for reduction in rice yield. The present study was undertaken to find out the effect of PM and VC with chemical fertilizers on yield and yield attributes of T. Aman and Boro rice and its impacts upon soil nutrient status and nutrient uptakes. The experiment was conducted at BRRI farm, Gazipur since Boro 2015. Initial soil (0-15 cm depth) properties were: clay loam texture; pH 6.78; 12.3 g $kg^{-1}$ organic C; 1.3 g $kg^{-1}$ total N, 1.8 mg $kg^{-1}$ available P and 50 mg $kg^{-1}$soil exchangeable K. The VC contained 50% MC, 2.0% total N, 0.52% P, 0.42% K and 0.3% S. PM contained 50% MC, 1.9% total N, 0.56% P, 0.75% K and 1.1% S. PM and VC were used with full doses of chemical fertilizer @ 0.5, 1.0, 1.5, 2.0 and 2 t $ha^{-1}$ + IPNS fertilizer and compared with control. Each treatment was assigned in 4- × 5-m sized plot and repeated three times in a RCB design. Forty-five and 25-day-old seedlings of BRRI dhan29 and of BRRIdhan49 respectively were transplanted at 20 × 20-cm spacing in Boro and T. Aman seasons. Chemical fertilizers (N-P-K-S-Zn = 138-10-80-5-5 kg $ha^{-1}$) were applied one day before rice transplanting. Flood water level of 5-7 cm depth was maintained in the field and drained 21 days before crop harvesting. At harvesting, rice plants were collected for analysis of N, P and K content and nutrient uptakes based on BRRI standard methods.

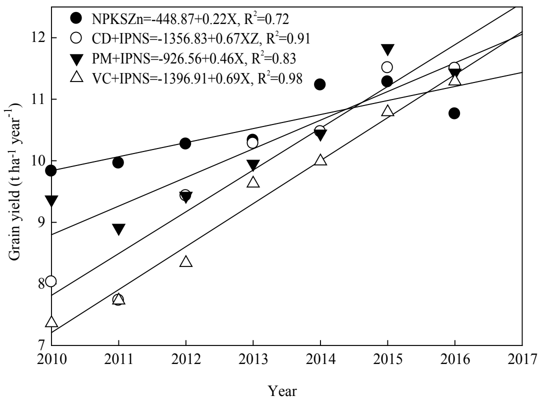



Fig. 2. Annual rice grain yield trend under inorganic and organic amended soil.

**Rice productivity.** Integrated use of OM and chemical fertilizer significantly improved rice yield in both the seasons. Grain yield was 3.00-3.86 t ha$^{-1}$ in control plot, which increased with higher VC rates. Only chemical fertilizer (NPKSZn) showed significant difference of rice yield than PM and VC treated plots. Nutrient added through VC was N, P, K and other minerals might have affected rice yield. Since selected VC contained 2-5.0-4.2 g kg$^{-1}$ of N-P-K its application at 2 Mg ha$^{-1}$ supplied approximately 40-10-8.2 kg ha$^{-1}$ of N-P-K. These nutrients could be helpful to replace chemical fertilizer requirements. The use of 0.5 Mg ha$^{-1}$ VC with full doses of chemical fertilizers showed higher grain yield than other treatments.

**Soil organic carbon dynamics in rice-rice cropping system**. In rice field, C emission as $CO_2$ and $CH_4$ are potential sources of C loss. Besides, C mineralization pattern varies with soil amendments. Considering temperature, rainfall and fertilizer management practices, it is difficult to determine SOM turnover in a cropping system. Soil C dynamics after 10 years exposure of changing climate and management practices were investigated with DNDC and DSSAT models. The models were validated with observed SOC data. Carbon mineralization rate (*r*) was determined through laboratory incubation study and compared with model generated data.

**Carbon mineralization rate.** The *r* value obtained in incubation study was comparable with model generated data. Carbon mineralization rate was lower in control plot compared to balanced chemical fertilizer use and INM treatment. The highest C mineralization rate was obtained in INM treatment and simulated *r* value was higher in both tested crop models compared to observed data (Table 13).

**Carbon balance.** Application of PM along with chemical fertilizers in INM treatment increased SOC stock compared to initial soil (Table 14). The SOC stock was increased by 27.98% due to addition of PM at 3 t ha$^{-1}$ for the last 10 years. The SOC decreased by 46% in fertilizer control and 15% in balanced chemical fertilizer treatment. At per DNDC model, total C (TC) sequestration was 47 kg ha$^{-1}$ yr$^{-1}$ in control and 151 kg ha$^{-1}$ yr$^{-1}$ in chemical fertilizer plot. Whereas, it was 539 kg ha$^{-1}$ yr$^{-1}$ in INM practised soil. The DNDC model derived Closses were 236, 866 and 1,343 kg ha$^{-1}$ yr$^{-1}$ from control, complete chemical fertilization and INM, respectively.

## SOIL PHYSICS AND PLANT NUTRITION

**Carbon storage and aggregate stability of paddy soil under continuous organic amendment**. Long-term organic amendment in paddy field play an important role for improving soil physiochemical properties and crop productivity but no such study has yet been conducted under rice based cropping patterns in Bangladesh. A field experiment was carried out to evaluate the effect of continuous organic amendments on SOC stock and aggregate stability. The experiment was established in 2009 and continued up to 2016 under rice-fallow-rice pattern with fourtreatments: control (no amendment), use of NPKSZn fertilizers, CD and PM with IPNS based inorganic fertilizations. Soil bulk density was reduced in organic amendment plots than control and NPKSZn treated plots after eight years. Aggregate C and Ncontents were greater with organic and inorganic fertilizers compared to non-treated control.

**Table 13. Carbon mineralization rate under different fertilizer management practices, BRRI, Gazipur.**

| Treatment | C mineralization rate (r) = tyr$^{-1}$ | | |
|---|---|---|---|
| | Incubation study | DNDC | DSSAT |
| Fertilizer control | 0.009 | 0.005 | 0.007 |
| Chemical fertilizer | 0.010 | 0.010 | 0.018 |
| INM | 0.011 | 0.020 | 0.030 |

Table 14. Carbon balance after last 10 years in a rice-rice-fallow cropping pattern, BRRI, Gazipur.

| Treatment | C stockyear (tha$^{-1}$yr$^{-1}$) | | | C sequestration (kg ha$^{-1}$yr$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | Observed OC | DNDC TC | DSSAT | Observed OC | DNDC (TC) | DSSAT (TC) |
| Fertilizer control | 10.95 | 10.7 | 18.4 | -213 | 46.6 | 149 |
| Balanced chemical fertilizer | 17.303 | 19.7 | 25.6 | -72.15 | 151.5 | 457 |
| INM | 26.304 | 30.7 | 30.8 | 127.86 | 539 | 706 |
| Initial soil | 20.55 | - | - | - | - | - |

**Changes in rice productivity and soil carbon.** Rice grain yield decreased significantly in control plot than other treatments, although it did not vary significantly among inorganic and organic treated plots (Fig. 3). The amounts of SOC were higher in each aggregate size fraction of IPNS based CD and PM fertilized plotsthan NPKSZn (Table 15). Aggregate size fraction (0.30 mm) showed the highest SOC (1.6 to 2.15%) than other aggregate size fraction under all treatments. In 0.30 mm aggregate sieve size, SOC increased by about 19-34% with CD and PM than control treatment.

**Changes in mean weight diameter of water-stable (MWDw) aggregates.** The highest MWDw observed were 7.05 and 7.02 mm in CD and PM treatments, respectively (Table 16). About 5-6% increase in MWDwwas observed because of CD and PM addition compared to control indicating that amendment with organic materials can improve soil structure and increase aggregate stability. Bulk density and SOC have also been improved because of organic amendments.

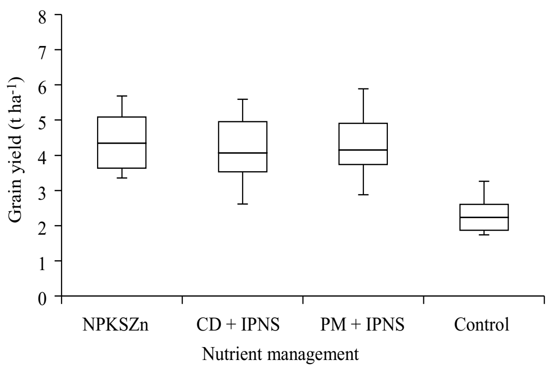



Fig. 3. Grain yields under organic and inorganic amended soil during 2009-16, BRRI, Gazipur.

SOIL AND ENVIRONMENTAL PROBLEMS

**Influence of N and water management on $N_2O$ and NO emissions**. Use efficiency of reactive N is only about 30-40% and the rest is responsible for environmental pollution such as $N_2O$ emission. Soil is considered to be one of the most important sources and sinks of GHG. So, experiments were conducted to study the effects of N placement and its sources on rice yield, NUE and to quantify N losses as ammonia volatilization, ammonium-N in flood water, and emissions of $N_2O$ and NO under continuous standing water (CSW) and alternate wetting and drying (AWD) irrigation regimes.

Field experiments were conducted at BRRI farm, Gazipur during T. Aman 2016 and Boro 2016-17 under both AWD and CSW conditions. Eight treatments were tested. PU was applied as broadcast in three equal splits in Boro season and two splits in T. Aman season at 7-10 DAT, while urea briquettes (UB) were applied as a single application during first top dressing (TD) of PU. UB were placed at 7-10 cm below the soil surface between four hills at alternate rows. Integrated plant nutrient system (IPNS) based PM, VC was applied before transplanting. Under CSW condition, plots were remained flooded until two weeks before harvesting. Under AWD condition, irrigation water was applied when water falls below 15 cm of soil surface. Grain yield was adjusted at 14% moisture content and straw yield was adjusted as oven dry basis.

Flood water samples were collected every day at 8:00 AM before one day of fertilizer application and continued for seven days after each TD of PU to measure flood water $NH_4^+$-N using spectrophotometer at 420 µm. Ammonia ($NH_3$) volatilization were measured using 'closed chamber technique' and boric acid trap method. NO emissions were measured with a Teledyne

Table 15. Mean SOC content (%) at different sieve size in organic and inorganic amended soil (8-year average), BRRI, Gazipur.

| Treatment | Sieve size (mm) | | | | |
|---|---|---|---|---|---|
| | 0.074 | 0.149 | 0.30 | 0.59 | 2.0 |
| NPKSZn | 0.50 | 1.03 | 1.86 | 1.59 | 1.18 |
| CD with IPNS | 0.57 | 1.57 | 2.15 | 2.25 | 1.28 |
| PM with IPNS | 0.55 | 1.36 | 1.90 | 1.77 | 1.27 |
| No fertilizer | 0.40 | 0.90 | 1.60 | 1.50 | 1.16 |

Table 16. Changes of SOC stock as influenced by organic amendment, BRRI, Gazipur.

| Treatment | MWDw (mm) | Bulk density (g $cm^{-3}$) | SOC (g $kg^{-1}$) |
|---|---|---|---|
| NPKSZn | 6.77 | 1.40 | 11.8 |
| CD with IPNS | 7.05 | 1.37 | 12.8 |
| PM with IPNS | 7.02 | 1.38 | 12.7 |
| Control | 6.66 | 1.40 | 11.6 |
| Initial soil | 6.78 | 1.39 | 12.2 |

API T200 Chemiliminescence Analyzer and $N_2O$ with a Teledyne API T320U Gas Filter Correlation Analyzer. Calibration was done using Teledyne API T700 Dynamic Dilution Calibrator. Gas sampling and analysis system were controlled by Campbell Scientific CR3000 Datalogger.

**Rice yield, total N uptake and NUE.** In T. Aman, grain yields recorded in control treatment were 3.5 t $ha^{-1}$ in AWD and 3.7 t $ha^{-1}$ in CSW condition, while in Boro season; it was 2.7 t $ha^{-1}$ in AWD and 3.2 t $ha^{-1}$ in CSW. Deep placement of UB significantly increased grain yield compared to broadcast PU at similar N rate in both water management practices. No yield variations were observed among IPNS based organic amendments in T. Aman season, while PU+IPNS with VC showed poor performance in Boro season. Deep placement of UB remarkably increased total N uptake (TNU) and recovery efficiency of N ($RE_N$) than PU in both the seasons. In T. Aman, there were no significant differences of TNU and $RE_N$ among IPNS based organic treatments, but in Boro season IPNS based organic amendments showed variation irrespective of water regimes.

**Flood water $NH_4^+$-N and $NH_3$ volatilization.** Irrespective of N rates, sources and seasons, the amount of flood water $NH_4^+$-N was higher in broadcast PU treatment after 1-2 days of fertilizer application, while it was negligible in deep placement of UB throughout 7 days of measurement (Fig. 4). Similarly, IPNS based organic fertilizers, except UB+IPNS with PM showed a slight peak of flood water $NH_4^+$-N after two days of fertilizer application. Broadcast application of PU significantly increased $NH_3$ volatilization compared to UB and PU+IPNS with PM (Fig. 5). The variation in $NH_3$ volatilization between UB and PU+IPNS with PM treatment was similar. As in Boro, similar pattern of flood water $NH_4^+$-N and $NH_3$ volatilization was observed in T. Aman season.

**Cumulative $N_2O$-N and NO-N emissions.** Cumulative $N_2O$-N and NO-N fluxes were measured from control, UB, PU and PU+IPNS with PL treatments during T. Aman 2016 (Fig. 6a) and Boro 2017 (Fig. 6b) under AWD conditions. UB significantly increased $N_2O$ and NO emissions compared to broadcast PU, PU + IPNS with PL and control treatment in T. Aman season. Emissions from PU, PU + IPNS with PL and control treatments were similar. In contrast, no significant difference in total $N_2O$ fluxes between UB and PU were observed in Boro season. PU + IPNS with PL and control treatment produced similar cumulative $N_2O$ fluxes, which was lower than PU and UB treatment.

**Greenhouse gas emissions from selected cropping patterns**. There are many cropping patterns existed in Bangladesh. Variable amounts of GHG emission takes place from such patterns, but data are not available. In order to estimate GHG emission from agriculture fields, Cool Farm Tool Beta-3 was used. Non-rice based cropping patterns had lower global warming potential (GWP) than rice-rice based cropping patterns. Onion-Jute-Fallow, Jute-Rice-Fallow, Wheat-Mungbean-Rice and Maize-Fallow-Rice patterns are relatively more suitable for reducing GHG emission and subsequently GWP. Potato-Boro-T. Aman and Mustard-Boro-T. Aman cropping pattern showed the highest total REY and low GWP than Boro-T.

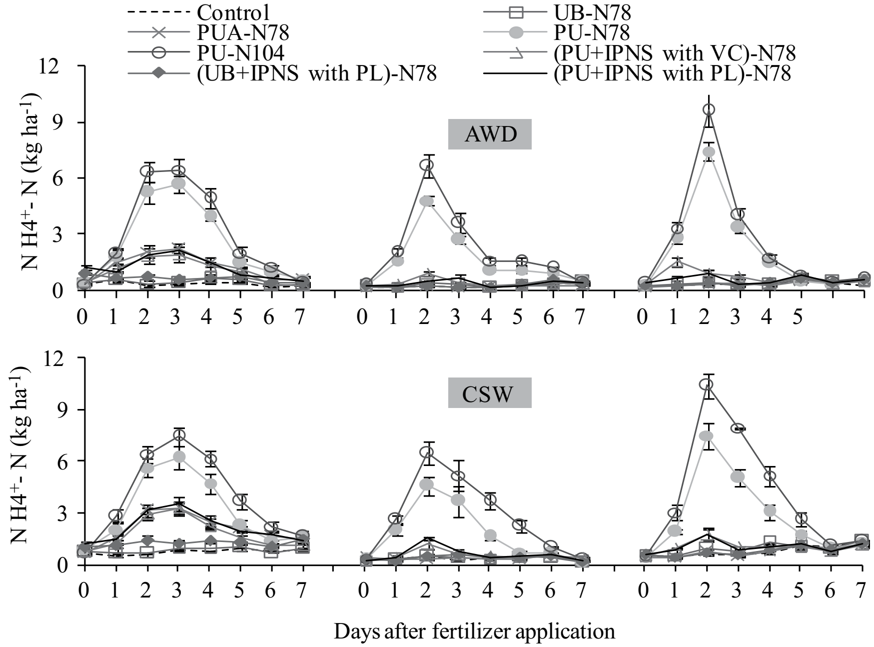



Fig. 4. Changes in flood water $NH_4^+$-N in AWD and CSW conditions as influenced by N sources, rates and methods of application, Boro 2017. TD-1, TD-2, TD-3, PU, UB, PL, VC and PUA represent first, second and third topdressing of urea, prilled urea, urea briquette, poultry litter, vermicompost and PU deep placement by applicator, respectively. Vertical bars indicate SE of mean (n=3).

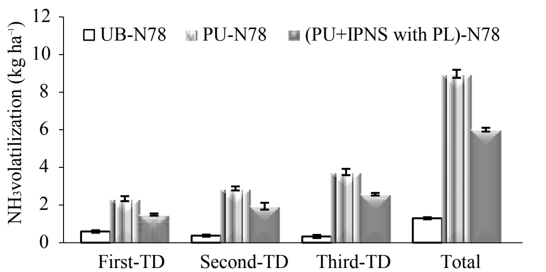



Fig. 5. Ammonia volatilization from UB, broadcast PU and PU+IPNS with PL during Boro 2017 under AWD condition. Vertical bars indicate standard error of mean (n=3).

Aman-Fallow pattern. Intermittent drainage for growing dry season irrigated rice under Potato-Boro-T. Amanand Mustard-Boro-T. Aman patterns can be adopted to reduce about 24-26% of total GHG emissions than continuous flooding and also to maintain higher crop productivity and food security in Asian countries.

**Methane emission scenariosin Bangladesh**. Mymensingh and Dinajpur districts were the hotspot areas in Bangladesh from where significantly higher amounts of $CH_4$ emission took place than other

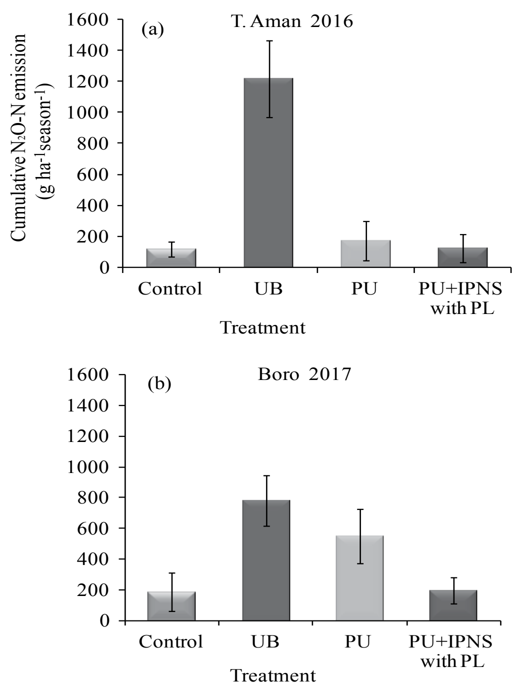



Fig. 6. Cumulative $N_2O$ and NO-N emissions as influenced by N sources and methods of application under AWD condition, Gazipur. Vertical bars indicate SE of mean (n=3).

districts (Fig. 7). Among 64 districts, the lowest $CH_4$ emission was found in Ramgati and Bandarban districts. In terms of $CH_4$ emission rate, it varied from 89 to 148 kg $ha^{-1}$ $year^{-1}$ depending on locations of the country and types of rice culture and variety used (Fig. 8). In total, estimated $CH_4$ emission was about 1.56 Tg $year^{-1}$ in Bangladesh in which the contribution of T. Aman was greater than other seasons (Fig. 9). This implies that we have to take necessary steps to reduce methane emission from paddy fields. Fertilizer, water and organic matter management along with choice of variety would be future priority areas of research.

**Climate smart agricultural practices**. Activities on climate smart agricultural practices were initiated at three villages of Gazipur and Kishoreganj districts during 2015. Experiments were conducted at Pakundia and Kotiadia of Kishoreganj district. Short duration T. Aman varieties with rice crop manager (RCM) based practices were introduced and compared with farmers' practices. Cool Farm Tool Beta-3 was used to determine total GHG emission.

Introduction of short duration rice variety not only helped in mustard crop sowing at the right time but also reduced about 15-20 GWP ($CO_2$eq kg $ha^{-1}$) and increased about 15-30% rice yield than long duration variety. There was no significant yield difference because of 50% reduction in fertilizer rate. In machine and hand transplanting after one pass by tractor gave higher yield than 3-4 pass

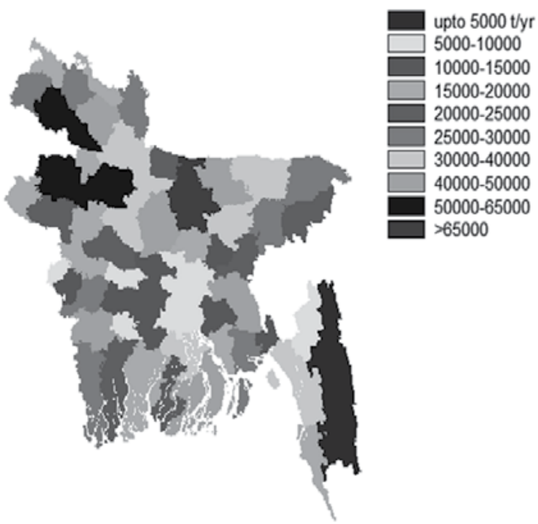



Fig. 7. Annual CH4 emission from paddy fields.

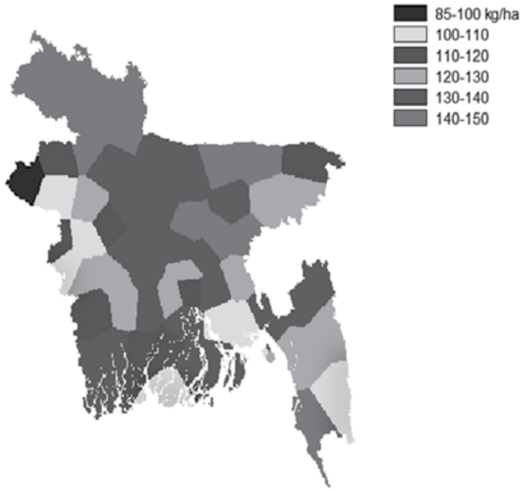



Fig. 8. Methane emission rates from paddy fields.

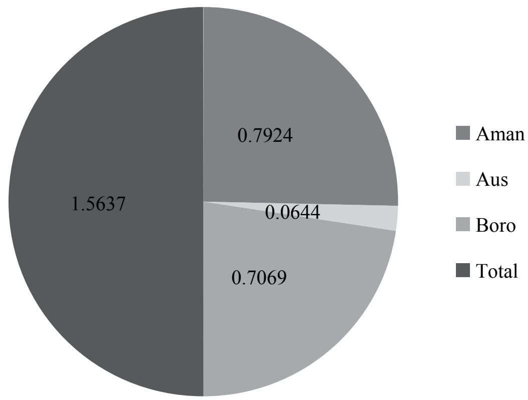



Fig. 9. Total methane emission (Tg $year^{-1}$) from paddy fields in Bangladesh.

conditions. About 50% of recommended fertilizer dose for Boro rice could be reduced if mustard crop is grown under standard fertilizer practices. GHG emission can also be reduced due to mustard and short duration rice variety cultivation.

**Compositions of wet and dry depositions in Bangladesh**. Composition of dry and wet atmospheric depositions varies depending on geographic locations. Fog water was collected from different regions of Bangladesh and dust from Gazipur during 2016-17 and its compositions were analyzed. The composition of fog water and dust varied greatly among locations. The $NH_4^+$-N content was the highest (about 36 ppm) in Gazipur district and the lowest in Sylhet district (Table 17). Cadmium (0.16 ppm) and P (1.75 ppm) contents are

Table 17. Chemical composition of fog water at different region in Bangladesh, 2015-16.

| Composition | Habiganj | Rangpur | Sylhet | Sonagazi | Rajshahi | Gazipur | Comilla | $LSD_{0.05}$ | Gazipur (dust)* |
|---|---|---|---|---|---|---|---|---|---|
| pH | 6.62 | 7.03 | 7.14 | 7.25 | 7.52 | 6.98 | 7.44 | 0.24 | - |
| EC (dS $m^{-1}$) | 0.09 | 0.33 | 0.21 | 0.25 | 0.24 | 1.01 | 0.37 | 0.25 | - |
| $NH_4^+N$ (ppm) | 10.10 | 18.44 | 3.60 | 5.35 | 18.40 | 35.47 | 25.53 | 3.62 | 0.57 |
| P (ppm) | 0.89 | 0.18 | 0.01 | 0.18 | 0.04 | 1.75 | 1.00 | 0.44 | 0.11 |
| K (ppm) | 6.27 | 16.35 | 4.96 | 18.10 | 6.05 | 20.95 | 26.87 | 9.1 | 0.42 |
| S (ppm) | 6.31 | 8.57 | 2.10 | 6.10 | 5.05 | 7.08 | 8.59 | 2.80 | 0.35 |
| Zn (ppm) | 0.82 | 2.15 | 0.30 | 0.28 | 0.28 | 0.30 | 0.14 | 0.47 | 0.57 |
| Na (ppm) | 0.00 | 7.50 | 10.00 | 5.00 | 2.50 | 8.75 | 0.00 | 4.7 | 0.12 |
| Ca (ppm) | 4.43 | 4.43 | 0.00 | 0.00 | 9.99 | 27.58 | 0.00 | 4.29 | 1.61 |
| Cd (ppm) | 0.12 | 0.12 | 0.13 | 0.12 | 0.12 | 0.16 | 0.13 | 0.99 | - |
| Mn (ppm) | 1.10 | 0.15 | 0.00 | 1.61 | 0.15 | 0.53 | 4.06 | 0.41 | 0.06 |
| Fe (ppm) | 0.83 | 1.42 | 2.55 | 2.00 | 0.89 | 0.32 | 0.00 | 0.02 | - |

*Values are in percent.

also high in Gazipur district along with electrical conductivity (1.01 $dSm^{-1}$). In Gazipur, S, Zn, K N, Ca, etc are depositing as dust. These indicate that industrialization is influencing wet and dry deposition in Bangladesh. This study needs to be done elaborately for assessing ecological consequences and soil fertility management.

## SOIL MICROBIOLOGY

**Evaluation of bio-organic fertilizers in soil-plant system**. Chemical fertilizer manufacturing and its use for crop production is causing air, water, and soil pollution along with increased GHG emission and thus are responsible for alteration of ecosystem and biodiversity. Free-living $N_2$-fixing and PSB and PGPB can play an important role in reducing the use of chemical fertilizers for crop production. Five bio-organic fertilizers (BoF) were formulated at BRRI soil microbiology laboratory using a consortium of free-living $N_2$ fixing and PSB. The objectives of the study were to evaluate the BoF and its efficacy to promote rice plant growth and yield and to standardize chemical N and K requirements with BoF for rice yield maximization.

The BoF was tested at BRRI farm, Gazipur in Boro 2016-17. The experiment was conducted on clay loam soil. The compositions of BoF were: 17% C, 1.4% available N, 0.13% available P, 0.72% exchangeable K, $6 \times 10^8$ cfu $g^{-1}$ free living $N_2$ fixing bacteria, $8 \times 10^8$ cfu $g^{-1}$ PSB, 5% rock phosphate and pH 8. Fertilizer control, 100% chemical NPKS fertilizer, 100% chemical NKS fertilizer, BoF (2 t $ha^{-1}$ dry weight) +100% chemical NKS fertilizer, 75% chemical NPKS fertilizer, BoF (2 t $ha^{-1}$) +75% chemical NKS fertilizer, BoF (2 t $ha^{-1}$) + 65% chemical NKS fertilizer, BoF (2 t $ha^{-1}$) + 55% chemical NKS fertilizer, $T_9$ = bio-organic fertilizer (2 t $ha^{-1}$) and seed inoculation. Each treatment was assigned in $4 \times 3$ $m^2$sized plot and repeated three times in a RCB design. Forty-day-old seedlings of BRRI dhan29 were transplanted at 20-× 20-cm spacing. Recommendation rates of chemical fertilizers (N-P-K @ 140-20-80-10 kg $ha^{-1}$) were applied one day before rice transplanting. Bio-organic fertilizers were applied at the same time of chemical fertilizers. Flood water level of 5-7 cm depth was maintained during rice cultivation and drained 21 days before harvesting.

**Yield and yield components**. Application of bio-organic fertilizer can substitute 100% TSP fertilizer and supplement 25% crop N requirement (Table 18). Similar results were also obtained for yield contributing characters such as panicle length, panicle$m^{-2}$ and filled grain.

**Influence of long-term nutrient management on soil health**. A study was conducted at BRRI farm, Gazipur to find out the effect of long-term (10 years) nutrient management on soil health. Soil samples (0-20 cm) were collected from balanced chemical fertilizers, -N, -P, -K, IPNS (CD) and IPNS

**Table 18. Yield and other parameters of BRRI dhan29 as influenced by fertilizer management, BRRI farm, Gazipur, Boro 2016-17.**

| Treatment | Grain yield ($tha^{-1}$) | Straw yield ($tha^{-1}$) | Panicle $m^{-2}$ | Panicle length (cm) | Filled grain $panicle^{-1}$ | TGW (g) |
|---|---|---|---|---|---|---|
| Control | 2.60 c | 2.01 f | 178 c | 24.04 c | 107 c | 24.24 |
| 100% NPKS | 7.43 a | 6.01 a | 302 a | 25.88 a | 163 a | 23.86 |
| 100% NKS | 7.20 a | 5.66 abc | 293 a | 25.65ab | 141 b | 24.15 |
| BoF+ 100% | 7.45 a | 5.85 ab | 278 a | 25.65ab | 162 a | 24.04 |
| 75% NPKS | 6.74 b | 5.34 bcd | 279 a | 25.89 a | 139 b | 24.26 |
| BoF+ 75% NKS | 7.40 a | 5.74 abc | 288 a | 25.68ab | 130b | 24.67 |
| BoF+ 65% NKS | 6.43 b | 5.24 cd | 234 b | 25.58ab | 139b | 24.06 |
| BoF+ 55% NKS | 6.30 b | 4.44 e | 233 b | 25.42ab | 134b | 23.74 |
| BoF | 5.80 b | 5.39 bcd | 297 a | 24.86bc | 133b | 23.95 |
| Seed inoculation | 5.67 b | 4.99 de | 278 a | 24.20 c | 125bc | 24.25 |
| CV (%) | 1.93 | 3.77 | 5.32 | 1.17 | 4.69 | 1.98 |

(PM) treated plots and compared with fertilizer control treatment. Ten soil health indicators such as SOM, $NH_4^+$-N available P, exchangeable K, total microbial population, free-living $N_2$ fixing bacteria, PSB, phosphatase and urease activities were determined. These soil health indicators were co-related with different fertilizer management options using principal component analyses (PCA).

Application of organic matter as IPNS treatment increased total microbial population, $N_2$ fixing, PSB population (Fig. 10), urease and phosphatase activity in soil along with improvement of SOM, $NH_4^+$-N, available P and K (Table 19). Missing of N and K nutrients significantly reduced microbial populations. Balanced fertilization affected soil biology by reducing total and beneficial microbial communities. The influence of fertilizer management practices followed the order of $NH_4^+$-N>$N_2$ fixing bacteria>SOM>yield>

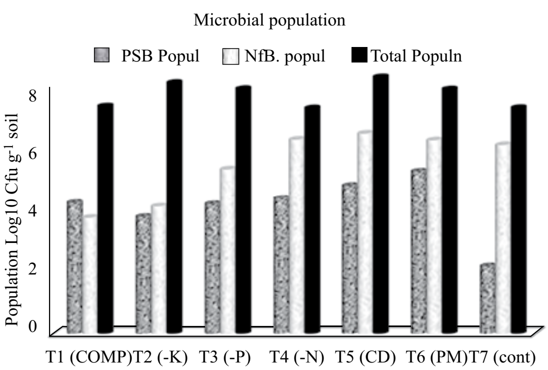



Fig. 10. Bacteria population at 0-20 cm soil depth

**Table 19. Soil properties and rice yield after 10 years of nutrient management practices, BRRI, Gazipur.**

| Treatment | SOM (%) | $NH_4^+$-N | Available P | Available K | Rice yield* (t $ha^{-1}$) |
|---|---|---|---|---|---|
| Complete fert. | 0.95 | 154.0 | 27.0 | 0.15 | 5.40 |
| -K | 1.18 | 105.0 | 34.5 | 0.11 | 3.94 |
| -P | 0.84 | 149.3 | 20.9 | 0.14 | 3.84 |
| -N | 0.94 | 87.5 | 42.1 | 0.14 | 3.09 |
| CD | 1.17 | 177.3 | 43.2 | 0.18 | 6.13 |
| PM | 1.18 | 515.7 | 83.2 | 0.17 | 6.47 |
| Control | 0.71 | 75.8 | 21.9 | 0.11 | 2.19 |
| LSD (0.5) | 0.06 | 11.0 | 4.0 | 0.02 | 0.72 |

*Rice yield in Boro 2015.

urease>available P>exchangeable K>total bacterial population>PSB population>phosphatase. Long-term study proved that IPNS improved soil health and sustained soil biology over balanced chemical fertilizer management options.

**Isolation and characterization of plant growth promoting bacteria.** The PGPB can improve plant growth by $N_2$ fixation, phytohormone and siderophore production, phosphorus solubilization and disease control. Wetland rice ecosystem can harbor diverse group of PGPB. Hence, this study was undertaken to isolate indigenous PGPB from different rice varieties grown in acid and terrace soils and to determine some of their beneficial traits for rice cultivation. Soil samples were collected from acid (Lalmonirhat and Komalganj) and terrace (Gazipur) soils. Total bacteria, fungus, actinomycetes, free living $N_2$ fixing bacteria and PSB population were estimated using serial dilution technique. Isolated PGPBs were tested for their ability to fix $N_2$, solubilize phosphorus and produce IAA.

**Microbial population**. Total bacteria population was higher than fungal, actinomycetes, $N_2$-fixing bacteria and PSB populations. Total bacteria populations were higher ($6.67 \times 10^7$ cfu $g^{-1}$ soils) in Komalganj and lower in Habiganj. Higher number of fungus ($2.08 \times 10^3$ cfu $g^{-1}$ soil), actinomycetes ($2.10 \times 10^3$ cfu $g^{-1}$ soils) and free living $N_2$ fixing bacteria ($3.01 \times 10^4$ cfu g-$^1$ soils) were found in soils of Bhanga, while PSB population ($1.73 \times 10^4$ cfu $g^{-1}$ soils)was higher in Habiganj soil (Table 20).

**Indole acetic acid (IAA) production**. Isolated bacteria were able to produce IAA, which varied with strains and locations. In the presence of tryptophan, the bacterial isolates of three different locations produced IAA ranging from 0.01 to 0.05%, except one strains (SL4) in Lamonirhatthat produced 0.36% IAA.

**Capacity of fixing $N_2$and solubilizing phosphate**. The PSB and $N_2$ fixing ability of the isolated strains in Gazipur varied from 0.01 to 0.12% and 0.03 to 0.08%, respectively.Phosphorus solubilizing ability of the isolated strains form Lalmonirh at soil varied from 0.01 to 0.16%, while $N_2$ fixation ranged from 0.05 to 0.13%. In Komalganj, values for P and N varied from 0.01 to 0.8% and 0.03 to 0.08%, respectively.

**Table 20. Microbial population (Cfu $g^{-1}$ soil) in different locations.**

| Location | Total bacteria | Fungus | Actinomycetes | $N_2$-fixing bacteria | PSB |
|---|---|---|---|---|---|
| Komalganj | $6.67 \times 10^7$ | $1.70 \times 10^3$ | $1.67 \times 10^3$ | $8.22 \times 10^3$ | $1.65 \times 10^3$ |
| Habiganj | $6.44 \times 10^6$ | $7.85 \times 10^2$ | $1.96 \times 10^2$ | $8.23 \times 10^3$ | $1.78 \times 10^4$ |
| Bhanga | $3.95 \times 10^7$ | $2.08 \times 10^3$ | $2.10 \times 10^3$ | $3.01 \times 10^4$ | $1.73 \times 10^4$ |

# Irrigation and Water Management Division

SUMMARY

ALART material of BR8340-16-2-1 under FBR gave good performance than the check with AWD but, none of the ALART from PQR and CTR was found better than check. ALART BR(BE)6158-RWBC2-1-2-1-1 and BR (Bio) 9786-BC2-49-1-2 gave better performance and may be expected for the variety. Therefore, AWD should not be imposed during reproductive stage.

Generally a decreasing trend with the depth of layers was observed. Hydraulic conductivity was very less in the lower profiles of Tanore, Ishurdi and Kaharolupazilas. The profile data indicates that soil hydraulic conductivity is higher in Thakurgaon, Mithapukur and Sherpur compared to Tanore, Ishurdi and Kaharol. AWD irrigation upto 15 cm below the ground can be followed for Boro rice cultivation for higher water productivity. Potato-Braus- T. Aman pattern can ensure higher productivity with less amount of irrigation. BRRI dhan31 is more drought tolerant than BRRI dha70 and BRRI dhan72 according to long duration varieties.

Almost all the chemical properties of water after filtration by treatment $FM_1$ and $FM_2$ satisfied the WHO standard limit. Treatment $FM_3$ showed higher value of alkalinity, calcium and potassium, although these values were within the permissible limit. This may be the residual effect of charcoal. Peak discharge found 0.82, 0.74 and 0.90 L $s^{-1}$ for $FM_1$, $FM_2$ and $FM_3$ respectively.

In both of the study locations, river water became saline (> 4.0 dS/m) after December and as high as 20-25 dS/m in April. Therefore, surface fresh water was trapped in local canals within December. In Dacope, groundwater level varied from 0.75-0.95 m and salinity from 2.3-3.52 dS/m. In Amtali, groundwater level varied from 1.02-1.40 m and its salinity from 3.25-11.7 dS/m, which is beyond the permissible limit of irrigation. In both the sites, soils were slightly alkaline in nature and soils were dominated by clay fraction having bulk density of 1.34-1.38 g/cc in Dacope and 1.39-1.42 g/cc in Amtali site. In Dacope, field capacity moisture level varied from 33.1 to 43.0% and it gradually decreased up to 23.5 to 29.0% in wilting point and its water holding capacity varied from 8.3 to 14.0%. This is an indication of clay dominant poor drainage capacity. In both the locations, salinity increased gradually with depth of soil and over time; soil salinity in rice field was about five times higher than irrigation water salinity. In non-rice field, soil salinity varied from 4 to 8 dS/m at varied depth.

Production of Boro rice in the coastal area is an option for cropping intensification in the comparatively low land areas where water receding delayed after T. Aman harvesting. Boro rice can be successfully grown in both of the tested locations.

Increase in minimum temperature and decrease in sunshine hours are likely to reduce T. Aman rice yields in north-west part of Bangladesh. The study clearly indicates the usefulness of the regression based approach for evaluating the impact of climatic variability on yield of T. *Aman* rice; however there is a need to include other biotic and abiotic stresses that are operative simultaneously along with climatic conditions for precise estimates. For this purpose, use of simulation tools and artificial intelligence systems need to be employed.

Rice grain yield was reduced by 256 to 403 kg $ha^{-1}$ for BRRI dhan28, 172 to 370 kg $ha^{-1}$ for BRRI dhan29 and 268 to 432 kg $ha^{-1}$ for BRRI dhan58 per 1°C temperature rise. On the contrary, $CO_2$ concentration compensated yield by 225 to 275 kg $ha^{-1}$ for BRRI dhan28, 230 to 267 kg $ha^{-1}$ for BRRI dhan29 and 198 to 275 kg $ha^{-1}$ for BRRI dhan58 per 50 ppm $CO_2$ rise. In general, grain yield reduction and compensation rate was lower in warmer region and higher in cooler region. Growth duration was reduced by about nine days irrespective of location and variety with an exception for BRRI dhan58, which has comparatively less growth duration reduction per degree temperature rise. In the projected climate change scenarios, maximum temperature at flowering stage of rice might cross the critical limit and thus reduction in rice yield is expected. To avoid this situation, shifting of sowing window for Boro rice and to develop cold and heat tolerant rice varieties would be the options for sustaining food security in Bangladesh and similar environments in other parts of the world.

WATER USE EFFICIENCY IMPROVEMENT IN IRRIGATED AGRICULTURE

**Study on water stress tolerance capacity for different advanced rice genotype of BRRI**

The experiment was conducted in experimental field of BRRI HQ, Gazipur during Boro season, 2017. In total, twenty-one materials were used. Water stress imposed throughout the growing season. In this experiment AWD means applying irrigation water when perched water table goes below 15 cm from ground surface. The treatments were as follows: $T_0$= Continuous flooding, $T_1$=irrigation water when perched water table goes below 15 cm from ground surface (GS), $T_2$= Irrigation three days after going perch water table at 15 cm below GS, $T_3$= Irrigation five days after going perch water table at 15 cm below GS,$T_4$=Irrigation seven days after going perch water table at 15 cm below GS and $T_5$=Irrigation 10 days after going perch water table at 15 cm below GS.

Water stress prior to irrigation were measured from the tensiometer reading. Results revealed that for different levels of water stress in terms of kPa at 15 cm below the soil surface were also different by water treatment at vegetative, ripening and reproductive stages. Same water treatment gave different levels of water stress by different stages. For example, in mid March, $T_2$ treatment showed water stress at 12 kPa and it was reach only 15 to 20 kPa at $T_3$ and $T_4$ treatment but in mid April the same treatment showed 60 to 80 kPa.

**Yield performance of ALART material supplied by Breeding Division**

Table 1 presents the grain yields of ALART under premium quality rice (PQR), favourable Boro rice (FBR) and cold tolerant rice (CTR). Two ALART materials with check variety BRRI dhan50 and BRRI dhan63 were evaluated under PQR. All the materials under PQR showed better performance in AWD than CF. Up to $T_3$ treatment gave optimum yield for all ALART and grain yields were decreased after that treatment. Two ALART with check variety BRRI dhan58 were evaluated under FBR. ALART BR8340-16-2-1 gave the highest yield (5.86 t/ha) from AWD treatment. Yield reduced significantly with more stress than $T_1$. But $T_3$ treatment gave significantly higher yield than the check variety and other ALART.

ALART BR7812-19-1-6-1-P2 with check variety BRRI dhan28 and BRRI dhan36 were evaluated under CTR. ALART did not give good performance in respect of yield than the two check variety.

**Table 1. Rice yield of ALART materials of PQR, FBR and CTR and check variety along with irrigation treatment at BRRI HQ farm, Gazipur during Boro 2017.**

| ALART and check variety | Grain yield (t/ha) | | | | | |
|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| | | | *PQR* | | | |
| BR8076-1-2-2-3 | 4.35 | 4.88 | 4.21 | 4.12 | 3.92 | 3.55 |
| BR7372-18-2-1-HR1-BR6(Com) | 4.19 | 4.52 | 4.06 | 4.05 | 3.73 | 3.75 |
| BRRI dhan50 | 3.97 | 5.14 | 4.32 | 4.14 | 3.83 | 3.73 |
| BRRI dhan63 | 4.42 | 4.36 | 4.17 | 4.14 | 3.92 | 3.28 |
| $LSD_{0.05}$ | | | | | | ns |
| CV% | | | | | | |
| | | | *FBR* | | | |
| BR8338-34-3-4 | 4.40 | 4.69 | 4.25 | 4.08 | 3.82 | 3.74 |
| BR8340-16-2-1 | 5.62 | 5.86 | 4.73 | 4.66 | 4.03 | 3.84 |
| BRRI dhan58 | 5.64 | 4.92 | 4.70 | 4.05 | 3.86 | 3.60 |
| $LSD_{0.05}$ | | | | | | 0.60 |
| CV% | | | | | | |
| | | | *CTR* | | | |
| BR7812-19-1-6-1-P2 | 4.36 | 4.24 | 3.40 | 3.15 | 3.17 | |
| BRRI dhan28 | 4.98 | 5.44 | 4.58 | 4.16 | 3.66 | |
| BRRI dhan36 | 4.70 | 4.80 | 4.18 | 4.03 | 3.62 | |
| $LSD_{0.05}$ | | | | | | ns |
| CV% | | | | | | |

**Yield performance of ALART material supplied by Biotechnology Division**

ALART BR (BE) 6158-RWBC2-1-2-1-1 gave better yield performance than check variety of BRRI dhan29. This ALART gave the higher yield in all the AWD treatment because it escaped the water stress during panicle initiation to flowering stage. But it gave the highest yield in CF treatment. Three ALART-1 (short duration) materials named BR (Bio) 9787-BC2-63-2-2, BR (Bio) 9787-BC2-63-2-4 and BR (Bio) 9787-BC2-173-1-3 with check variety of BRRI dhan28 significantly influenced by water treatment (Table 2). CF and AWD treatment gave higher yield for all the materials along with check variety. BR (Bio) 9787-BC2-173-1-3 materials and BRRI dhan28 showed better yield up to the treatment of $T_2$, but yield was significantly reduced with the higher water stress by the other two materials.

ALART-2 (long duration) materials along with check variety gave better yield performance with all AWD treatments. $T_3$ gave significantly same yield but yield decreased significantly by the more water stress treatment.

All the genotypes gave better performance with AWD treatment. This year optimum rainfall occurred in reproductive stage for long duration ALART, that is why, yield was better in more stresses with AWD treatment but short duration ALART felt water stress and yield reduced significantly in more stresses with AWD treatment. ALART material of BR8340-16-2-1 under FBR gave good performance than the check with AWD but none of the ALART from PQR and CTR was found better than the check. ALART BR(BE)6158-RWBC2-1-2-1-1 and BR(Bio)9786-BC2-49-1-2 performanced better and may be expected for the variety. Therefore, more water stresses with AWD should not be imposed during reproductive stage.

**Table 2. Rice yield of ALART, ALART-1 (short duration) and ALART-2 (long duration) materials and check variety along with irrigation treatment at BRRI HQ farm, Gazipur during Boro 2017.**

| ALART material and check variety | Water treatment | | | | | |
|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| *ALART material* | | | | | | |
| BR(BE)6158-RWBC2-1-2-1-1 | 6.41 | 6.15 | 5.87 | 5.12 | 5.09 | 4.75 |
| BRRI dhan29 | 6.13 | 5.25 | 5.35 | 4.09 | 3.76 | 3.65 |
| $LSD_{0.05}$<br>CV% | | | | | | ns |
| *ALART-1 (short duration) materials* | | | | | | |
| BR(Bio)9787-BC2-63-2-2 | 4.58 | 4.34 | 3.62 | 3.57 | 3.36 | 2.41 |
| BR(Bio)9787-BC2-63-2-4 | 4.41 | 4.67 | 3.93 | 3.66 | 2.85 | 2.89 |
| BR(Bio)9787-BC2-173-1-3 | 4.25 | 4.17 | 4.06 | 3.82 | 3.72 | 3.00 |
| BRRI dhan28 | 4.35 | 4.73 | 4.22 | 4.19 | 3.60 | 3.25 |
| $LSD_{0.05}$<br>CV% | | | | | | 0.51<br>8.2 |
| *ALART-2 (long duration) materials* | | | | | | |
| BR(Bio)9786-BC2-122-1-3 | 5.61 | 5.53 | 5.52 | 4.51 | 4.31 | 4.35 |
| BR(Bio)9786-BC2-49-1-2 | 4.99 | 6.18 | 5.19 | 4.96 | 4.33 | 4.02 |
| BR(Bio)9786-BC2-59-1-2 | 5.52 | 5.67 | 5.51 | 4.93 | 4.72 | 4.66 |
| BR(Bio)9786-BC2-124-1-1 | 5.77 | 5.23 | 4.91 | 4.87 | 4.53 | 4.18 |
| BRRI dhan29 | 6.13 | 5.25 | 5.35 | 4.09 | 3.76 | 3.65 |
| $LSD_{0.05}$<br>CV% | | | | | | 0.68<br>8.4 |

**Determination of physical and hydraulic properties in different soil types**

Soil samples were collected from Tanore (Rajshahi), Ishurdi (Pabna), Thakurgaon sadar (Thakurgaon), Kaharol (Dinajpur), Sherpur (Bogra) and Mithapukur (Rangpur). Undisturbed soil samples were collected from different layers (0-10, 10-25, 25-50 and 50-100 cm). Saturated hydraulic conductivity of the soil samples were determined using falling head method. Each trial was repeated for at least three times.

Hydraulic conductivity varies with sites and depth of the layer. The highest saturated hydraulic conductivity of the top layer soil was found in Thakurgaon (0.4567090 m/day) followed by Mithapukur (0.0882103 m/day), Tanore (0.0062800 m/day), Sherpur (0.0048241 m/day), Kaharol (0.0044759 m/day) and Ishurdi (0.0036729 m/day), respectively. Generally a decreasing trend with the depth of layers was observed. Hydraulic conductivity was very less in the lower profiles of Tanore, Ishurdi and Kaharol upazilas. The profile data indicate that soil hydraulic conductivity is higher in Thakurgaon, Mithapukur and Sherpur compared to Tanore, Ishurdi and Kaharol.

**Development of soil moisture declination model for alternate wetting and drying (AWD) irrigation for rice cultivation**

This experiment was undertaken to develop a model for proper irrigation scheduling of rice with AWD method. There were four treatments as- maintaining continuous standing water from +5 cm to 0 cm ($T_1$), AWD irrigation from +5 cm to -15 cm ($T_2$), AWD irrigation from +5 cm to -20 cm ($T_3$), and AWD irrigation from +5 cm to -25 cm ($T_4$). RCB design was followed with four replications. BRRI dhan28 was the tested variety. Seeding was done on 10$^{th}$ December 2016. Forty-five-day-old seedlings were transplanted on 24$^{th}$ January 2017. Individual plot size was 6 m × 6 m and each plot was separated from others with 1 m buffer area. A spacing of 20 cm × 20 cm was maintained. Recommended fertilizer management and cultural practices were followed. Crop was harvested on 2$^{nd}$ May 2017.

Experimental results show that yield of BRRI dhan28 varies with different irrigation treatments. The number of irrigations applied in treatment $T_1$, $T_2$, $T_3$ and $T_4$ were 17, 14, 13 and 12, respectively. The irrigation water applied in treatment $T_1$, $T_2$, $T_3$ and $T_4$ were 890 mm, 736 mm, 690 mm and 636 mm, respectively. The highest yield was obtained from treatment $T_1$ (5109 kg/ha) followed by $T_2$ (5087 kg ha$^{-1}$), $T_3$ (4833 kg ha$^{-1}$) and $T_4$ (4426 kg ha$^{-1}$). The yield difference between $T_1$ and $T_2$ were statistically insignificant. Study data also indicate that treatment $T_2$ (15 cm AWD) gives similar yield to $T_1$ (continuous standing water) but saves 17.3 percent of irrigation water (3 irrigations). Therefore, AWD irrigation up to 15 cm below the ground can be followed for Boro rice under similar condition for higher water productivity.

**Optimization of irrigation water for maximum year round production**

The experiment was conducted to findout suitable cropping patterns that gives higher productivity with less amount of irrigation. Six cropping patterns were tested during 2016-17. These patterns include the most popular Boro-Fallow-T. Aman ($P_1$) with Mustard-Late Boro-T. Aman ($P_2$); Potato-Braus-T. Aman ($P_3$); Lentil-Braus-T. Aman ($P_4$); Wheat-Braus-T. Aman ($P_5$) and Maize-Aus-T. Aman ($P_6$). Both long duration Boro (BRRI dhan29) and Aman (BRRI dhan49) varieties were used in $P_1$. In all other patterns, short duration BRRI dhan62 was used as a Aman variety. Short duration Boro variety BRRI dhan28 and Aus variety BRRI dhan48 were used in other patterns as late Boro/Braus/Aus rice. BARI Sarisha-14, BARI Masur-6, BARI Alu-41, BARI Gom-26 and hybrid Maize NK-40 were used as Rabi crop.

BRRI dhan29 gave the highest yield (7.99 t/ha) in Boro season. Satisfactory yield was obtained from BRRI dhan28 (5.03 t/ha) as late Boro and BRRI dhan48 (4.17 t/ha) as Braus rice. In Aman season, highest yield was obtained from BRRI dhan49 (4.90 t/ha) followed by BRRI dhan62 (3.92-4.18 t/ha). Satisfactory yield was obtained from Potato (20.21 t/ha) in Rabi season. The highest rice equivalent yield was obtained from Potato-BRRI dhan28- BRRI dhan62 (18.00 t/ha) and Potato-BRRI dhan48-BRRI dhan62 (17.90 t/ha) patterns that required 760 mm irrigation. The rice equivalent yield of Fallow-BRRI dhan29-BRRI dhan49 was 12.89 t/ha with 1125 mm irrigation. Therefore, Potato-Braus-T. Aman pattern can ensure higher productivity with less amount of irrigation.

UTILIZATION OF WATER RESOURCES IN RAIN-FED ENVIRONMENT

**Effect of drought on different T. Aman varieties**

The experiment was conducted to evaluate relative drought tolerance of some Aman varieties based on yield performance. Nine popular T. Aman varieties classified into three groups based on the growth duration were grown. BRRI dhan56, BRRI dhan57 and BRRI dhan62 were under small growth duration ($G_1$); BRRI dhan33, BRRI dhan66 and BRRI dhan71 were under medium growth duration ($G_2$); and BRRI dhan31, BRRI dhan70 and BRRI dhan72 were under long growth duration categories ($G_3$). Three water management treatments were applied as- application of supplementary irrigation whenever necessary ($T_1$); rainwater conservation by placing polythene sheets in levee ($T_2$); and maintaining rained condition ($T_3$). Transplanting was done on 8$^{th}$ August 2016 with 21-day-old seedlings of $G_1$ varieties, 28 days old seedlings of $G_2$ varieties and 35 days old seedlings of $G_3$ varieties. BRRI recommended fertilizers were applied. Similar other management practices were followed for each treatment.

Water stress was found from 2$^{nd}$ decade of October 2016. Stress induced was highest on the long duration varieties followed by medium and short duration varieties. The yield of BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan33, BRRI dhan66, BRRI dhan71, BRRI dhan31, BRRI dhan70 and BRRI dhan72 under irrigated condition were 3294, 3135, 3179, 4174, 4008, 4698, 4872, 4399 and 4255 kg/ha, respectivelyand under rainfed condition were 3048, 2923, 2957, 3625, 3595, 4176, 4309, 3733 and 4217 kg/ha, respectively. Among the short duration varieties, yield loss was lowest in BRRI dhan57 (6.75%) followed by BRRI dhan62 (6.98%) and BRRI dhan56 (7.48%). Growth duration of BRRI dhan56 (107 days) was higher than BRRI dhan56 (104 days) BRRI dhan62 (102 days). Therefore, BRRI dhan56 is more drought tolerant compared to the two other varieties. Among the medium duration varieties, yield loss was lowest in BRRI dhan66 (10.30%) followed by BRRI dhan71 (11.12%) and BRRI dhan33 (13.16%). Growth duration of BRRI dhan66, BRRI dhan71 and BRRI dhan33 were 112, 113 and 116 days, respectively. Therefore, these varieties were similar in respect to drought tolerance. Among the long duration varieties, yield loss was lowest in BRRI dhan31 (11.55%) followed by BRRI dhan72 (14.51%) and BRRI dhan70 (15.16%). Growth duration of BRRI dhan31, BRRI dhan70 and BRRI dhan72 were 139, 136 and 133 days, respectively. Therefore, BRRI dhan31 is more drought tolerant compared to the two other varieties. Thus, BRRI dhan31 was found as the most drought tolerant among the selected varieties.

SUSTAINABLE MANAGEMENT OF WATER RESOURCES

**Determination of suitable method for safe groundwater recharge**

The experiment was conducted at BRRI HQ farm, Gazipur to identify a suitable method for safe groundwater recharge. A prototype of 1 m × 1 m ×1 m (original size 3 m × 3 m ×3 m) recharge tank was constructed with mild steel sheet. A 4 cm diameter (original 10 mm) strainer of 33 cm long (original 1 m) was placed at the bottom of the tank. Different filter materials were placed according to order into the tank. The experiment involved three different filter media. These are 1) $FM_1$= Fine sand+ medium sand+ coarse sand 2) $FM_2$= Fine sand+ medium sand+ Gravel+ Khoa, and 3) $FM_3$= Soil+ fine sand+ Coarse sand+ Charcoal+ stone+ Khoa. Locally available filter materials were collected and placed them in the recharge tank according to order. Coarser materials were placed at the bottom of the tank and finer materials at the top. Runoff water from rainfall was collected from a canal network. Water was lifted in to the tank using a plastic beaker. The time of filling the tank was recorded. Initial water sample was collected for analysis its quality. Three tanks were filled with the same water. The times of starting water fall through the outlet of the tanks were recorded. Discharge of the tanks at regular interval was monitored. Water samples after filtration from each method were collected to identify the final quality of recharged water. Different quality parameters like turbidity, pH, free chlorine, hydraulic conductivity, Magnesium, Calcium, colour, iron, sodium, potassium etc. were analyzed both in source water and recharged water using spectrophotometer in laboratory.

Table 3 shows the chemical properties of runoff water from rainfall and after filtration by different filter media were analyzed. All the chemical properties were compared with World Health Organization (WHO) drinking water standard. Electric conductivity of water remained in desired limit (<1 dS $m^{-1}$) in all the treatments although slightly increased in $FM_3$. This may be caused due to presence of charcoal. Almost same pH value (7.5-7.8) was found in each treatment and source. Each filter media had a great potentiality to remove solid particles. Source water had the highest turbidity 305 NFU but after filtration 1.7, 3.7 and 2.1 NFU were found in $FM_1$, $FM_2$ and $FM_3$, respectively. Since desired limit of turbidity is less than 5 NTU, so all filtered water were suitable for drinking in context of turbidity. Residual free chlorine found suitable (<0.2 mg $L^{-1}$) in all treatment except source water (0.43 mg $L^{-1}$). Source water had alkalinity of 190 mg $L^{-1}$ and this value reduced in $FM_1$ and $FM_2$ but increased in $FM_3$. Calcium value found suitable (<75 mg $L^{-1}$) in $FM_1$ and $FM_2$ but increased in $FM_3$ (110 mg $L^{-1}$). Magnesium, potassium and sodium in water for all treatments and source showed suitable for drinking and irrigation.

Discharge rate of water from each treatment were analyzed (Fig. 1). It was found that after filling the recharge tank about 18 minutes for $FM_3$, 27 minutes for $FM_2$ and 72 minutes for $FM_1$ time required for starting of discharge. Peak discharge found 0.82, 0.74 and 0.9 L $s^{-1}$ was found after 2.5, 2.0 and 1.5 hours for $FM_1$, $FM_2$ and $FM_3$ respectively.

Almost all the chemical properties of water after filtration by treatment $FM_1$ and $FM_2$ satisfied the WHO standard limit. Treatment $FM_3$ showed higher value of alkalinity, calcium and potassium, although these values were within the permissible limit. This may be the residual effect of charcoal. Peak discharge found 0.82, 0.74 and 0.9 L $s^{-1}$ for $FM_1$, $FM_2$ and $FM_3$ respectively. First year experiment revealed that runoff water from rainfall can be recharged artificially by following treatments $FM_1$ and $FM_2$. But more chemical analysis should be done to identify chemical properties and microbial activities.

## TECHNOLOGY VALIDATION IN THE FARMERS' FIELD

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

The experiment was setup in a randomized complete block design (RCBD) at Dacope, Khulna and Amtali, Barguna. Tested rice varieties were BR23, BRRI dhan53, BRRI dhan54, BRRI dhan62, BRRI dhan66 and BRRI dhan73 along with the popular local variety as a check. Individual farmers plot was treated as disperse replications for the similar variety.

**Study on soil properties and salinity dynamics of soil and water in coastal areas**

For monitoring river and trapped canal water salinity, three spots were selected at a certain

**Table 3. Chemical compositions in water from runoff and after filtration by different filter media during 2016 at BRRI HQ farm, Gazipur.**

| Parameter | Source | $FM_1$ | $FM_2$ | $FM_3$ | Desirable limit (WHO standard) | Permissible limit |
|---|---|---|---|---|---|---|
| EC (dS $m^{-1}$) | 0.36 | 0.32 | 0.37 | 0.6 | 1.0 | - |
| pH | 7.5 | 7.7 | 7.7 | 7.8 | 6.5-8.5 | No relaxation |
| Turbidity (NFU) | 305 | 1.7 | 3.7 | 2.1 | 5.0 | 10.0 |
| Free chlorine (mg $L^{-1}$) | 0.43 | 0.04 | 0.11 | 0.09 | 0.2 | - |
| Alkalinity (mg $L^{-1}$) | 190 | 115 | 110 | **280** | 200 | 600 |
| Calcium (mg $L^{-1}$) | 40 | 60 | 60 | **110** | 75 | 200 |
| Iron (µg $L^{-1}$) | 195 | 58 | 74 | 150 | 200 | 1000 |
| Magnesium (mg $L^{-1}$) | 15 | 10 | 10 | 5 | 30 | 100 |
| Sodium (mg $L^{-1}$) | 30 | 19 | 20 | 26 | 200 | - |
| Potassium | 13 | 1 | 1 | **16** | 3.1 | - |

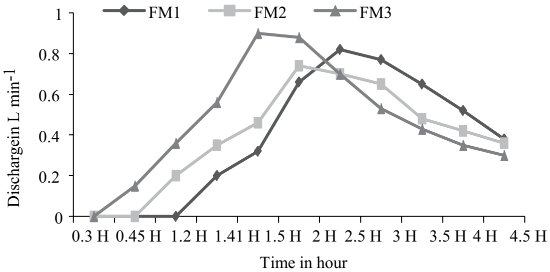


Fig. 1. Discharge pattern for different filter media.

distance in both the locations of Dacope, Khulna and Amtali, Barguna and measured water salinity of the selected points by EC meter. Irrigated rice field water salinity was measured at the same date and time. An observation well was installed in one corner of the experimental field within the weather station boundary at Pankhali village of Dacope, Khulna and very near to the experimental field at Sekandarkhali village of Amtali, Barguna to measure groundwater level and salinity. The groundwater level and salinity was measured from shallow aquifer, which may be connected to the canal and river water.

Soil samples were collected to determine soil physical and chemical properties after T. Aman harvest. Soil salinity from rice field was measured weekly and non-rice field was measured at 15 days intervals after transplanting at 0-15, 15-30, 30-45 and 45-60 cm soil depth.

**Dynamics of surface water salinity.** Salinity of the river Jabjapia was measured twice in a week at three selected places nearby the experimental area. Average salinity of the river water remained below 1.0 dS/m up to 4 December 2016 (Fig. 2) and is considered highly suitable for irrigating crops. Even river water remained suitable (<4.0 dS/m) for irrigation up to end of December 2016. After that the river water salinity gradually increased and at the end of Rabi/Boro cropping season it reached about 25 dS/m in April 2016. It was indicated that after December there is no possibility to use river water for crop cultivation. The canal water was trapped on 13 December 2016 at the period of high tide making canal water salinity of 1.23 dS/m. Its salinity increased in a slower rate and reached up to 3 dS/m in March 2017 due to evaporation and influence of groundwater flow (Fig. 2). This limit was also permissible for crop cultivation. The field water salinity varied corresponding to canal water salinity and successfully grown the crops in Dacope region.

In Amtali area, canal water was trapped on 20 December 2016 and canal water salinity was 1.1 dS/m. Its salinity increased in a slower rate and reached up to 2.3 dS/m in April, 2017 due to evaporation (Fig. 2). This limit was also permissible for crop cultivation. The field water salinity varied corresponding to canal water salinity and successfully grown the crops in Amtali region. But, the storage volume of the canal was very limited and at later part Boro/Rabi crops suffered from water shortage. It is essential to excavate the canal and also to link with existing fresh water source from the Pyra River for successful growing of dry season crops in that area.

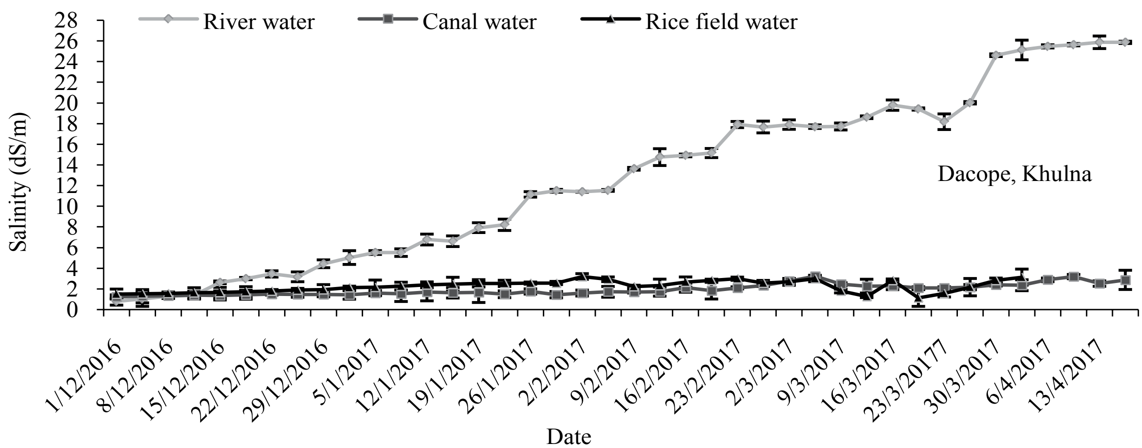


Fig. 2. River, canal and rice field water salinity, Dacope, Khulna, dry season 2016-17.

**Dynamics of groundwater salinity.** Generally, groundwater level and salinity in the experimental field at Pankhali, Dacope varied between 0.75-0.95 m from field surface and 2.3-3.52 dS/m, respectively (Fig. 3). The lowest value of 2.3 dS/m was observed in January and the highest was 3.52 dS/m. In Dacope, groundwater salinity remained less than 4.0 dS/m during the study period and is considered suitable for irrigation development. But, withdrawal of groundwater from the upper low saline aquifer is a risky venture for increasing salinity by intrusion of river high saline water in dry season. Whereas, groundwater level at Sekandarkhali, Amtali varied between 1.02 to 1.4 m from ground surface and groundwater salinity at 3.25 to 11.7 dS/m (Fig. 3). The lowest value of 3.25 dS/m was observed in February 2016 and the highest value of 11.7 dS/m was observed in May 2017 and it indicated that the upper aquifer groundwater in most cases is not suitable for irrigation.

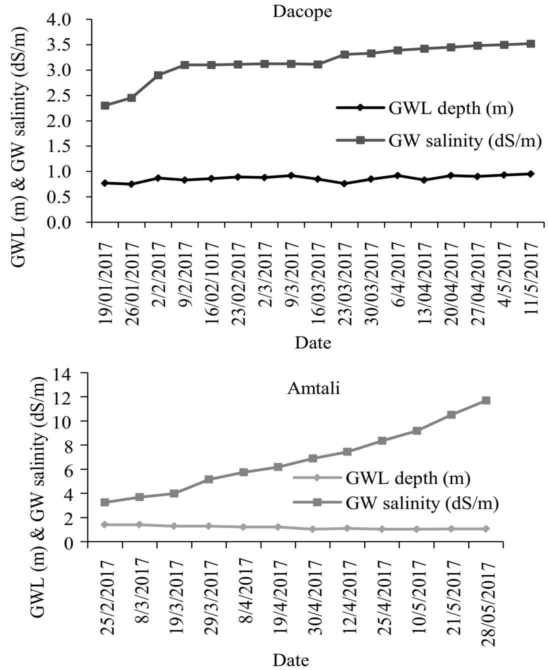



Fig. 3. Groundwater level and salinity at Dacope, Khulna and Amtali, Barguna, dry season 2016-17.

**Soil physical and chemical properties.** Soils are slightly alkaline in nature (pH ranges from 6.56 to 7.24) in all tested locations. In Dacope, soil texture was silty clay to clay, bulk density 1.34-1.38 g/cc indicating poor drainage ability. Initial soil salinity after T. Aman was 2.42-3.98 dS/m; 1.3-2.6% organic matter, 0.08-0.13% total N and 3.7-4.9 ppm phosphorous, but high S content (Table 4). In Amtali, soil texture was silty clay loam, bulk density 1.39-1.42 g/cc indicating comparatively better drainage ability. Initial soil salinity after T. Aman was 2.12-2.68 dS/m; 0.6-1.7% organic matter, 0.05-0.08% total N and 1.1-1.7 ppm phosphorous, but high S

**Table 4. Soil physical and chemical properties at Dacope, Khulna, Amtali, Barguna and BRRI RS, Barisal.**

| Depth | pH | BD (g/cc) | EC (dS/m) | %OC (Oxidizable) | %OC (Total) | %OM | Total N (%) | P (ppm) | S (ppm) | $SO_4^=$ (ppm) | %clay | %sand | %silt | Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Dacope, Khulna | | | | | | | |
| 0-15 | 7.02 | 1.38 | 2.42 | 1.0 | 1.3 | 2.2 | 0.13 | 4.8 | 88.24 | 264.71 | 45.64 | 10 | 44.36 | Silty clay |
| 15-30 | 7.22 | 1.36 | 2.55 | 0.7 | 0.9 | 1.6 | 0.09 | 3.7 | 58.59 | 175.77 | 55.64 | 8 | 36.36 | Clay |
| 30-45 | 7.20 | 1.35 | 3.74 | 0.6 | 0.7 | 1.3 | 0.08 | 4.0 | 72.20 | 216.60 | 57.64 | 8 | 34.36 | Clay |
| 45-60 | 7.04 | 1.34 | 3.98 | 0.6 | 0.8 | 1.3 | 0.08 | 4.9 | 98.84 | 296.52 | 55.64 | 12 | 32.36 | Clay |
| | | | | | | | Amtali, Barguna | | | | | | | |
| 0-15 | 6.56 | 1.42 | 2.21 | 0.8 | 1.0 | 1.7 | 0.08 | 1.7 | 71.40 | 214.20 | 27.64 | 10 | 62.36 | Silty clay loam |
| 15-30 | 6.96 | 1.41 | 2.22 | 0.5 | 0.6 | 1.0 | 0.06 | 1.2 | 47.99 | 143.96 | 29.28 | 10.36 | 60.36 | Silty clay loam |
| 30-45 | 7.05 | 1.40 | 2.45 | 0.3 | 0.4 | 0.6 | 0.05 | 1.1 | 56.28 | 168.84 | 33.64 | 8 | 58.36 | Silty clay loam |
| 45-60 | 7.00 | 1.39 | 2.68 | 0.3 | 0.4 | 0.7 | 0.06 | 1.3 | 64.65 | 193.94 | 39.28 | 10.36 | 50.36 | Silty clay loam |
| | | | | | | | BRRI RS farm, Barisal | | | | | | | |
| 0-15 | 6.97 | 1.43 | - | 1.5 | 1.9 | 3.3 | 0.23 | 11.4 | 44.46 | 133.38 | 39.64 | 22 | 38.36 | Clay loam |
| 15-30 | 7.04 | 1.42 | - | 1.5 | 1.9 | 3.3 | 0.20 | 10.8 | 40.80 | 122.40 | 39.64 | 18 | 42.36 | Silty clay loam |
| 30-45 | 7.12 | 1.41 | - | 0.8 | 1.0 | 1.8 | 0.13 | 9.9 | 34.05 | 102.15 | 33.64 | 18 | 48.36 | Silty clay loam |
| 45-60 | 7.24 | 1.44 | - | 0.7 | 0.9 | 1.5 | 0.11 | 11.0 | 32.70 | 98.10 | 27.64 | 18 | 54.36 | Silt loam |

content. In BRRI RS farm Barisal, soil texture was silt loam to clay loam with bulk density 1.41-1.44 g/cc; 1.5-3.3% organic matter, 0.11-0.23% total N and 9.9-11.4 ppm phosphorous, but with high S content (Table 4).

The moisture characteristics curves for different experimental plots in Dacope area indicated that at field capacity (0.3 bar) soil moisture varied from 33.1 to 43.0% and it gradually decreased up to 23.5 to 29.0% in wilting points (Fig. 4). This also an indication of clayey poorly drained soil. The water holding capacity varied from 8.3 to 14.0% in different experimental field soils.

**Dynamics of soil moisture and salinity.** Figure 2 shows that rice field water salinity was always slightly higher than canal water salinity. In both the locations, soil salinity was about five times higher than that of irrigation water salinity (Fig. 5) and salinity increased gradually with soil depth. Irrigated rice field soil moisture indicated the saturation soil moisture and it varied from 36-40% in Dacope, Khulna and that of 35-36% in Amtali, Barguna.

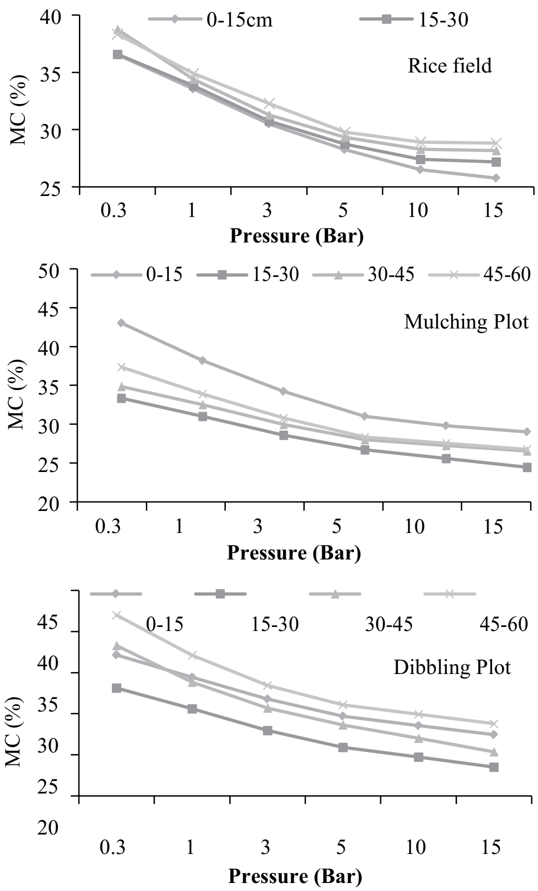



Fig. 4. Soil moisture characteristics curve at Rice field, dibbling plot and mulching experimental plot, Dacope, Khulna, Rabi/Boro 2016-17.

**Planting time for Boro rice cultivation in saline areas**

The study was conducted at Dacope in the dry season of 2016-17. The trapped canal water was used for irrigation. The experiment was laid out in a split plot design with three replications. The seeding date was in mail plot and variety in sub-plot. The six seeding date starts from 15 October and end at 30 December with 15 days interval. There were three varieties like BRRI dhan28 (popular but non-saline tolerance Boro variety), BRRI dhan67 and BINA dhan10 (saline tolerance Boro varieties) were tested in this study. Forty-five-day-old seedlings were transplanted with 20 × 20 cm hill spacing – following BRRI recommendation with the scheduled date in each location.

The growing season maximum temperature varied from 24.5 to 37.5°C and the maximum temperature beyond critical limit (35°C) in April. But the sowing date of 5th and 6th set flowering occurred during April, which creates some sterility problem. In coastal area minimum temperature range have not create any problem in rice growing. During growing season, about 175 mm of total rainfall was occurred, which is congenial for rice growth and reduce the irrigation cost and salinity effect.

Among the six sowing dates 30 November and 15 December performed better irrespective of tested variety in plant height and yield (Table 5). But the

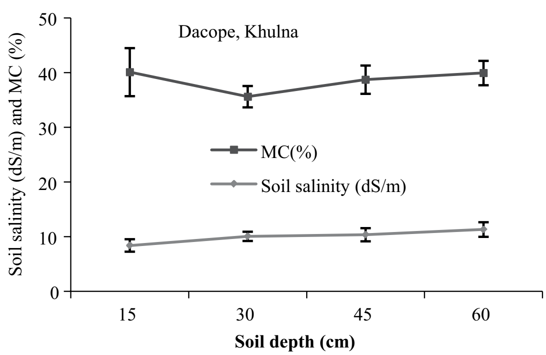



Fig. 5. Soil moisture and salinity at rice field with different soil depths at Dacope, Khulna and Amtali, Barguna, Boro 2016-17.

number of tiller per unit area produced the highest in first sowing i.e. 15 October and decreased gradually due to shorter growth duration. The growth duration was decreased gradually due to higher temperature effect on the later part of rice growing season. The Boro rice start to grow at winter i.e. in cool temperature in seeding, transplanting and up to mid vegetative stage and after that it grows at summer i.e. in warm temperature in booting, flowering and ripening stages. For that reason, late sowing most of the rice growing stages passes in warm temperature and reduced its growth duration. The data revealed that irrespective of variety 30 November sowing produced the highest yield followed by 15 December. These are the optimum rice sowing time in all over the country. Among the tested variety both of salt tolerant variety, BRRI dhan67 and BINA dhan10 produced the similar higher yield compared to non-salt tolerant variety BRRI dhan28 because of low salinity level of irrigation water (Table 5). Among the variety, BINA dhan10 produced highest yield due to its coarse grain. Early sowing produced more effective tillers and yield, but it was highly affected by pest like birds and rats. The salinity level of the trapped irrigation water within whole rice growing season was in permissible limit, for that if water resource is available farmers can grow rice successfully.

Early sowing required more water due to its long growth duration and less rainfall used. The highest amount of irrigation water was used in 15

**Table 5. Sowing time effects on plant height, 1000 grain weight (TGW), effective tillers, yield and growth duration of BRRI dhan28, BRRI dhan67 and BINA dhan10 at Dacope, Boro 2016-17.**

| Variety | Plant height (cm) | TGW (gm) | Eff. Till/m$^2$ | Yield (t/ha) | Growth duration (day) |
|---|---|---|---|---|---|
| | | | *Sowing date*: *15 Oct* | | |
| BRRI dhan28 | 88.66de | 21.63cdef | 406ab | 5.28ef | 158c |
| BRRI dhan67 | 95.60bcd | 22.50bcde | 434a | 5.68bc | 161b |
| BINA dhan10 | 88.30de | 25.63b | 426a | 5.87ab | 164a |
| | | | *Sowing date*: *30 Oct* | | |
| BRRI dhan28 | 80.50f | 20.96cdefg | 347cdef | 5.56cd | 155d |
| BRRI dhan67 | 86.16ef | 23.96bc | 360cd | 5.80abc | 155de |
| BINA dhan10 | 90.40cde | 29.96a | 317efgh | 5.57cd | 160bc |
| | | | *Sowing date*: *15 Nov* | | |
| BRRI dhan28 | 80.50f | 21.76cde | 347cdef | 5.37de | 147g |
| BRRI dhan67 | 86.16ef | 20.00defg | 360cd | 5.79abc | 151f |
| BINA dhan10 | 90.40cde | 30.76a | 317efgh | 5.75bc | 153ef |
| | | | *Sowing date*: *30 Nov* | | |
| BRRI dhan28 | 100.03ab | 22.50bcde | 292gh | 5.56cde | 140ij |
| BRRI dhan67 | 104.06a | 21.10cdef | 317efgh | 5.82abc | 142i |
| BINA dhan10 | 102.00ab | 29.40a | 288h | 5.95ab | 144h |
| | | | *Sowing date*: *15 Dec* | | |
| BRRI dhan28 | 97.33abc | 20.76defg | 353cde | 5.54cde | 131l |
| BRRI dhan67 | 100.46ab | 19.40efg | 314fgh | 5.88ab | 136k |
| BINA dhan10 | 98.86ab | 23.26bcd | 329defg | 6.03a | 139j |
| | | | *Sowing date*: *30 Dec* | | |
| BRRI dhan28 | 80.50f | 19.73efg | 327 defg | 5.03f | 126n |
| BRRI dhan67 | 86.16ef | 18.46fg | 358cde | 5.74bc | 129m |
| BINA dhan10 | 88.30de | 25.56b | 317efgh | 5.69bc | 132l |
| LSD (0.05) | 7.52 | 3.29 | 38.80 | 0.27 | 2.11 |
| CV (%) | 4.93 | 8.53 | 6.61 | 2.93 | 0.87 |

October sowing and the lowest amount of irrigation water was used in 30 December sowing (Fig. 6). Most of the rainfall occurred during March and April in this season, which reduce the irrigation amount after 15 November sowing. The rainfall not only reduces the irrigation amount, but it also reduces the salinity effects of soil and water for growing rice. The irrigation water productivity varied from 0.54 to 0.96 kg $m^{-3}$ and the total water productivity varied from 0.50 to 0.75 kg $m^{-3}$ and those were increased at late sowing due to its higher yield and less amount of irrigation water needed for its shorter growth duration (Fig. 7).

**Data source and temporal trend analysis.** Temperature, rainfall and sunshine duration data from 1971-2010 were obtained from four stations of Bangladesh Meteorological Department (BMD) and rice grain yield data were collected from Bangladesh Bureau of Agricultural Statistics for the whole north-west districts. The Mann–Kendall trend test (Mann, 1945) was used to detect trends in time series data and the test statistic distribution was explained by Kendall (1975) for testing non-linear trends and turning points. Sen's slope estimator was used to determine the magnitude of change in the climatic parameter. The present study computed the confidence interval at p = 0.01 and p = 0.05.

Trend analyses for inter-annual and inter-seasonal, maximum, minimum and mean temperatures, rainfall and sunshine duration were carried out for those four locations. The descriptive statistics for yield of T. Aman rice and seasonal climatic elements were prepared. Growth rates of area and productivity of T. Aman rice were worked out as decadal basis.

The combined effect of maximum and minimum temperatures, rainfall and sunshine hours on T. Aman rice yield was computed through multiple regression analyses. Several T. Aman varieties are grown in the test regions, but for the convenience of the climate change impact study average grain yield of all T. Aman varieties (local and/or HYV) cultivated in the tested locations was considered as ideotypic response of variety.

In general, T. Aman rice area decreased continuously but grain yield increased from 1981 to 2010 because of adoption of modern high yielding varieties, improved fertilizer and cultural managements and use of supplemental irrigation water. The share of T. Aman rice to total rice production is 38% in Bangladesh (BBS, 2013) and its contribution will be changed if temperature, rainfall and sunshine duration changes in future (IPCC, 2013).

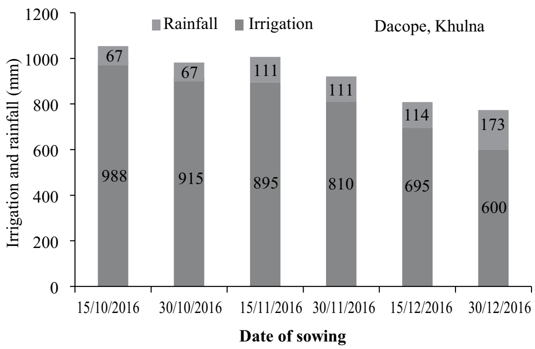



Fig. 6. Applied irrigation and rainfall in rice growing season, Dacope, Khulna, Boro 2016-17.

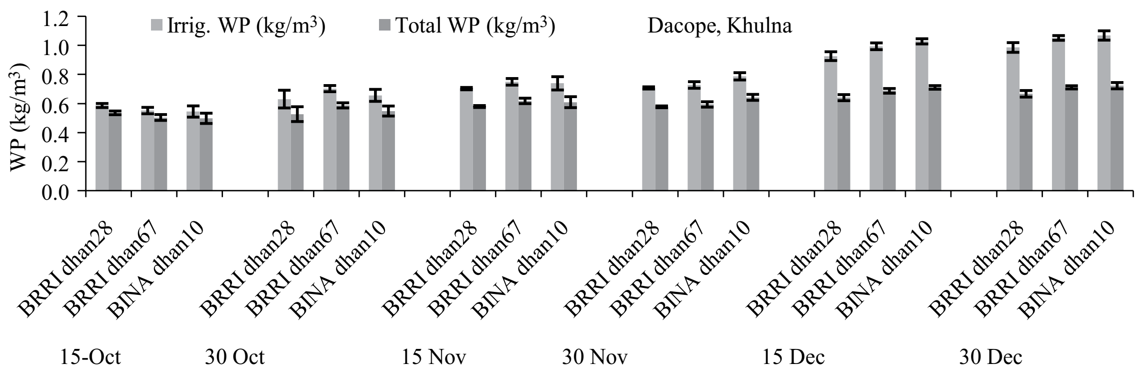



Fig. 7. Irrigation and total water (irrigation + rainfall) water productivity of different variety under different sowing dates, Dacope, Khulna, Boro 2016-17.

The Mann-Kendall trend test showed a significant increase in maximum and mean temperatures. Sen's slope showed increase in average annual maximum, minimum and mean temperatures by 0.001°C year$^{-1}$, 0.016°C year$^{-1}$ (Z = 3.20, $p<0.001$) and 0.009°C year$^{-1}$ (Z = 2.52, $p<0.05$), respectively from 1971 to 2010 (Fig. 8). However, wet seasonal maximum, minimum and mean temperaturesincreased by 0.0174°C year$^{-1}$ (Z = 3.85, $p<0.001$), 0.0083°C year$^{-1}$and 0.0129°C year$^{-1}$ (Z = 3.53, $p<0.001$), respectively. Increasing trend of maximum temperature in wet season might be responsible for higher evapo-transpiration rate along with exposure of drought in study locations.

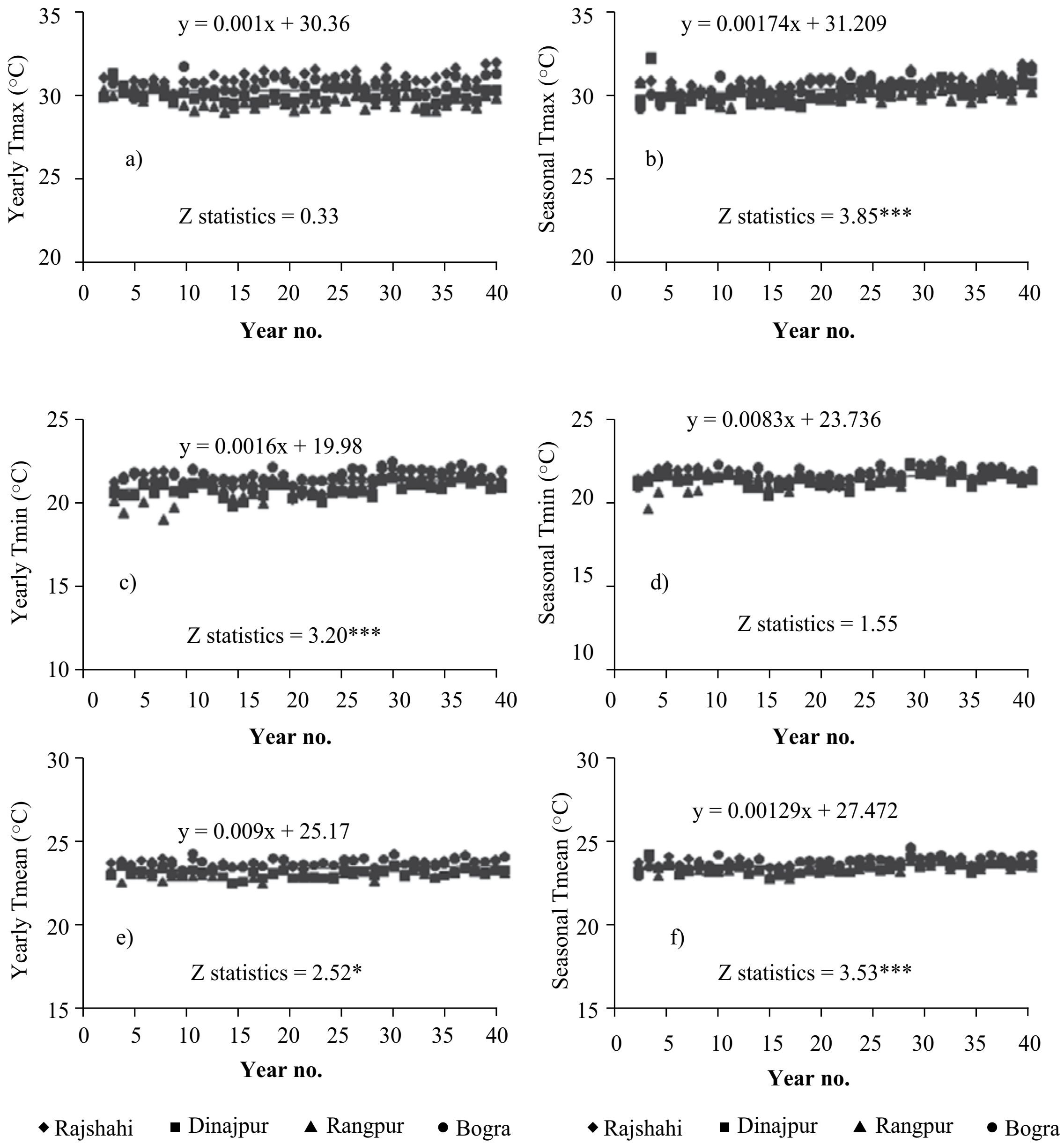
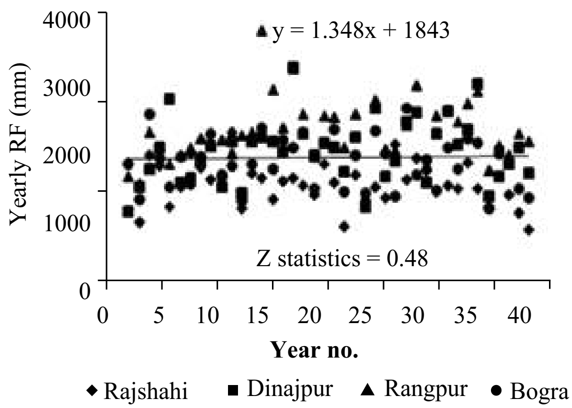



Fig. 8. Observed trends in average yearly and T. Aman seasonal temperature: (a and b)-maximum, (c and d)- minimum and (e and f)- mean in north-west region of Bangladesh, year no. starts from 1971 (* $p< 0.05$; ** $p<0.01$; *** $p<0.001$).

Average annual rainfall of the study region increased by 1.38 mm year$^{-1}$ and wet season rainfall increased by about 0.7266 mm year$^{-1}$ (Fig. 9). The average wet season rainfall in north-western region of Bangladesh varied from 1243 to 1813 mm, which is sufficient if it is uniformly distributed in wet season. But, in some years it is as low as 637 mm and distribution is not also uniform. Long-term (1971-2010) rainfall data revealed that both annual and wet seasonal rainfall was slightly increasing in trend (Fig. 9). Supplemental irrigation was essential in those low rainfall years for successful T. Aman rice production.

Annual average sunshine hours in study locations were decreasing (Z = -6.05, p<0.001). Sen's slope estimator showed annual sunshine hour decreaseof 0.027 hrs year$^{-1}$from 1971 to 2010; butwet season sunshine hours decreased by 0.0259 hrs year$^{-1}$ (Z = -4.82, p<0.001) for the same period (Fig. 10). Sunshine hour is decreasing at a continuous rate per year, which is primarily because of increased suspended particulate matter (SPM) and aerosols concentration in the atmosphere. Our findings are in agreement with the works in South Asian region under Atmospheric Brown Cloud Project of UNEP (Kalra *et al.*, 2006).

**Inter-seasonal climatic variability effects on T. Aman rice yield.** Average maximum temperature of study regions varied from 31.17 to 31.99°C and average rice yield varied from 2.39 to 2.64 t ha$^{-1}$. If maximum temperature increases by1°C, T. Aman rice yield is likely to decrease by 10.94% i.e. about 0.27 t ha$^{-1}$ (Fig. 11a). Since north-western part of the country is relatively hotter during wet season, minimum increase in maximum temperature will cause yield reduction, because of increased



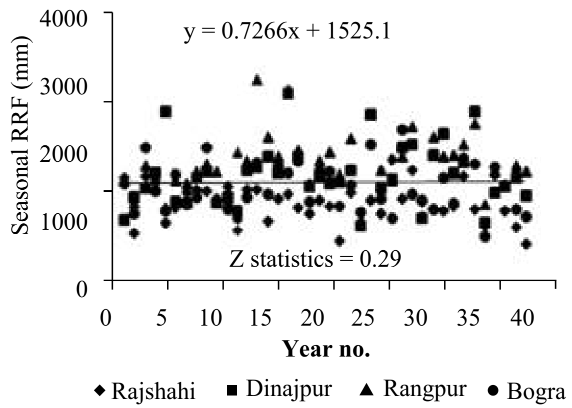
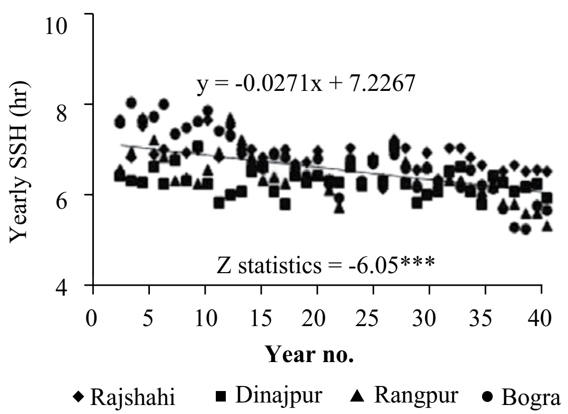




Fig. 9. Observed trends in rainfall: (a)- yearly and (b)- T. Aman season in north-west region of Bangladesh, year no. starts from 1971.



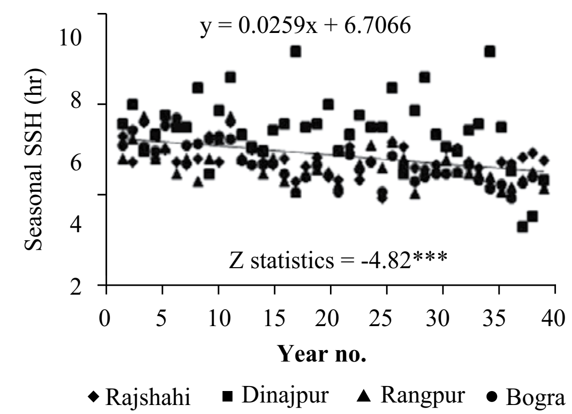




Fig. 10. Observed trends in average sunshine hours: (a)- yearly and (b)- T. Aman season in north-western region of Bangladesh, year no. starts from 1971 (* p< 0.05; ** p<0.01; *** p<0.001).

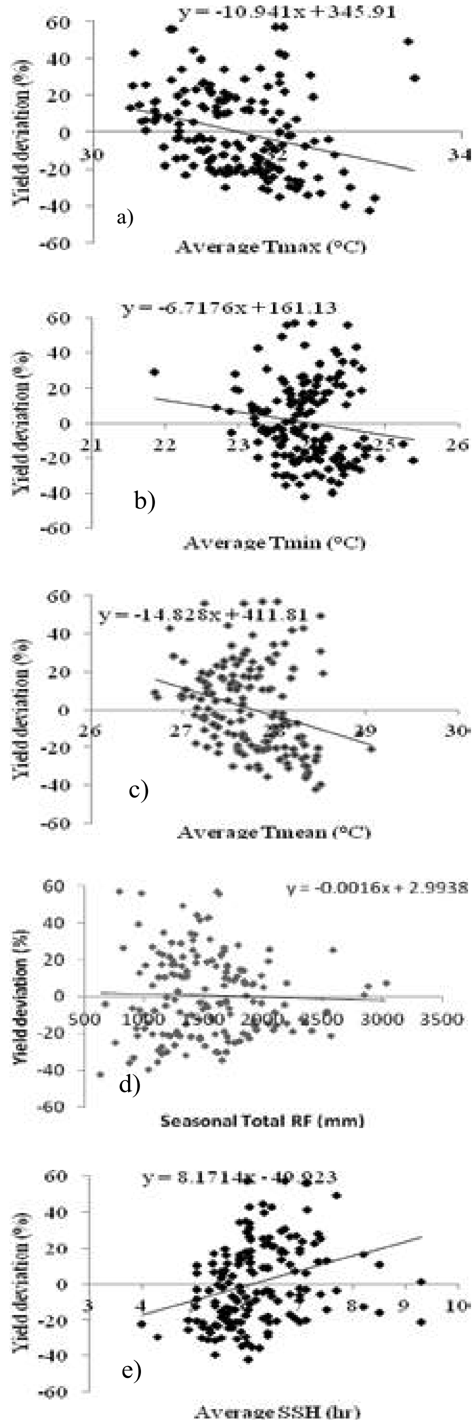



Fig. 11. Relationship of percent deviation in T. Aman rice yield with growing season weather parameter: (a) maximum temperature, (b) minimum temperature, (c) mean temperature, (d) rainfall and (e) avrerage sunshine hours in the north-west region of Bangladesh.

evapo-transpiration and reduced growth duration of T. Aman rice. On contrary, average minimum temperature in the study regions varied from 23.673 to 24.21°C.Wet season minimum temperature was in increasing trend (Fig. 8). If minimum temperature increases by about 1°C, T. Aman rice yield would be reduced by 6.72%, i.e. about 0.17 t $ha^{-1}$ (Fig. 11b).

Mean temperature during wet season was increasing in trend (Fig. 8). If mean temperature increases by about 1°C, T. Aman rice yield reduction would be 14.83% i.e. about 0.37 t $ha^{-1}$ (Fig. 11c), which is very much similar to the findings of Mabe *et al.*, 2014. The country is predicted to experience an increase in average temperature of 1.4°C by 2050 and consequently, the rice production is likely to decline by 8-17% (IPCC, 2007).

Seasonal rainfall was slightly increasing in north-western part of Bangladesh (Fig. 9). Effect of seasonal total rainfall on T. Aman rice yield wasin significant (Fig. 11d). Water demand was fulfilled through supplemental irrigation in most cases. So, decrease in rainfall has not yet been created any yield loss in north-west region of the country. Seasonal sunshine hourswere in decreasing trend (Fig. 10). If sunshine hour decreases by 1 hour, T.Aman rice yield is likely to decrease by 8.17% i.e. about 0.20 $tha^{-1}$ (Fig.11e).

Combined effect of average maximum and minimum temperatures and sunshine hours on rice yield was computed through multiple regression analyses.Predicted rice yield was in close agreement with the observed yield (Fig. 12). Our analyses indicate that increased in average minimum temperature and reduction in sunshine hours will play an importantrole for reduction of T. Aman rice yield in future. The model has an F-value of 12.65 with a p-value of 0.000 indicating that overall model result was statistically significant at 1% level of probability. About 25% of the variations in T.Aman rice yields are explained by climatic variables. The t-value of average maximum temperature was 4.27 and for average sunshine hours was -4.88, which were statistically significant at 1% level of probability.

**Climate change impact assessment by DSSAT model for Boro rice in Bangladesh**

The study was conducted in six locations across the country having diverse soil and weather conditions. The study locations wereGazipur,

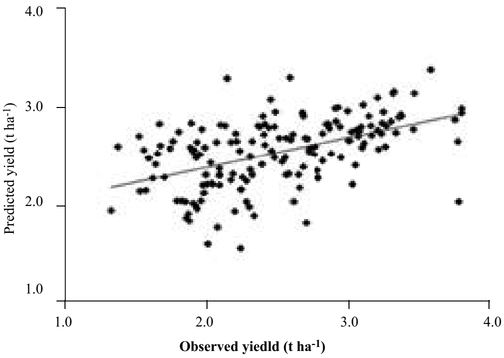



Fig. 12. Multiple regression of maximum (Tmax) and minimum (Tmin) temperatures, total rainfall (RF) and sunshine hours (SSH) on T. Aman rice yield in north-western region of Bangladesh.

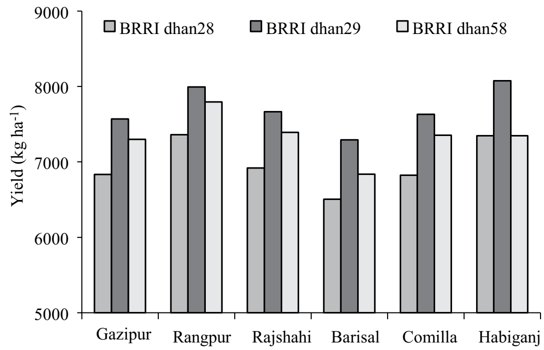



Fig. 13. Grain yields of selected varieties under normalized weather conditions in different regions of Bangladesh.

Rangpur, Rajshahi, Barisal, Comilla and Habiganj districts of Bangladesh. Weather data for the study regions were collected from the Bangladesh Meteorological Department (BMD) for the period of 1981-2015. Base year daily average of maximum and minimum temperatures, rainfall and sunshine hours were calculated and created two successive years' weather file for DSSAT format, because Bororice grows from November in one year and ends at April or May in the next year. The seasonal model simulation was run in SIMMETEO mode for 30 years to capture temperature and $CO_2$ effects on yield and growth duration of selected varieties.

In future, the rise in temperature is likely to be 2 to 4°C by 2100 in South Asia including Bangladesh (IPCC, 2013). So, the CERES-Rice model was applied for normal (T*air*) and 1, 2, 3 and 4°C above normal conditions. According to CMIP5 and Earth System Model, predicted $CO_2$ concentrations will be reaching 421 ppm (RCP2.6), 538 ppm (RCP4.5), 670 ppm (RCP6.0), and 936 ppm (RCP 8.5) by the year 2100 (IPCC, 2013). So, we have selected those $CO_2$ levels and compared with ambient $CO_2$ concentration (380 ppm).

Grain yields of selected rice varieties varied among regions mainly due to climatic variability and soil properties. In general, the highest potential grain yield was found in Rangpur and the lowest in Barisal region irrespective of varieties. Grain yield varied from 6.50 to 7.36, 7.29 to 8.08 and 6.84 to 7.80 t $ha^{-1}$ for BRRI dhan28, BRRI dhan29 and BRRI dhan58, respectively based on long-term (1981-2015) weather parameters (Fig. 13). These variations are related with weather parameters and soil properties.

At all $CO_2$ levels (380, 421, 538, 670 and 936 ppm), grain yield decreased due to increase in temperature. But increase in $CO_2$ level at any particular temperature improved rice yields. Average increase in grain yield was 2.6-2.8% for RCPs 2.6, 10.8-11.8% for RCPs 4.5 and 19.4-21.2% for RCPs 6.0 and 32.7-37.1% for RCPs 8.5 with varied $CO_2$ levels. The highest yield increase was 40.3% for BRRI dhan28, 33.6% for BRRI dhan29 and 40.3% for BRRI dhan58 with 936 ppm $CO_2$. In all regions of Bangladesh, predicted mean yield reduction was 4.77, 3.44 and 5.03% per degree temperature rise for BRRI dhan28, BRRI dhan29 and BRRI dhan58, respectively at 380 ppm $CO_2$ level. Grain yield reduction rate was higher with short and medium duration varieties compared to long duration BRRI dhan29. Among the study regions, grain yield reduction was the lowest in Barisal and Comilla areas at all temperature regimes. In Rangpur region, grain yield reduction with BRRI dhan29 was minimum (3%) because of temperature rise up to 2°C. This part of the country generally enjoys cooler environment for a longer period in winter season and thus predicted temperature increase by 2°C might not be hazardous for Boro rice production in future.

In all studied regions, growth duration of rice varieties was not significantly influenced by $CO_2$ levels but it was reduced by 7.45, 7.49 and 7.88 days for BRRI dhan28, BRRI dhan29 and BRRI dhan58, respectively with every degree increase in temperature compared to ambient temperature.

At the ambient $CO_2$ concentration, grain yield of rice is likely to be reduced by 16.4-21.3% for BRRI dhan28 (Fig. 14), if temperature increases by 4°C. But 936 ppm $CO_2$ concentration (RCPs 8.5) might increase yield by 36.6-41.1% for BRRI dhan28 (Fig. 14), in different areas of Bangladesh with existing temperature pattern. In most areas, BRRI dhan28 showed a competitive yield advantage under ambient conditions (no temperature rise and 380 ppm $CO_2$) that extended up to 2°C temperature rise with 538 ppm $CO_2$ level except in southern Bangladesh. Grain yield reduction due to 3°C temperature rise could be compensated up to 670 ppm $CO_2$ level in all studied regions except in Rangpur areas. Similarly, if $CO_2$ 936 ppm level might be able to compensate grain yield reduction due to 4°C rise in all test regions of Bangladesh (Fig. 14).

This study was conducted to determine the effect of increased daily maximum and minimum temperatures and elevated $CO_2$ levels using CERES-Rice model on grain yield and growth duration of dry season rice (Boro) at six representative locations across Bangladesh. Long-term normalized weather data were used to predict grain yields of those varieties under variable increased temperature and $CO_2$ levels. Temperature increase rate considered was 0, +1, +2, +3 and +4°C with the elevated $CO_2$ concentrations of 380, 421, 538, 670 and 936 ppm based on different RCPs. Rice grain yield was reduced by 256 to 403 kg $ha^{-1}$ for BRRI dhan28.

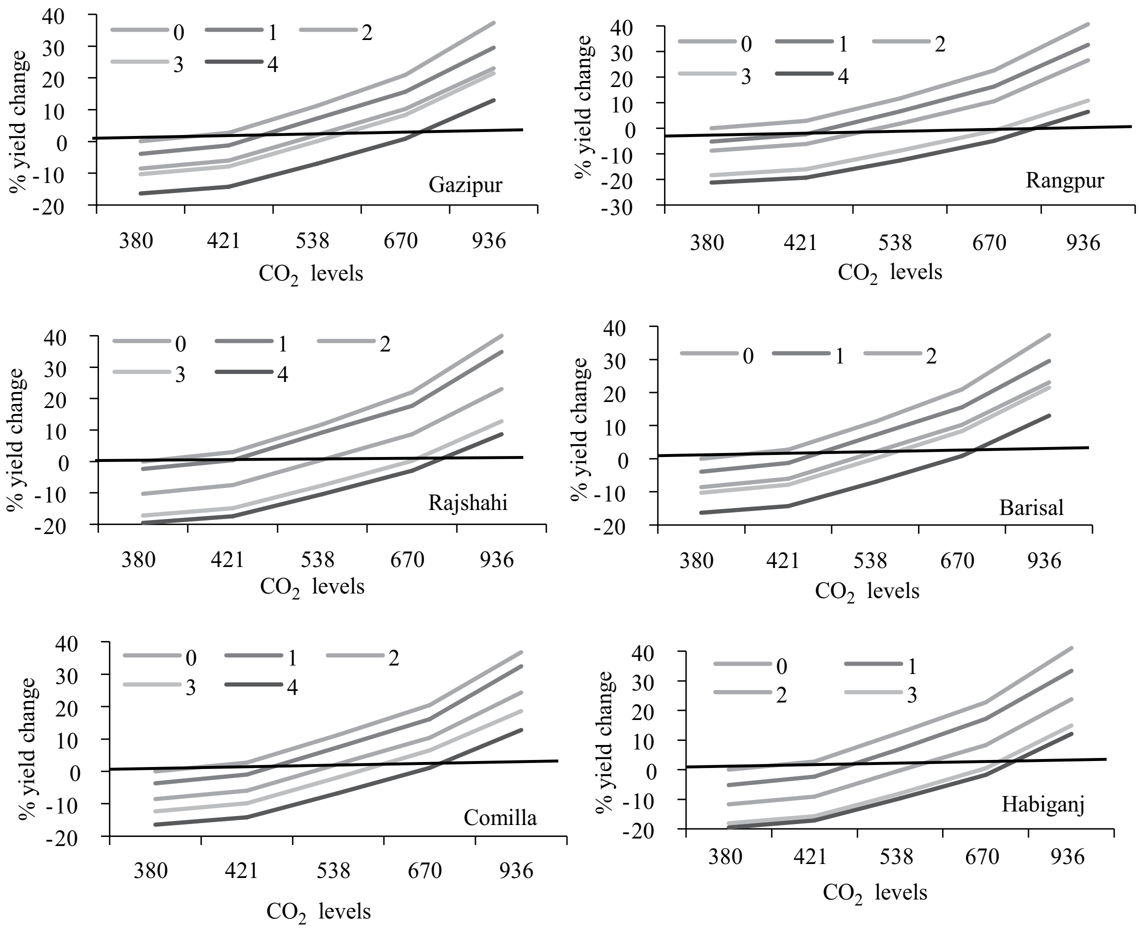



Fig. 14. Combined changes in yield as affected by increased temperature and elevated $CO_2$ concentration over control (no temperature rise, 380 ppm $CO_2$) for BRRI dhan28 at various test regions of Bangladesh.

# Plant Physiology Division

SUMMARY

A total of 30 experiments under eight different projects have been carried out during 2016-2017 in the Plant Physiology Division of BRRI. Among different research projects most of the experiments pertaining to five major stress environments i.e. salinity, submergence, drought, heat and cold. Only few experiments are associated with growth studies and seed physiology. In salinity stress, around 700 germplasm and breeding lines were characterized and 59 of them found tolerant at seedling stage. But for reproductive stage, BR10238-5-1 was found tolerant @ 8 dS/m salinity stress. A total of 12 QTLs were identified from a Bangladeshi germplasm Ashfal Balam for seedling and reproductive stage tolerances. Under two weeks submergence environments, only 15 were found tolerant for flash flood submergence. Out of the tested 200 germplasm and breeding lines. Submergence tolerant genotypes are able to survive only two-weeks of complete submergence. At deep flooding environment (>1.0 m) Habiganj Aman-1 perform better than any tested genotypes. Out of 20 advanced breeding lines, IR96977-B-B-7-B showed 50% germination in anaerobic condition. In drought tolerance, more than 250 germplasm and advanced breeding lines were tested. Out of the tested genotypes 26 germplasm, three lines (HHZ17-DT6-Y1-DT1, HHZ23-DT16-DT1-DT1 and BR10230-7-1) were selected as drought tolerant. At high temperature environment, seven advanced breeding lines were identified as heat tolerant. Under marker assisted breeding programme 20 and 13 lines of 2nd and 3rd backcross generations were advanced and 40 and 20 fixed QTL lines were selected based on genotypic and phenotypic similarity. Some 200 BRRI Genebank germplasm and 31 advanced breeding lines of Biotechnology Division were screened for cold tolerance at seedling stage of which 31 accessions and nine advanced genotypes were selected as moderately tolerant. Thirteen advanced rice genotypes and six IRRI materials were evaluated for reproductive stage cold tolerance at natural condition of which an advanced genotype BR8907-B-1-2-CS1-4-CS2-P3-4 and an IRRI material IR87322-65-2 were selected. BRRI dhan69 was evaluated for cold tolerance and it was found moderately cold tolerant both at seedling and reproductive phase. Under growth studies project, newly released Boro varieties were tested at four different sowing dates. BRRI dhan28 performed better at 3rd sowing (12/12/16) with shorter growth duration but BRRI dhan68 performed well at 2nd sowing (27/11/16). Long duration variety did not perform well when sown late due to different natural hazards. Forty-four Aus germplasm were tested and 17 yielded better after breakdown of apical dominance. Twenty selected Bangladeshi rice germplasm were tested for $CO_2$-responsiveness at field condition. Finaly-Wilkinson regression analyses showed photosensitive low-land varieties are more resilient than insensitive upland varieties in changing climatic condition. Tiller and panicle number, panicle dry weight and harvest index are strongly associated with $CO_2$ responsiveness in rice. The dormancy period varied from 20-45 days and 5-36 days in Aman and Boro season, respectively. Seed viability of Aman varieties (210 days) is longer than Boro varieties (110 days).

## SALINITY TOLERANCE

**Exploring new sources of salinity tolerance from BRRI Gene bank germplasm at seedling stage.** Five-hundred thirty-five germplasm along with standard tolerant Nona Bokra, Pokkali, IR58443 and sensitive check IRRI154 were screened and out of which 36 germplasm were found tolerant to moderately tolerant (SES score and survivability ranged from 2.5-3.9 and 87.5-100.0% respectively).

**Screening of rice genotypes for salinity tolerance at seedling stage**

Rice genotypes from different sources i.e. STBN and IRSSTN, GSR, OT materials and advanced breeding lines along with tolerant checks IR58443-6B-10-3 and susceptible check IR154 were screened under 14 dS/m, while anther cultured lines were screened under 12 dS/m salinity stress to identify salt tolerant genotypes at seedling stage. Screening was done according to Gregorio *et al.*, 1997.

**STBN and IRSSTN materials.** Ninety-eight rice genotypes along with IR58443-6B-10-3 and IR154 as standard tolerant and sensitive check respectively were screened. Thirty genotypes showed visual score 3 to 5 that is tolerant to moderately tolerant. The survivability percentage of these genotypes varied from 60% to 100%.

**GSR materials.** Forty-five rice genotypes along with standard tolerant IR58443-6B-10-3 and sensitive check IR154 were screened and only one genotype namely GSR IR1-D4-135-Y2-Y1 was found moderately tolerant at high salinity stress. The survivality percentage of the genotype was 65%.

**OT materials.** Thirty-three genotypes along with standard tolerant IR58443-6B-10-3 and sensitive check IR154 were screened. Among them, only eight OT materials and two varieties as BR9535-15-23-7, BR9535-3-1-9, BR9536-2-1-7, BR9536-2-1-14, BR9536-B-10-1-26, BR9536-B-4-1-38, BR9536-B-4-1-40, BR9539-B-12-11-13, BRRI dhan54 and BRRI dhan73 showed visual score 4 to 5 that is moderately tolerant at 14 dS/m salinity stress.The survivality percentage of these genotypes varied from 65 to 100%.

**IRSSTN materials.** Twenty-six IRSSTN materials along with tolerant checks IR58443-6B-10-3 and susceptible check IR154 were screened. Among 26 genotypes, 12 IRSSTN materials IR100634-78-AJY1-3, IR100634-96-AJY2-2, IR13T135, IR14T106, IR91669-16-3-2-2-2, IR91833-7-BAY 3-2-3-2-AJY, A69-1, IR51485-AC 6534-1-1(CSR 28), IRRI147, IR86385-117-1-2-B showed visual score 4 to 5 that is moderately tolerant and two genotypes IR90477-74-1-2-3-2 AJY, IR77674-5-1 scored 3 that is tolerant to high salinity stress at 14 dS/m salinity stress. The survivality percentage of the genotypeswere 55% to 100%.

**Anther cultured lines.** Six anther culture lines along with tolerant and susceptible check IR58443-6B-10-3 and IR154 respectively were screened and among six genotypes, there was no line showed tolerance ability compared to check at high salinity stress.

**Advanced breeding lines.** Seven advanced breeding lines along with tolerant and susceptible check IR58443-6B-10-3 and IR154 respectively were screened and among seven genotypes, there was no line showed tolerance ability compared to check at high salinity stress.

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

To identify salt tolerant rice genotypes, two sets of experiment were conducted in the net house of Plant Physiology Division of BRRI during T. Aman, 2016-17. In 1st set, six advanced breeding lines BR9392-6-2-1B, BR10238-5-1, BR9392-6-2-3B, BR10230-7-1, BR10247-14-18, BR11 along with IR58443-6B-10-3 and IR29 as tolerant and susceptible checks were characterized and evaluated under salinity stress during T. Aman season. Whereas, in 2nd set, five advanced breeding lines BR9379-21-3B, BR9392-2-6-2B, BR9379-10-1-13, BR10230-15-27 and Habiganj Aman-1 along with same checks were considered. Thirty-six days after sowing, all rice genotypes were exposed to salinity stress of 8 dS/m by adding NaCl in the bucket. One set of plants without adding salt was used as control.

In, 1st set, BR10230-7-1 gave the highest yield followed by BR10238-5-1, BR9392-6-2-3B and BR10247-14-18 at control condition. Grain yield decreased for all the tested genotypes at salt stress condition. The highest grain yield was obtained with BR10238-5-1 at stress condition. Reduction percentage of yield over control was minimum in the tolerant check (12.8%) followed by BR10238-5-1 (24.9%). However yield of some other tested genotypes reduced below 50% (Table 1).

In 2nd set, salinity × genotype interaction showed significant effect on grain yield. At non saline condition, BR9379-10-1-13 gave the highest yield followed by BR9392-2-6-2B and Habiganj Aman-1. But at salinity stress 8 dS/m, grain yield was decreased for all the tested genotypes. Tolerant check IR58443-6B-10-3 had the highest yield at 8 dS/m salinity stress. All the tested genotypes had more than 50% yield reduction at this stress. But tolerant check had the least reduction of grain yield

**Table 1. Yield and reduction percentage of yield over control of some rice genotypes affected by salinity stress.**

| Genotype | Grain yield/hill Salinity stress (dS/m) Control | 8 | % reduction of yield over control |
|---|---|---|---|
| BR9392-6-2-1B | 5.9 | 3.3 | 44.1 |
| BR10238-5-1 | 6.7 | 5.03 | 24.9 |
| BR9392-6-2-3B | 6.7 | 3.1 | 53.7 |
| BR10230-7-1 | 7.6 | 3.03 | 60.1 |
| BR10247-14-18 | 6.7 | 3.8 | 43.3 |
| BR11 | 6.4 | 3.9 | 39.1 |
| IR58443-6B-10-3 | 3.9 | 3.4 | 12.8 |
| IR29 | 4.04 | 2.4 | 40.6 |

$LSD_{0.05}$ for genotype (G) is 0.4, $LSD_{0.05}$ for salinity stress (S) is 0.2, $LSD_{0.05}$ for G × S is 0.6.

(34.7%) (Table 2). Considering yield potential and salt tolerance ability genotype BR10238-5-1 could be used for further breeding programme.

**Mapping QTLs for salinity tolerance of Ashfal balam at seedling and reproductive stage**

Linkage map of 105 KASP SNP markers in 200 $F_{2:3}$ population of the cross between BR11/Ashfal balam was constructed. QTL mapping was carried out by Inclusive Composite Interval Mapping method and LOD >3.0 considered as threshold value. Eleven and seven major QTLs were identified for SES, survivability, shoot and root length, SPAD value for seedling stage and number of panicle and grain, grain weight, straw weight for reproductive stage salinity tolerance from Ashfal balam (Table 3 and Fig. 1).

## SUBMERGENCE TOLERANCE

**Screening of rice genotypes for flash flood submergence tolerance.** Some 140 germplasm from BRRI Genebankand 60 advanced breeding lines along with resistant check FR13A and susceptible check BR5 were tested to identify tolerant germplasms at the seedling stage under complete submergence condition. Fourteen-day-old seedlings were grown in line at submergence tank. Two weeks after transplanting the plants were completely submerged by tap water and retained 70 cm water depth from the base of the plant for 14 days. Water temperature, light intensity (at different depths), pH and turbidity was recorded and measured two times a day during submergence period. The light intensity was 80-120, 30-45 and 10-20 μ mole/m$^2$/s at upper, middle and lower level respectively. The water pH was 7.50-8.50 and water temperature was 28-30°C during growing period. The range of water turbidity of the tank was 50-70 FNU (Formazin Nephelometric Unit).

**Table 2. Yield and reduction percentage of yield over control of some rice genotypes affected by salinity stress.**

| Genotype | Grain yield/hill | | % reduction of yield over control |
|---|---|---|---|
| | Salinity stress (dS/m) | | |
| | Control | 8 | |
| BR9379-21-3B | 5.2 | 2.6 | 50.0 |
| BR9392-2-6-2B | 8.5 | 2.6 | 69.4 |
| BR9379-10-1-13 | 8.7 | 2.7 | 69.0 |
| BR10230-15-27 | 6.2 | 2.6 | 58.1 |
| Habiganj Aman-1 | 8.5 | 2.5 | 70.6 |
| IR58443-6B-10-3 | 4.9 | 3.2 | 34.7 |
| IR29 | 5.4 | 2.4 | 55.6 |

$LSD_{0.05}$ for genotype (G) is 0.5, $LSD_{0.05}$ for salinity stress (S) is 0.2, $LSD_{0.05}$ for G×S is 0.7

All the germplasm were elongating type and could not be selected for flash flood submergence tolerance, rather they might be suitable for deepwater rice. Among 60 breeding lines, fifteen lines (IR92684-SUB-SUB-141-1-B, IR92458-SUB-SUB-116-1-B, IR90082-SUB 35-3-2-2, IR92694-SUB-SUB-151-1-B, IR92466 SUB-SUB-59-1-B, IR92471-SUB-SUB-39-3-B, IR91545-SUB-SUB-4-1-2, IR92695-SUB-SUB 119-3-B, IR92462-SUB-SUB-205-2-B, IR13F548, IR13F478, IR13F441, IR13F652, IR13F470 and IR13F651) were found 100% survivability after submergence with non elongating characteristics.

**Evaluation of some submergence tolerant genotypes at different submergence condition.** An experiment was conducted to observe the growth duration and yield under normal and complete submergence condition of different durations. Fourteen-day-old seedlings of five submergence tolerant rice genotypes BRRI acc. no. 1838, BRRI acc. no. 4096, BRRI dhan51, BRRI dhan52, BINA dhan11 along with resistant check FR13A and standard check BRRI dhan33 were transplanted in three submergence tanks. Two weeks after transplanting the plants were completely submerged by tap water and retained 70 cm water depth from the base of the plant for 7, 14 and 21 days in tank-1, tank-2 and tank-3 respectively. Another one set was grown in normal condition. After seven days of complete submergence survivability of BRRI acc. no. 1838, BRRI acc. no. 4096, BINA dhan11 and tolerant check FR13A was 100%, while it was 98.6, 94.4 and 45 % for BRRI dhan51, BRRI dhan52 and BRRI dhan33 respectively (Table 4). Growth duration did not differ significantly between normal environment and seven days submerged plants. The lowest growth duration was observed in acc. no. 1838 (125 days) with 3.80 t/ha yields. The highest yield was found in BRRI dhan52 (4.85 t ha$^{-1}$) with 143 days growth duration. After 18 days of complete submergence, around 80% survivability

**Table 3. Significant QTLs identified for seedling stage salinity tolerance from Ashfal balam.**

| Trait | Chr. | Position (cM) | Left Marker-Right Marker | LOD | PVE (%) | Add | Dom |
|---|---|---|---|---|---|---|---|
| SES | 3 | 164 | Ud3001475-K_id3018242 | 4.43 | 56.23 | 0.14 | -1.51 |
| SES | 6 | 42 | K_id6001535-K_id6015421 | 3.85 | 60.93 | 0.36 | -1.53 |
| SES | 7 | 53 | Id7003043-id7002260 | 4.55 | 36.18 | 0.27 | -1.28 |
| SUR | 3 | 160 | Ud3001475-K_id3018242 | 4.12 | 48.96 | -11.76 | 16.86 |
| SUR | 6 | 54 | K_id6001535-K_id6015421 | 6.14 | 50.48 | -13.15 | 15.70 |
| SUR | 7 | 24 | Id7005036-id7003043 | 4.75 | 58.12 | -10.58 | 23.47 |
| SUR | 7 | 53 | id7003043-id7002260 | 3.25 | 29.59 | 11.71 | 12.38 |
| SL | 1 | 40 | K_id1024973-K_id1000955 | 16.72 | 62.75 | 4.37 | 0.61 |
| RL | 6 | 88 | K_id6001535-K_id6015421 | 4.93 | 16.59 | -1.00 | -0.31 |
| RL | 10 | 2 | Id10007241-id10006389 | 3.96 | 8.68 | -0.65 | 0.33 |
| SPAD | 3 | 156 | Ud3001475-K_id3018242 | 3.49 | 27.90 | -2.80 | 2.52 |

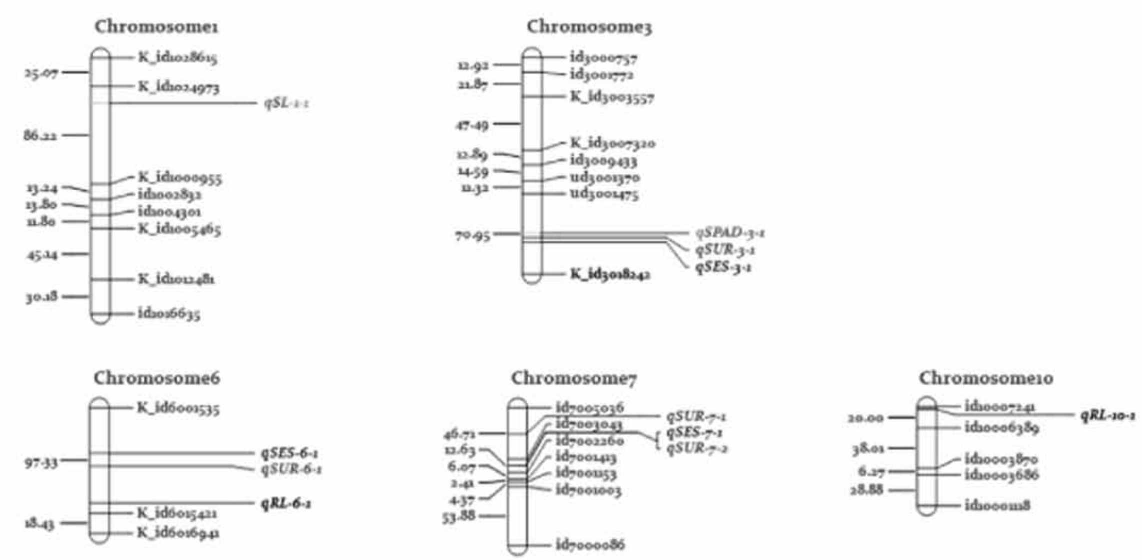



Fig. 1. Linkage map with distribution of salinity tolerance QTLs in Ashfal balam.

was recorded in four genotypes including tolerant check (acc. no. 1838, acc. 4096, BINA dhan11 and FR13A). Growth duration increased significantly for all genotypes after 14 days complete submergence. This increase was 19 days for BRRI dhan52, while 15 days for acc. no. 1838 indicating better recovery ability of that germplasm. Growth duration and yield did not differ significantly between BINA dhan11 and acc. no. 4096. However, BRRI dhan52 and BRRI dhan51 yielded better than other tested genotypes after 14 days submergence.

**Characterization of some advanced material under deep flooding environment.** Three advanced breeding line along with check HbjA-1 was characterized under deep flooding condition. At 5-leaf stage,seedlings were transplanted into the tank at single seedling per hill with 20cm × 20cm spacing. At 14 DAT, flooding was started and continued up to neck of the plant. Then water level was increased with 5 cm in each week, and the final depth of water was fixed up to 1.5 m. The deep flooding condition was maintained till maturity.

Among the advanced line only BR7730-5-1-2B survived under deep flooding condition and showed 80% survivability with 2.15 m plant height. However, check variety HbjA-1 had 100% survivability with the highest plant height (2.45 m). Tiller per hill was lower in BR7730-5-1-2B

**Table 4. Survivability, growth duration and yield of tested genotypes under normal and different submergence condition.**

| Genotype | Growth duration (day) | | | Yield (t ha$^{-1}$) | | | Survivability (%) | |
|---|---|---|---|---|---|---|---|---|
| | Normal condition | 7 days sub. | 14 days sub. | Normal condition | 7 days sub. | 14 days sub. | 7 days sub. | 14 days sub. |
| Acc. no. 1836 | 120 | 125 | 135 | 4.50 | 3.80 | 3.60 | 100.0 | 80.56 |
| Acc. no. 4096 | 118 | 125 | 139 | 3.25 | 3.50 | 3.09 | 100.0 | 80.56 |
| BRRI dhan51 | 140 | 144 | 155 | 4.30 | 3.77 | 4.35 | 94.6 | 23.61 |
| BRRI dhan52 | 142 | 143 | 161 | 5.00 | 4.45 | 4.37 | 96.4 | 75.00 |
| BINA dhan11 | 122 | 127 | 140 | 4.10 | 3.90 | 3.70 | 100.0 | 87.50 |
| BRRI dhan33 | 120 | 128 | not survived | 4.2 | 3.80 | not survived | 45.0 | 0.00 |
| FR13A | 152 | 155 | 156 | 3.20 | 3.10 | 2.80 | 100.0 | 94.4 |
| LSDat 0.05 for genotype | 2.24 | 2.48 | 2.84 | 0.13 | 0.16 | 0.26 | 0.87 | 0.84 |
| LSDat 0.05 for submergence condition | | 1.48 | | | 0.75 | | 0.25 | |
| LSDat 0.05 for gentype × environment | | 2.56 | | | 0.18 | | 0.63 | |

(3 tiller/ hill) than check variety (4 tiller hill). But BR7730-5-1-2B had significantly higher filled grain per tiller (as each tiller produced 2nd and 3rd branch) and produced more spikelet per tiller (104) than the check variety (50). BR7730-5-1-2B had 8.4 g/plant yield where as HbjA-1 had 5.8 g/plant yield.

**Screening of some advanced line for anaerobic germination.** Twenty advanced breeding lines along with two check varieties Khao Hlanon (Res. ck) and BRRI dhan52 (Sus. ck) were tested to determine the germination ability under anaerobic condition. Seed were directly sown 2 cm beneath the puddled soil in tray. The tray was flooded about 10 cm from the soil surface and one set were grown under normal condition in puddled soil. Anaerobic germination counted and expressed as percentage (%) relative to the number of sown seeds. Quantify seedling vigour after 21days of sowing. Out of 20 advanced breeding lines IR96977-B-B-7-B showed 50% germination in anaerobic condition.

**Screening of rice gremplasm for medium stagnation.** Thirty-one advanced breeding materials and 20 BRRI germplasms along with three standard check varieties BRRI dhan51, BRRI dhan52 and IR119 were tested within 60 cm (gradually increase) water pressure up to flowering to identify medium stagnation tolerant genotype. Over all, germplasms were performed better than advance breeding materials. Among the genotypes 23 advanced lines and 20 germplasms performed better than three standard check varieties. Acc. nos. 1038, 1028 and 1035 produced good number of tillers (8.25/plant, 7.5/plant and 7.75/ plant respectively) as well as yield. IR 92689-SUB-SUB-92-1-Band IR 13F621 performed better among the advanced lines.

## DROUGHT TOLERANCE

**Screening of rice germplasm for drought tolerance at reproductive phase, T. Aman2016**

Two hundred thirty-five rice germplasm collected from BRRI gene bank along with check variety BRRI dhan56 were tested during T. Aman season 2016 at BRRI farm, Gazipur following field-managed screening protocol (IRRI, 2008). Thirty-day-old seedlings were transplanted at a spacing of 20 × 20 cm. The experiment was laid out in Alpha lattice design with two replications. Standard agronomic management practices were followed. Irrigation was withheld four weeks after transplanting and field were drained out properly for not allowing any standing water until maturity. Out of 235 germplasm, 25 performed better in relation to yield under drought stress at reproductive phase.

**Selection of $F_2$ materials under drought stress at reproductive stage in the rain-out shelter**

This experiment was conducted in the rain-out shelter, Plant Physiology Division at BRRI HQ, Gazipur during T. Aman 2016 to evaluate $F_2$ plants of 17 crosses with check variety BRRI dhan56. Thirty-day-old seedlings were transplanted in puddled soil at a spacing of 20 × 20 cm. Standard agronomic management practices were followed. Weeds were controlled when needed. Ten lines of each cross were maintained. Four weeks after transplanting, the plots were drained out for inducing drought stress at reproductive phase. The water table depth and soil moisture was recorded. Tolerant plants were selected from each cross and seeds of selected plants were harvested with the help of breeders.

**Performance of some rice genotypes under drought stress at reproductive stage.** Eleven RYT, green super rice (GSR) materials namely HHZ5-DT20-DT3-Y2, HHZ5-SAL14-SAL2-Y2, HHZ8-SAL12-Y2-DT1, IR6483-87-2-2-3-3 (PSB Rc82), HHZ5-DT20-DT2-DT1, HHZ5-SAL10-DT3-Y2, HHZ17-DT6-Y1-DT1, HHZ23-DT16-DT1-DT1, HHZ15-DT4-DT1-Y1, HHZ5-Y3-Y1-DT1, HHZ5-SAL10-DT1-DT1 along with check variety BRRI dhan56, BRRI dhan66 and BRRI dhan71 were evaluated in Plant Physiology net house shaded by polythene sheet at BRRI HQ, Gazipur in T. Aman, 2016. Twenty-five-day-old seedlings were transplanted in drum (56 cm × 43 cm) containing 110 kg puddled soil in two sets where 1st set was grown in well-watered conditions and 2nd set was 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. Out of 11 genotypes HHZ17-DT6-Y1-DT1 and HHZ23-DT16-DT1-DT1 performed better.

**Evaluation of five advanced breeding lines under drought stress at reproductive stage.** Five advanced breeding lines namely BR9379-21-3B, BR9392-2-6-2B, BR9379-10-1-13, BR10230-15-27, and BR10230-7-1 along with Habiganj Aman-1 and BRRI dhan56 were evaluated under control drought condition. The methodology was same as the previous experiment. Out of five advanced breeding lines BR10230-7-1 performed better.

## HEAT TOLERANCE

**Evaluation of advanced breeding lines for development of heat tolerant rice.** Two experiments were conducted to evaluate the breeding lines of rice to develop a high temperature tolerant rice variety. Seeds of fourteen BRRI breeding lines ($F_4$), six BRRI breeding lines ($BC_2F_2$) along with their parents and eight IRRI breeding lines were sown in the seed bed from February to March. Twenty-five-day-old seedlings were transplanted in earthen pot, which was filled with soil. All pots were placed in natural condition until heading with BRRI recommended management practices. During heading all the pots of BRRI breeding lines were placed in controlled glass house at high temperature (35±3°C)and high humidity (75±5%) for seven days. After that the pots were moved to natural condition. At harvest floret fertility and physiological traits for the plants were examined. Among the BRRI breeding lines seven entries showed 42 to 60% fertility under heat stress treatment and got SES score 5 and these were selected for advancement. Among the eight IRRI breeding lines four scored 5 and two lines were selected for field evaluation.

**Marker assisted introgression of spikelet fertility QTL from N22 into two Bangladeshi mega rice varieties BRRI dhan28 and BRRI dhan29.** For developing heat tolerant BRRI dhan28 and BRRI dhan29 by introgressing spikelet fertility QTL (*qHTSF4.1*) through MABC is on-going. From second backcross generation, 40 fixed lines and at third backcross generation 20 fixed lines were selected through genotypically by using an InDel (R4M30) and later the presence of QTL confirmed by a CAPS marker (Fig. 2). During harvesting of the selected lines phenotypic similarity with reference to the respective recurrent parents (BRRI dhan28 and BRRI dhan29) were alsochecked.

## COLD TOLERANCE

**Exploring new sources of cold tolerance from BRRI Genebank collections at seedling stage** Some 200 rice germplasm collected from BRRI Genebank along with five check varieties namely BRRI dhan28, BRRI dhan36, BRRI dhan69, Bhutan and HbjB-VI were tested for seedling stage cold tolerance in cold water tanks at artificial condition. Seeds were sown in plastic trays (60 cm length × 30 cm breadth × 2.5 cm height) filled with gravels and crop residue free granular soil and allowed to grow until three leaf stage. The plastic trays were then placed into cold water tanks adjusted to constant temperature at 13°C. Among the tested germplasm, three was found tolerant (BRRI acc. no. 1325,1583

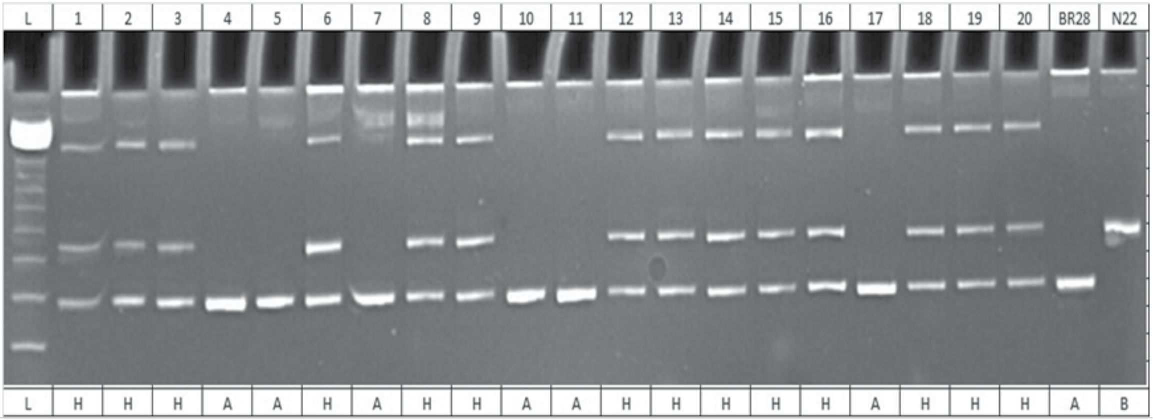



Fig. 2. PAGE (8%) of $BC_3F_1$ progenies of BRRI dhan28/N22///BRRI dhan28 genotyping through InDel marker R4M30 (where, B=BR28, N=N22 and L = Ladder 25 bp).

and 1584.), while another 27 germplasm (BRRI acc no. 895, 1001, 1003, 1005, 1027, 1048, 1296, 1300,1064, 1315, 1316, 1317, 1318, 1320, 1321, 1327, 1339, 1342, 1387, 1388, 1389, 1425, 1426, 1429, 1533, 1534 and 1581) showed average visual score (SES) 5.0 to 5.5 that is classified as moderately tolerant. However, other genotypes showed visual score 6 to 9 that is susceptible to highly susceptible.

**Screening for cold tolerance of advanced breeding lines at seedling stage.** Some 38 advanced breeding lines along with four check varieties namely BRRI dhan28, BRRI dhan36, Bhutan and HbjB-VI were tested in cold water tanks at artificial condition. Among the tested genotypes, none was found tolerant, while only nine genotypes showed average visual score (SES) 5.0 to 5.5 that is classified as moderately tolerant. The selected genotypes are BR(Bio)833-BC5-1-1, BR(Bio)833-BC5-1-20, BR(Bio)833-BC5-2-16, BR(Bio)9777-106-7-4, BR(Bio)9777-84-4-1-1, BR(Bio)9777-112-2-3-2, BR(Bio)9777-116-12-2-2, BR(Bio)9777-116-12-2-4, BR(Bio) 9777-123-4-6-1.

**Evaluation of some selected rice genotypes for reproductive stage cold tolerance.** Thirteen advanced (OT) lines, 6 IRTON materials along with BRRI dhan28, BRRI dhan36 and Bhutan as checks were evaluated for reproductive stage cold tolerance under natural condition in BRRI farm, Gazipur during Boro 2016-17 season. There were two seeding times for each genotype. One set of seeds were sown on 15 October with a view to falling rice reproductive phase at cold. Other set was sown on 15 November as control. Thirty-day-old seedlings were transplanted in main field. Considering plant height, growth duration, last internode length, panicle exertion, phenotypic acceptance, sterility, grain size and yield, an advanced line BR8907-B-1-2-CS1-4-CS2-P3-4 and an IRRI materials IR87322-65-2 were selected (Table 5).

**Characterization and evaluation of BRRI dhan69 for cold tolerance.** BRRI dhan69 was tested for seedling stage cold tolerance in cold water tanks at artificial condition where BRRI dhan28, BRRI dhan36 and Bhutan were used as checks. Its reproductive stage cold tolerance was tested in natural field condition using same check varieties through manipulation of seeding time. There were two seeding times i.e. 15 October (early planting) and 15 November (as control). BRRI dhan69 showed moderately cold tolerant, both at seedling and reproductive stages which was higher than our standard variety BRRI dhan28 and BRRI dhan36 but lower than resistant check Bhutan. In 15 November sowing, growth duration and sterility were increased, whereas plant height, last internode length, panicle length, panicle exertion and field grain/ panicle were reduced greatly in all rice genotypes except BRRI dhan69 and Bhutan, which were less affected. In contrast to 15 November sowing, growth duration of all the tested genotypes was increased by 15-20 days when they were sown on 15 October. BRRI dhan69 had significantly higher grain yield but growth duration was one week more than the check varieties (Table 6).

**Table 5. Effect of cold treatment on selected rice genotypes, Boro 2016-17.**

| Genotype | Growth duration (d) | | Plant height (cm) | | Last internode length (cm) | | Sterility (%) | | 1000 grain wt (g) | | | Yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 14 Oct | 15 Nov | 14 Oct | 15 Nov | 14 Oct | 15 Nov | 14 Oct | 15 Nov | 14 Oct | 15 Nov | 14 Oct | 15 Nov |
| IR87322-65-2 | 172.5 | 151.5 | 79.0 | 87.5 | 26.22 | 31.78 | 35.15 | 20.25 | 21.31 | 21.76 | 4.05 | 6.34 |
| BR8907-B-1-2-CS1-4-CS2-P3-4 | 165.0 | 145.0 | 92.5 | 98.0 | 29.0 | 32.66 | 39.96 | 23.12 | 24.85 | 2.05 | 4.0 | 7.0 |
| Bhutan | 157.5 | 142.0 | 144.75 | 144.0 | 43.15 | 44.23 | 32.59 | 22.24 | 21.89 | 22.37 | 2.39 | 2.75 |
| BRRI dhan28 | 165.0 | 145.0 | 71.56 | 95.45 | 26.41 | 30.64 | 48.87 | 20.98 | 21.25 | 21.84 | 3.13 | 6.0 |
| BRRI dhan36 | 170.0 | 146.0 | 70.68 | 94.48 | 25.32 | 30.21 | 49.59 | 24.0 | 23.46 | 23.77 | 3.13 | 5. 5 |
| LSD $_{5\%}$ genotype (G) | 3.42 | | 6.52 | | 2.42 | | 12.87 | | 0.42 | | | 1.08 |
| $LSD_{5\%}$ sowing time (S) | 0.98 | | 1.93 | | 0.78 | | 4.26 | | | 0.31 | | 0.42 |
| $LSD_{5\%}$ for G*S | 4.63 | | 9.12 | | 3.49 | | 14.36 | | | 0.60 | | 1.51 |

**Table 6. Growth duration, yield and cold tolerance potential of BRRI dhan69.**

| Genotype | Growth duration days | | Yield t/ha | | Cold tolerance Score | |
|---|---|---|---|---|---|---|
| | 15 Oct sown | 15 Nov sown | 15 Oct sown | 15 Nov sown | Vegetative stage | Reproductive stage |
| BRRI dhan69 | 170 | 153 | 3.8 | 6.5 | 5 | 5 |
| Bhutan (Tolerant ck) | 157 | 142 | 2.39 | 2.75 | 3 | 3 |
| BRRI dhan28 (Standard ck) | 165 | 145 | 3.13 | 6.0 | 9 | 7 |
| BRRI dhan36 (ck) | 170 | 146 | 3.13 | 5.5 | 7 | 7 |
| LSD $_{5\%}$ genotype (G) | 3.78 | | 0.93 | | - | - |
| $LSD_{5\%}$ sowing time (S) | 1.06 | | 0.49 | | - | - |
| $LSD_{5\%}$ for G*S | 4.71 | | 1.35 | | - | - |

## GROWTH STUDIES

**Physiological characterization of $CO_2$ responsiveness of Bangladeshi rice germplasm through planting geometry technique**. Two-hundred-two BRRI Genebankgermplasm were tested in the field condition through planting geometry technique to identify $CO_2$ responsiveness in the T. Aman 2015. The selected top and bottom 10 germplasm were again tested in T. Aman 2016 in three sowing time early (June), optimum (July) and late (August). Finaly-Wilkinson regression analyses showed photosensitive low-land varieties are more resilient than insensitive upland varieties in changing climatic condition. Tiller and panicle number, panicle dry weight and harvest index are strongly associated with $CO_2$ responsiveness in rice. Photosynthetic responses to varying Intercellular $CO_2$ concentration of top ranked germplasm such as Chini sagar (acc. no. 157) showed better responses compared to bottom ranked KanchaNcni (acc. no. 270) (Fig. 3 and 4).

**Evaluation of different BRRI Boro varieties for growth and yield.** The experiment was conducted in four different sowing dates. BRRI dhan28 performed better at 3rd sowing 20 Dec 2016 with less growth duration but BRRI dhan68 performed well at 2nd sowing 27 Nov 2016. Long duration variety did not perform well when sown late due to different natural hazards.

**Characterization of Aus germplasms affected by Apical dominance**

An experiment was conducted at BRRI farm, Gazipur to study the effect of breaking apical dominance on growth and yield of Aus germplasm. For this experiment 44 Aus germplasms along with two check varieties BRRI dhan43 and BRRI dhan65 were sown in two plot (Control and apical dominance breaking). Thirty days after sowing apical dominance was broken down by mowing. Experiment was laid out by augmented design. Out of 44 germplasms, four were found early

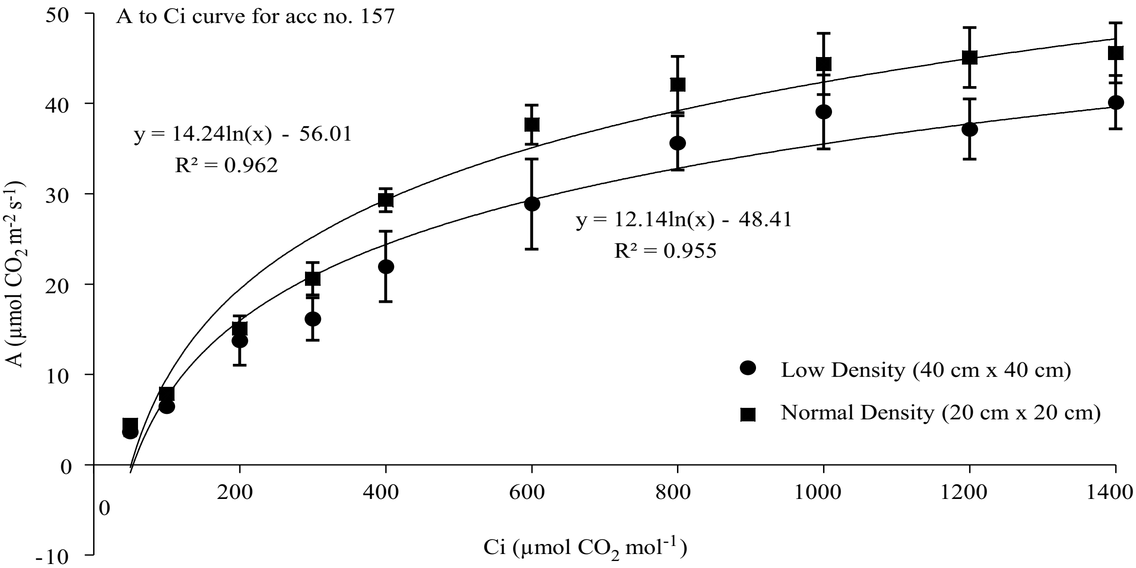



Fig. 3. Photosynthetic responses of top ranked germplasm Chini sagar (Acc. no. 157).

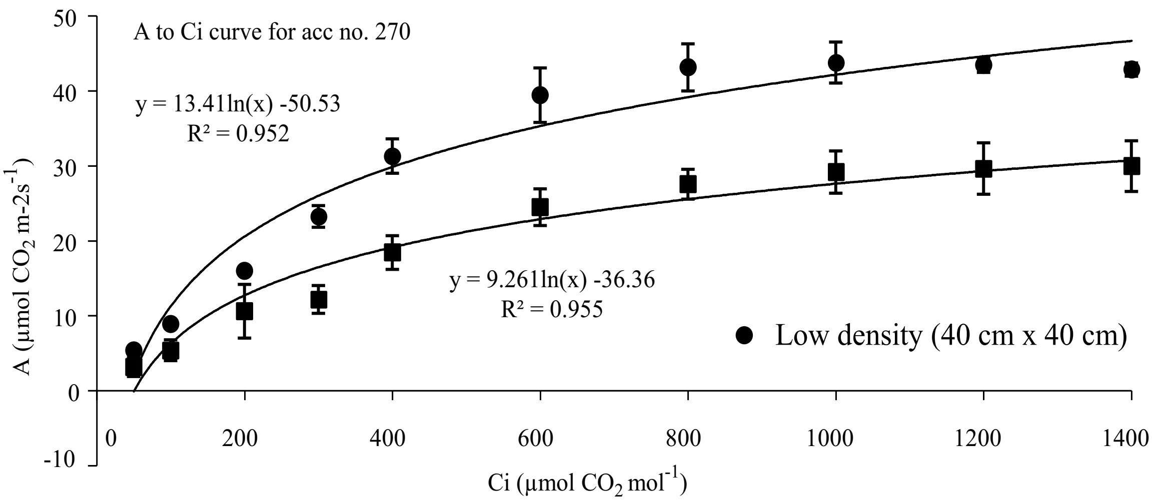



Fig. 4. Photosynthetic responses of bottom ranked germplasm Kancha Ncni (Acc. no. 270).

(60 days) heading habit namely, KALA MANIK (acc.1203), BOLIUM (acc. 1205), SAITA (acc. 1681) and MANIK MONDAL (acc. 1692). Among all germplasms 20 germplasms performed better in respect to yield after breaking apical dominance and other germplasms perform better at control conditions. At apical dominance broken treatment 10 germplasms and at control treatment six germplasms performed better than the check variety BRRI dhan65. At both conditions RANG MAHAL (acc. 1629) produced maximum yield.

SEED PHYSIOLOGY

**Dormancy and viability test of BRRI varieties grown in Aus, Aman and Boro seasons.** The experiment was done to determine the dormancy and viability period of rice varieties. Seven varieties in Aman season and nine varieties in Boro season were grown in the field up to maturity using the normal cultural practices in 2015-16. Plants were grown in the field up to maturity using the normal cultural practices. Seeds were collected, sun dried at

12% moisture content. The collected seeds would be preserved and them used for dormancy and viability test. For dormancy test, germination test was done at the date of harvest and then at an interval of seven days until the dormancy is broken. For viability test, when germination percent was 80% or above seeds were preserved in refrigerator or packet. These seeds were used for viability test. The viability test would be done at an interval of 30 days beginning from the date of broken dormancy.

**Seed dormancy.** The seeds of all the varieties had higher dormancy than that of Boro season except BRRI dhan52 and BRRI dhan57. In Aman season, the seeds of BRRI dhan54 had high dormancy period (49 days) than that of other varieties. The range of dormancy period varied from 21 to 49 days and seven to 35 days in Aman and Boro season respectively.

**Seed viability.** In Aman season all the varieties were viable up to 210 days in case of polythene packet storage condition except BRRI dhan52 (180 days), BRRI dhan57 (150 days) and BRRI dhan62 (150 days). Moreover, BRRI dhan54 had the longer viability period (240 days). In Boro season all the varieties remained viable up to 110 days in case of polythene packet storage condition. However, BRRI dhan58 and BRRI dhan67 were viable up to 170 days. Moreover, BRRI dhan67 remained viable for longer period (200 days). The seeds stored in freeze condition gave long viability period due to very low temperature.

# Entomology Division

SUMMARY

Among the three rice growing seasons comparatively higher number of insect pests and their natural enemies were found in Aus season. Overall occurrence of insect pests was low and did not cross the ETL in any place. Grasshoppers were commonly observed in all surveyed areas. Among the natural enemies, damsel fly was common. Brown planthopper population (191395) were higher followed by green leafhopper (126509), yellow stemborer (83056) and white-backed planthopper (44997) in all seven locations in the light trap. Use of perching, sweeping, and need based insecticide produce at par yield compared to prophylactic insecticide use in rice field. This technique can reduce 75-100% of insecticide usage in rice field. The highest parasitism rate was found in eco-engineering treated plot and least number of natural enemies and rate of parasitism observed in rice field where prophylactic use of insecticides. In natural condition 27.54% rice leaf folder larvae were parasitized by *Elasmus sp*. and rate of parasitism varied from 9 to 75%. The frog can consume 21.78-41.67 BPH (4$^{th}$ instar nymph) within 48 hours. Carabid beetle and lady bird beetle consumed 3.57 and 3.22 BPH (4$^{th}$ instar nymph) within 24h respectively. Incubation period of green mirid bug was 10-14 days. It has five nymphal stages and requires 15-18 days to reach adult. Adult longevity was 10-25 days. Fumigation action of mahogany oil causes 100% mortality to rice weevil and Angoumois grain moth at 48 h exposure period. BRRI dhan49 showed 37.5% yield loss when infested by leaffolder. One percent onion shoot corresponds to 0.96, 0.90 and 0.85% yield loss of BRRI dhan52, BRRI dhan73 and BRRI dhan62 respectively in T. Aman season. A suitable culture medium (boiled rice) for *Metarhizium anisopliae*, was identified. At maximum tillering stage, 6:1 (six rows planting and one row gap) planting system showed effective spraying method with double nozzle sprayer than the 8:1 and 10:1 planting system. A total of 50 insecticides were tested. Among those 27 were found effective against brown planthopper and one against yellow stemborer. BR(Bio)9785-BC2-6-2-2 and BR8079-19-1-5-1 advanced materials showed moderately resistant against WBPH and GLH respectively. BR8526-9-2-3-5 and IR12N177 rice germplasms showed highly and moderately resistant against gall midge respectively.


SURVEY AND MONITORING OF RICE ARTHROPODS

**Pest and natural enemy monitoring at BRRI farm**

The incidence of rice insect pests and their natural enemies was monitored weekly at BRRI research farm, Gazipur. The overall insect pest incidence was low in the reporting year. Higher incidences of insect pests were found in Aus and T. Aman seasons than the Boro season (Fig. 1). Grasshoppers (GH) and green leafhopper (GLH) were the most abundant pests and found in all the three seasons. The highest population of GH was found in the grass fallow at Aus and T. Aman seasons. Higher numbers of natural enemies were observed in Aus season than Boro and T. Aman seasons. Spider, damsel fly, ladybird beetle (LBB) and carabid beetle (CDB) was the dominant predators (Fig. 1) in all the habitats irrespective of season except in few cases. Likewise, insect pests, the natural enemies also concentrated mostly in the rice fields in all the seasons except Boro.

Insect population and damage intensity were also investigated using 20 hills counting method at every week. Insect pests were below the economic threshhold level (ETL) in all the three rice seasons (Table 1). Whorl maggot (WM), rice leaffolder (RLF) and grasshoppers were the most abundant pests. Damages caused by stem borers (SB), grasshoppers, long horned cricket (LHC), rice leaffolder (RLF) and whorl maggot (WM) were observed throughout the year (Table 1). The damage due to SB was comparatively higher in the T. Aman season than that of the other seasons. However, damage intensity did not cross ETL. Spiders were the dominant predators and found in all habitats throughout the year (Table 1).

**Insect pests survey in different AEZs of Bangladesh**

We also surveyed different locations of Bangladesh including Rajshahi, Habiganj, Pirojpur, Gopalganj, Bagerhat and Barisal to find out the incidence patterns of major insect pests and their natural enemies. Overall insect pest occurrence in surveyed areas was low and did not cross the ETL in any place. During Aus season, the highest number of grasshoppers was found in Barisal than that of the other surveyed area. The highest number of damsel fly was observed in Pirojpur (18) followed

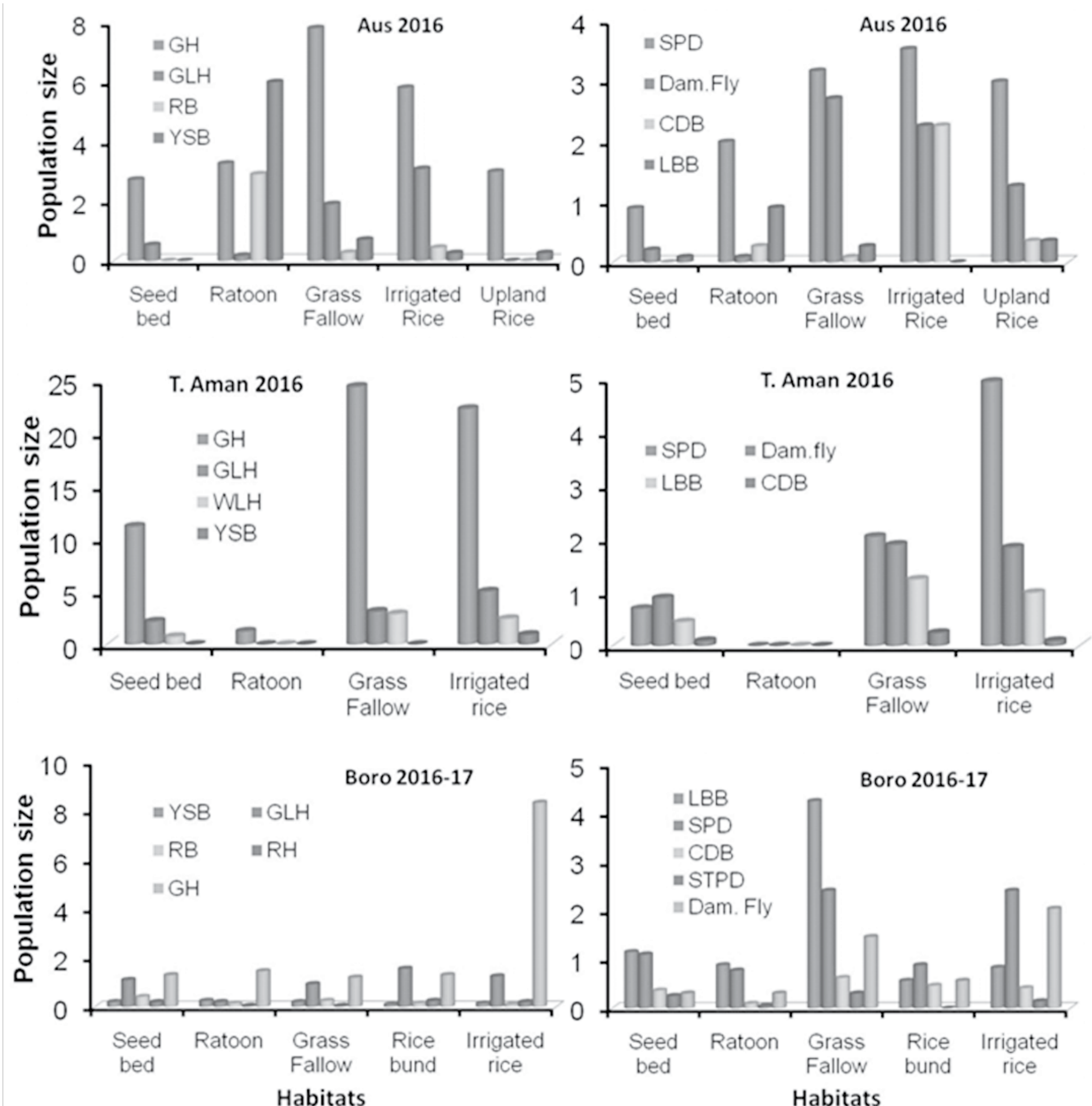



Fig. 1. Incidence of insect pests and natural enemies in rice and non-rice habitats (determined by sweep net) during Aus 2016, T. Aman 2016 and Boro 2016-17 in BRRI farm, Gazipur.

by Barisal (7), Gopalganj (2), Habiganj (1.27) and Rajshahi (1). Likewise, Aus season insect pest infestation was low in all the surveyed areas in T. Aman 2016. However, among the natural enemies damsel fly was the dominant predator and found in all surveyed areas. However, Pirojpur harvoured highest the numbers (28) of damsel fly followed by Bagerhat (22), Rajshahi (10), Gopalganj (6.7), Barisal (6) and Jhalokati (6). Rice bug population was observed only in Rajshahi in T. Aman season.

**Incidence of insect pest and natural enemies in light trap**

We also monitored rice arthropods using light trap in order to create a database on insect pests and their natural enemies to develop a forecasting system. Rice insect pests and their natural enemies were recorded using light trap during July 2016 to June 2017 at BRRI HQ farms in Gazipur as well as BRRI RS farms in Barisal, Rajshahi, Comilla, Habiganj, Sonagazi and Rangpur. Figure 2 shows monthly

**Table 1. Insect pest and natural enemy incidence and damage levels in rice, Aus 2016, T. Aman 2016 and Boro 2016-17, BRRI, Gazipur.**

| Pest and natural enemy | | Aus | | | | T. Aman | | Boro | |
|---|---|---|---|---|---|---|---|---|---|
| | | Upland rice | | T. Aus | | | | | |
| | | No./20 hills/ week | Damage (%) | No./20 hills/week | Damage (%) | No./20 hills/week | Damage (%) | No./20 hills/week | Damage (%) |
| *Insect pests* | | | | | | | | | |
| SB | DH | 0.00 | 0.09 | 0.00 | 0.12 | 2.57 | 0.06 | 0.00 | 0.06 |
| | WH | 0.00 | 0.17 | | 0.03 | | 0.1 | | 0.01 |
| BPH | | 0.09 | 0.00 | 0.00 | 0.00 | 0.45 | 0.029 | 0.00 | 0.00 |
| WBPH | | 0.00 | 0.00 | 0.00 | 0.00 | 2.6 | 0.21 | 0.00 | 0.00 |
| GLH | | 0.63 | 0.00 | 0.73 | 0.00 | 1.2 | 0.08 | 0.315 | 0.00 |
| GH | | 1.63 | 8.81 | 1.00 | 7.45 | 3.95 | 0.938 | 1.78 | 0.21 |
| RLF | | 0.27 | 0.36 | 0.27 | 0.45 | 5.85 | 0.29 | 0.26 | 0.11 |
| LHC | | 0.36 | 0.81 | 0.45 | 0.82 | 1.2 | 0.067 | 0.47 | 0.10 |
| *Natural enemies (No./20 hills/week)* | | | | | | | | | |
| LBB | | 0.18 | | 0.36 | | 1.55 | | 0.21 | |
| SPD | | 1.36 | | 2.09 | | 4.25 | | 0.84 | |
| GMB | | 0.00 | | 0.00 | | 0.00 | | 0.11 | |
| CDB | | 1.09 | | 1.54 | | 0.5 | | 0.68 | |
| Dragon fly | | 0.00 | | 0.00 | | 0.4 | | 0.00 | |
| Damsel fly | | 0.54 | | 0.18 | | 1.0 | | 0.21 | |

CS= Complete sweep i.e. left to right and right to left stroke of sweep net. [1]Populations and damage based on weekly direct count of 20 hills/plot; BPH=Brown planthopper, CDB=Carabid beetle, CW=Case worm, DH=Dead heart, Dam. fly=Damsel fly, Drag. fly=dragon fly, ECC=Ear cutting caterpillar, 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, TB=Tiger beetle, WBPH=White-backed planthopper, WM=Whorl maggot, WLH=White leafhopper, WH=White head, ZLH=Zigzag leafhopper.

incidence pattern of four principal rice insect pests and two natural enemies. Brown planthopper population (191395) were higher followed by green leafhopper (126509), yellow stemborer (83056) and white-backed planthopper (44997) in all seven locations. Brown planthopper (124596), green leafhopper (77942), yellow stemborer (55655) and white-backed planthopper (25399) dominated in Habiganj. Among the natural enemies green miridbug, carabid beetle, staphylinid beetle and spider were most prevalent. The highest population of green mirid bug (240863) was also observed in Gazipur.

## INTEGRATED PEST MANAGEMENT

### Conservation of natural enemies in rice ecosystem

Natural enemies of rice insect pests can be conserved in rice ecosystem through ecological engineering approach. Eco-engineering treated plot showed the highest parasitism activity to the exposed BPH, WBPH, YSB and rice hispa egg in rice field. Rice hispa egg was parasitized by *Trichogramma zahiri* and YSB egg by *T. chilonis* (Fig. 3). Severe pest outbreak was not found in the experimental plot. Moreover, eco-engineering plot reduced 50% key pest population and 75% chemical insecticides from rice field. In addition, in insecticide treated plot where insecticide used three times but yield was similar to that of eco-engineering and control plot. This result indicates that rice could be produced without insecticide using ecological engineering technique.

### Monitoring of larval parasitism of rice leaf folder

Larval parasitism was investigated to understand the efficiency of natural enemies against rice leaf folder in crop field. A total of 69 larvae of rice leaf folder were collected from rice field at seven dates. Collection started on 29 July 2016 and ended on 28 September 2016. The collected larvae with rice leaves were kept in test tube in the laboratory for parasitoid emergence. The parasitized and non-parasitized larvae were identified. The 27.54% larvae showed parasitized by *Elasmus sp.* However,

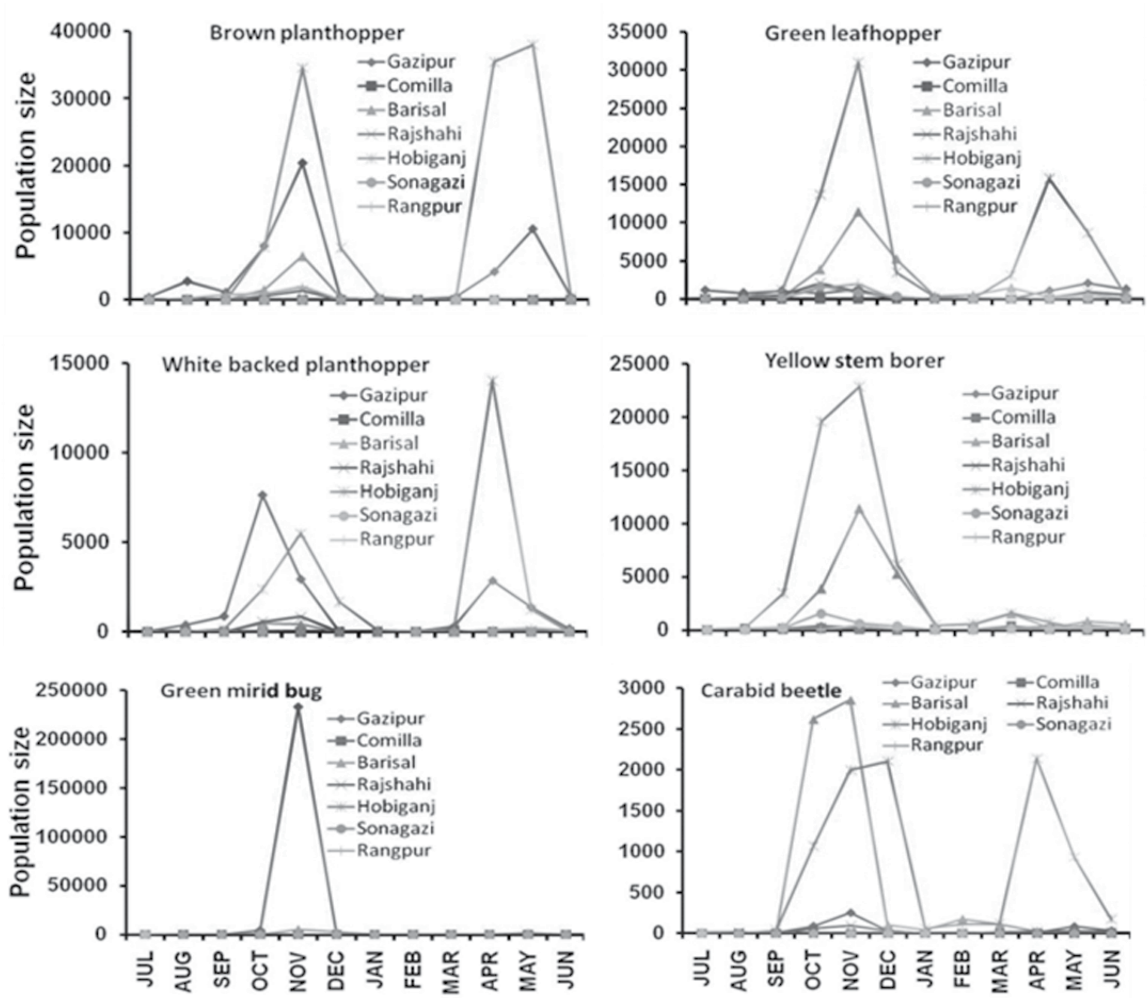



Fig. 2. Incidence pattern of insect pest and natural enemies in BRRI frams in Gazipur, Barisal, Rajshahi, Comilla, Habiganj, Sonagazi and Rangpur.

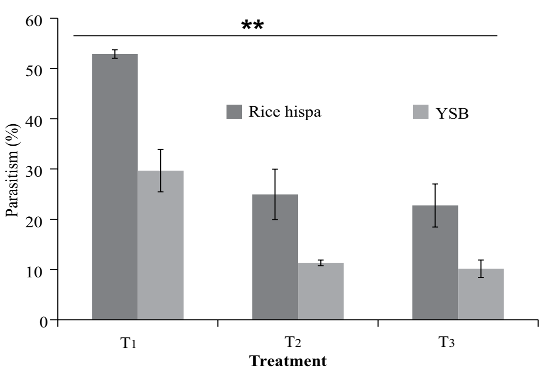



Fig. 3. Effect of treatments on the parasitism (%) of rice hispa and YSB eggs. $T_1$- eco-engineering, $T_2$ -insecticide treated plot and $T_3$- control plot. Egg bait trap was used to record the parasitism activity.

parasitism rate ranged from 9 to 75%. Parasitism rate was also varied with collection dates and 28 September showed the highest percentage (75%).

**Functional response of predator (frog, carabid beetle and lady bird beetle) against planthoppers**
This study was conducted to evaluate the biological control potential of the predacious frog, carabid beetle and lady bird beetle against brown planthopper (BPH). The consumption rate of frog, carabid beetle and lady bird beetle were investigated in confined field and laboratory condition respectively. Experimental results showed that the frog consumed 21.78-41.67 BPH ($4^{th}$ instar nymph) within 48 hours. Carabid beetle

and lady bird beetle consumed 3.57 and 3.22 BPH within 24h respectively. More experiments are required for getting conclusive results.

**Study on the biology of green mirid bug**

Gravid BPH females were confined inside the mylar on 40-day-old BR3 plant for egg laying on three consecutive nights. Then adult green mirid bugs (GMB) (both male and female) collected from BPH infested rice field were allowed to lay eggs on the leaf sheath of previously deposited BPH eggs. It took around 10-14 days to hatch nymph from eggs depending on temperature (ranging from 25-30°C). The emerged nymph completed five nymphal instars to become adult and it required around 15 to 18 days depending on the room temperature. GMB nymphs feed on 1st and 2nd instar BPH nymphs for their growth, development and survival. GMB adult longevity ranged from 10-25 days depending on the availability of natural honey. Adult GMB is used to find out the alternate host(s) to be multiplied in off-season.

**Study on entomogenous fungi to control brown planthopper (BPH)**

A study on entomogenous fungi (e.g. *Metarhizium anisopliae*) was conducted in greenhouse condition to explore suitable media for mass production. Potato dextrose agar and boiled rice media were tested to culture this fungus. Boiled rice is more suitable to culture it quickly. The culturing technique of *M anisopliae* was newly developed at BRRI. It took around 4-5 days to develop conidia. Conidia were washed with distilled water and sprayed on infested rice plant. Fungal conidia or mycelia have capacity to infect brown planthopper, white backed planthopper and small brown planthopper.

**Validation of BRRI recommended practices for insect pest management in Pirojpur, Bagerhat and Gopalganj regions (PGB)**

Field trials were conducted at farmers' fields in Pirojpur, Gopalganj and Bagerhat districts during T. Aman 2016 and Boro 2016-17 seasons. Three treatments including prophylactic use of insecticide ($T_1$) insecticide was applied in rice field at every 15 day intervals without judging the insect pest infestation levels; ($T_2$) perching (establishing perching sites for insectivorous birds) and concurrently using sweeping and need-based insecticide applications; and ($T_3$) farmers' practices. One portion of each farmer's field remained under the respective farmers' supervision without any intervention, which meant that $T_3$ is the control treatment of each experimental layout. During the experimental period insect infestation was below the ETL in all the locations. Insignificant numbers of insect pests were observed in trial fields both in Nazirpur and Gopalganj. Higher number of spiders and damsel fly were found in plots without insecticide application (Fig. 4). It indicates that insecticide affected the number of natural enemies in rice field. Lower yield was observed at $T_3$ (farmer practices) in all the demonstration plots of Pirojpur, Gopalganj and Bagerhat. No significant yield differences were observed among the treatments $T_1$ (5.24 t ha$^{-1}$) and $T_2$ (5.27 t ha$^{-1}$) at Nazirpur with rice variety BRRI dhan52. Similar results were also found in all the demonstrations of Gopalganj and Bagerhat with variety BRRI dhan39 and BRRI dhan49. Insecticide (Virtako 40WG @ 75 g ha$^{-1}$) was applied three/four times in $T_1$ plot but yield advantage was not significantly higher than the other treatment. The costs of insecticides and its application were higher than the yield advantage. Therefore, it is concluded that continuous use of insecticide had no significant effect on rice yield when insect infestation was below the ETL.

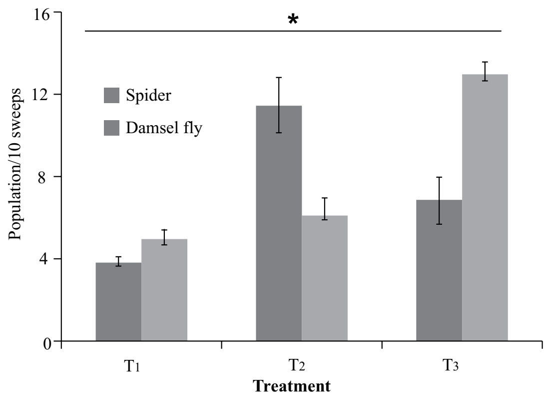



Fig. 4. Impact of treatment on the population of natural enemies in rice field at T. Aman 2016.
Error bars indicate the standard errors. *indicates significant at 5% level. $T_1$-insecticide was applied in rice field at every 15 days interval without judging the insect pest infestation levels; $T_2$-perching (establishing perching sites for insectivorous birds) and concurrently using sweeping and need-based insecticide applications; and ($T_3$)-farmers own chosen practices.

**Management of brown planthopper by configuration and geometry of rice planting**

Method of insecticide application in rice field is important to combat BPH. Spray swath is the important factor to control field population of BPH. At maximum tillering stage, six rows planting and one row gap (6:1) planting system showed better spraying capacity with double nozzle sprayer than the 8:1 and 10:1 planting system. The middle line of 8:1 and 10:1 planting geography received less volume of spray causing less mortality of insects at this position. At maximum tillering stage, 6:1 planting system showed effective spraying method with double nozzle sprayer than the 8:1 and 10:1 planting systems. This study indicates that plants need to transplant at 6:1 ratio for effective control of BPH with double nozzle sprayer.

**Application of Recharge in rice field for crop protection**

Recharge was applied in rice field to boost up the production and evaluated its effectiveness against insect pest in T. Aman 2016 and Boro 2016-17. Two treatments including $T_1$-Recharge application and $T_2$-Control (without Recharge) were used for this experiment. It was repeated four times @ of 3 kg/ha. Recharge treated plot showed vigorous growth of crop and comparatively greener than that of control plot. Significant differences were not found in respect to pest's abundance when compared to control plot. But slightly lower population of two natural enemies including damselfly, spider and one pest, green leafhopper (GLH) was found in recharge treated plot. Disease was not observed in any experimental plot. Significant yield improvement was not found in Recharge treated plot when compared to control plot. Similar result was found both in T. Aman 2016 and Boro 2016-17 season. The incidence of YSB population was very low during the experimental period. Therefore, this experiment needs to be conducted in YSB outbreak area.

## CROP LOSS ASSESSMENT DUE TO INSECT PEST INFESTATION

**Effect of rice leaf folder damage on rice grain yield of BRRI dhan49**

The study was conducted in the natural infested field of BRRI dhan49. Fifty rice hills with high levels of natural rice leaf folder (RLF) damage and another 50 healthy hills were marked at the flowering stage in study field of T. Aman 2016 season. Panicles of infested and healthy hills were harvested and grain weight were measured and adjusted at 14% moisture content. Yield loss occurred in rice leaf folder infested hills compared to control hills in BRRI dhan49 variety. The yield loss was estimated at 37.5%, by adjusting the grain weight between healthy and infested hills.

**Relationship between rice gall midge damage and yield loss**

Five rice varieties (namely BRRI dhan52, BRRI dhan62, BRRI dhan73 and two checks) were tested against rice gall midge infestation at field condition in T. Aman 2016 at BRRI farm, Gazipur. BRRI dhan49 and BRRI dhan33 were used as susceptible and resistant check respectively. Artificial infestation of gall midge was done at 26 days after transplanting (DAT). Around 50 DAT, the emerged adults were allowed to lay eggs before panicle initiation (PI) stage. Results also showed that one per cent infestation of onion shoot caused 0.96, 0.90 and 0.85 percent yield loss of BRRI dhan52, BRRI dhan73 and BRRI dhan62 respectively.

## EVALUATION OF CHEMICALS AND BOTANICALS AGAINST RICE INSECT PESTS

**Test of different insecticides against major insect pests of rice**

A total of 50 commercial formulations of insecticides were evaluated against BPH and YSB. Among those 27 were found effective against BPH and one against YSB. Effective commercial formulations were recommended to PTASC for registration and commercial use.

**Fumigation action of botanical oils against stored grain insect pests**

The mortality (reported after watching recoveries for four days) caused by the fumigation action of mahogany oil was recorded. The results indicated that the first exposure period (24 hrs) of rice stored grain insects to mahogany oil fume caused significant mortality to rice weevil and angoumois grain moth compared to the control. The second exposure period (48 hrs) to mahogany oil caused significant death among test insects compared to the control. Mortality ranges from 51 to 100% and from 88.57 to 100% in the rice weevil and angoumois grain moth respectively. The result of this study indicates that mahogany oil would be an effective product for controlling stored grain insect pests. However, more experiments are required for delivering it as a technology.

## HOST PLANT RESISTANCE

**Screening of elite breeding lines against major insect pests of rice**

A total of 49 materials were screened against brown planthopper, white backed planthopper and green leafhopper at green house. All the materials were found susceptible to BPH. Out of 49 advanced materials, only two materials were found moderately resistant to WBPH and one material was found moderately resistant to GLH (Table 2).

**Pest reaction of BRRI released rice varieties against major insect pests**

Sixty-nine BRRI released rice varieties were tested against BPH, none of these varieties were found resistant (score 0-1). However, 11 varieties were found moderately susceptible (score 5-7) against brown planthopper (BPH). Out of 61 varieties, none of varieties was found resistant but five varieties (BRRI dhan27, BRRI dhan28, BRRI dhan55, BRRI dhan62, BRRI dhan74) showed moderately resistant (score 5) against white backed planthopper (WBPH).

**Screening of rice germplasm, advanced lines and $F_2$ materials against rice gall midge**

A total of 119 rice germplasm collected from Genetic Resources and Seed Division, BRRI were screened against gallmidge during the reporting period. Among those, IR12N177 and BR8526-9-2-3-5 were recorded as moderately resistant (6-10% OS) and highly resistant (0-1% OS) respectively.

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

Ten test entries including BRRI dhan29 were evaluated under natural infestation at the confined field trial (CFT) site of Bangladesh Agricultural Research Institute (BARI), Gazipur during Boro 2016-17. Prophylactic measures were taken to control insect pests during crop growing season. Four different groups of insecticides including Virtako 40WG, Malathion 57EC, Chlorpyriphos 20EC and Mipcin 75WP were applied in the trial plot. The major insects namely stem borer (SB), leaffolder (LF), grasshoppers and natural enemies namely; lady bird beetle, spider, dragon fly and damsel fly were found. However, insect infestation was very low at the crop establishment stage due to regular application of insecticide.

Stem borer infestation was observed from vegetative stage to the reproductive stage. But their level was negligible. No significant differences were observed between the transgenic golden rice lines and non-transgenic BRRI dhan29. A few number of stem borer egg masses were observed in the tested lines. Leaf damaged by leaffolder insect was observed both in transgenic and non-transgenic lines. No unusual insect pest infestation was found in transgenic lines. From this study it is concluded that transgenic rice line does not show any abnormal pest or natural enemies abundance in crop field.

**Table 2. Reactions of rice germplasm materials against BPH, WBPH and GLH at greenhouse of Entomology Division during July 2016 to June 2017.**

| Seed source | No. of entry | Target pest | Promising material | Score |
|---|---|---|---|---|
| Breeding line | 49 | BPH | - | - |
| | 49 | WBPH | BRRI dhan74 (ck)<br>BR (Bio) 9785-BC2-6-2-2 | 5 |
| Advanced line | 49 | GLH | BR 8079-19-1-5-1 | 5 |

Susceptible check: BR3 (for all), Resistant ck: T27A, IR64 for BPH, WBPH 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), S=susceptible (7-9).

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

A total of 21 owl watching towers were established in three heights 8, 10 and 12 feet in BRRI farm. Owls used the watching tower as their rostering sites and preyed the rodent during night. The active burrow became inactive when the owl caught the rat from that burrow. Active and inactive burrow count data were taken in 50 diameter area of each tower. Table 3 shows that the active burrow (4,228) was higher than the inactive burrow (3,772) during July 2016 to June 2017 count. Data also showed that the highest number (620) of inactive burrow was recorded at 12 feet height tower in west byed A block followed by B, C and D Block. The overall owl preying success was 47.15%.

**Table 3. Active and inactive burrow of rice field rats from July 2016 to June 2017 in BRRI farm, Gazipur.**

| Watching tower height | Owl watching tower locations in BRRI farm | | | | Control | Sub-total | Total | Success (%) |
|---|---|---|---|---|---|---|---|---|
| | A block | B block | D block (West) | D block (East) | C block | | | |
| | | | Active Burrow | | | | | |
| 8 feet | 498 | 425 | 39 | 303 | 87 | 1352 | | |
| 10 feet | 551 | 481 | 142 | 29 | 113 | 1316 | 4228 | |
| 12 feet | 641 | 674 | 93 | 16 | 136 | 1560 | | |
| | | | Inactive burrow | | | | | 47.15 |
| 8 feet | 428 | 393 | 30 | 248 | 90 | 1189 | | |
| 10 feet | 475 | 454 | 109 | 20 | 108 | 1166 | 3772 | |
| 12 feet | 620 | 565 | 104 | 8 | 120 | 1417 | | |

# Plant Pathology Division

SUMMARY

Experiments were conducted under seven projects in Plant Pathology Division to manage the rice diseases. Survey and monitoring of rice diseases were conducted in both T. Aman and Boro seasons in Gazipur, Rajshahi, Satkhira, Habiganj, Comilla, Barisal and Rangpur regions. Disease incidence (DI) and disease severity (DS) data of major rice diseases were recorded following SES, IRRI. Sheath blight (ShB), bacterial blight (BB) and brown spot (BS) diseases were prevalent during T. Aman. Early planting of Boro varieties especially BRRI dhan28, BRRI dhan50 and BRRI dhan61 were infected more by neck blast disease over the country. Most of the late planting Boro varieties were less affected with neck blast. In false smut disease, two distinct types of smut balls were observed-orange and greenish-black. The appearing time of both the smut balls were also different. The fungus produced chlamydospores and sclerotia on culture. The fungus was identified by PCR technique using *U. virens* specific primer, US1-5/US3-3. Based on morphological characters, *Fusarium* sp. and *Curvularia* sp. were identified from seedling blight symptom. A total of 25 standard differential blast isolates were selected preliminary for Bangladesh. Depending on the differentiating ability, virulence, rate of sporulation, colony stability and storage potentiality, 11 standard differential blast isolates were selected from 25 SDBIs, finally for Bangladesh. A total of 80 isolates of *Xoo* were evaluated on 12NILs of bacterial blight resistance. The results show that eight races of *Xoo* were existed in Bangladesh. The presence of Rice Tungro Bacilliform virus on the infected plants was confirmed by primer pairs such as ORF-I-F)/ORF-I-R and ORF-IV-F/ORF-IV-R. Among the 100 tested germplasm, five materials such as accession no. 523, 553, 578, 586 and 587 were found resistant to bacterial blight. Out of 100 germplasm, two accessions such as no. 363 and 369 were found resistant against bakanae. All 11 wheat blast isolates showed highly susceptible reaction to 22 BARI wheat varieties and non-pathogenic reaction to 23 blast resistant monogenic lines of rice. Conversely 10 rice isolates produced blast symptoms on monogenic rice lines and non-pathogenic to all wheat varieties. In T. Aman, out of 113, four entries such as BR8515-28-1-1-3-HR3(Com), IR08L181, IR92240-40-2-2-1, and IR64683-87-2-2-3-3 were moderately resistant to blast while in Boro season, six materials such as BR8079-19-1-5-1, BR9011-46-2-2, HHZ15-DT4-DT1-Y1, BR9025-50-2-1, BR8776-12-2-2, and BR8784-4-1-2 were moderately resistant to blast disease. For upland germplasm, genotypes Biaw Bood Pae, Blau Noc, Chirikata 2, IPPA, IR5533-50-1-10, IR5533-55-1-11, Ja Hau, Ja No Naq, BR26, BRRI dhan42, and BRRI dhan43 were resistant to blast. Introgression of effective genes such as *Pish, Pita2, Pi40* and *Pi9* were done in different backgrounds of HYV and a good number of seeds were produced. BC3F1 population was confirmed by the introgression of *Pi9* gene using linked marker. Seven crosses were made for the development of tungro resistant varieties. F1 and BC1F1 and BC2F1 seeds were obtained. Globally diverse 27 blast-resistant upland rice genotypes were evaluated. Chirikata 2, Choke Tang, BRRI dhan43 and Padi Beleong were identified as better yielders. Although functions yet to be known, the DEGs analysis revealed that 151 genes were involved in BRRI dhan43 and race P7.2 patho-system. Genetic variations for blast resistance in 334 Bangladesh rice accessions from four major ecotypes (Aus, Aman, Boro and Jhum) were clarified. These were classified into two clusters based on SSRs polymorphism. These results demonstrated that the accessions of Japonica group were found mainly in Aman, and Indica Group distributed in all ecotypes. Susceptible accessions were limited in Aus and Aman. Clarification of the existing genetic mechanism of blast resistance in Basmati 370 was done using standard differential system, QTL and bulk segregating analyses. Based on the reaction pattern of DVs of 23 known blast resistant genes with 18 SDBIs (native and exotic), suggested that *Pib* and one of *Pik* alleles were present in the genetic background of Basmati 370. In addition, comparative reaction patterns of the isolates PHL16 and Ba77a-B reveled that at least one unknown gene is present in Bashmati 370. This study establishes that differential system for blast is a powerful tool for estimating known blast resistant gene(s) in rice genome. To develop durable blast resistant popular rice varieties BC1F1 population has already confirmed using molecular markers. QTL analysis suggested that NERICA-L-19 harbored blast resistant genes on chromosomes 1,

4, 6, 8, 10, 11 and 12. Multilines of IR64-*Pi9* and IR64-*Pish* were found effective in Bangladesh. Three inoculation techniques of panicle blast such as, cotton wrapping, spray and injection of spore suspension were evaluated. Among the methods, cotton wrapping technique was selected for evaluating large number of segregating population in neck blast disease screening programme. Nativo two spray @ 500 g ha$^{-1}$, resulted the highest disease reduction (80.4%) of false smut in Rangpur while 77.6% in BRRI HQ, Gazipur. Among the 23 fungicides, only six such as Pazodi 32.5 SC, Navera, Seltima and Azonli 56 successfully controlled rice blast disease (above 80%) in Gazipur. A total of 20 demonstrations were conducted for blast and sheath blight disease management at farmers' field in Gopalganj and Bagerhat districts under PGB project. BRRI recommend practice showed less disease severity and incidence resulted in higher yield. Trichocopmpost treated plots showed the RLH 14.06 and DI 14.06%. Application of insecticide regent with alternate waiting and drying water management performed the best to control red eel worm and yield was also increased 12% compared to control.

SURVEY AND MONITORING OF RICE DISEASES

A survey was conducted in different upazilas of some selected districts during T. Aman and Boro 2016-17 to know the present status of different rice diseases under various rice ecosystems. Disease incidence (DI) and disease severity (DS) data of major rice diseases were recorded following SES, IRRI. Sheath blight (ShB), bacterial blight (BB) and brown spot (BS) diseases were prevalent during T. Aman. Early flowering of BRRI varieties especially BRRI dhan28, BRRI dhan50 and BRRI dhan61 in Boro were infected more by neck blast disease over the country. Most of the late flowering Boro varieties were not affected by neck blast.

**Disease survey and monitoring in T. Aman**

In Rajshahi, disease incidence of bacterial blight (BB), brown spot (BS) and sheath blight (ShB) ranged from 7-92% (DS 3-5); 5-70% (DS 1-3); 10-65% (DS 3-5), respectively. Besides these, very little amount of sheath rot (ShR) and false smut (FS) disease was observed. Irrespective of locations BRRI dhan28 showed more disease susceptible reaction compared to the widely cultivated local rice variety Zira-dhan. In Gazipur, BB (DI 37.9-46.3%, DS 3.3-5.9) and ShB (DI 40.6%, DS 4.1-4.4) were prevalent compared to brown spot, false smut, sheath rot and narrow brown leaf spot. In Rangpur, BB was widespread (DI 37.3-61.6%, DS 3.2-4.1) followed by ShB (DI 29.5-56.2%, DS 3.0-3.3) and brown spot (DI 10.1-43.0%, DS 1.5-1.8). The BB disease was prevalent (DI 10-60%, DS 1-5) compared to sheath blight (DI 5-30%, DS 1-3), brown spot (DI 10-40%, DS 1-5) in Barisal, while blast and false smut incidence was low. BRRI dhan22, BRRI dhan23, BRRI dhan52, BRRI dhan76 and BRRI dhan77 were found to be susceptible against ShB and BB diseases of rice; while local varieties Kalijira and Sakkhorkhora were found blast disease susceptible. In Satkhira district, BRRI dhan49, BRRI dhan52, BR23, BRRI dhan39, Guti Swarna, Binadhan-7, BRRI dhan34, Jamai babu, Chini kanai and Sonamukhi rice cultivars were found infected with BS, ShB, BB and false smut. valence of BS (DI 15-46.7, DS 1.7-3.0) and ShB (DI 8-24%, DS 3.7-5.0) were more compared to other diseases. Incidence of BB and FS was less. In Comilla, disease incidence % of BB, ShB and BS were 10-44.3 (2.1-4.4), 21.4-71.4 (1.6-5.6) and 15.7-67.1 (1.0) respectively.

**Disease survey and monitoring in Boro**

In Comilla, the disease incidence of BB, ShB, neck blast and BS were 7.5-82.5, 10-80, 1-80 and 5-100% respectively during Boro. BB (incidence: 40.4% and severity: 3.3) was predominant compared to ShB, blast and brown spot in Gazipur district. Blast disease incidence was severe in some areas but average incidence across the spots was 8.9 with disease severity 3.9 in Rangpur. Other diseases like ShB, BB and BS and FS incidence was 9.7, 7.5 and 12.6% respectively with corresponding disease severity 3.4, 2.4 and 0.79 over the spots in different upazilas. In Barisal, BB, ShB, Blast and BS incidences were 2.3-28.3, 4-20, 0.1-1.0 and 1.7-18.3% with their corresponding disease incidence such as 1-4, 1-3.3, 4-5.3 and 1-2.7, respectively.

POPULATION STRUCTURE AND BIOLOGY OF MAJOR PATHOGEN

**Biology of rice false smut pathogen**

Rice false smut disease symptom initiated as white-belly-spikelet about seven days after panicle emergence. The full size smut ball formation took about 12 days after initiation of the symptom. Two distinct types of smut balls were observed-orange and greenish-black. The appearing time of both smut balls were also different. Orange balls appear in Boro, Aus and early T. Aman (during October and early November).

On the other hand, greenish-black balls only appeared in late (mid-November onwards) T. Aman crops. After long waiting and rigorous search, sclerotia of rice false smut pathogen were identified on the 14th December 2014 (Fig. 1). This was the first report of the presence of true sclerotia, the teleomorphic stage (*Villosiclava virens*) of the pathogen, in the country. On average, 30.61% greenish-black smut balls produced sclerotia. Successful isolation of the pathogen had been made possible for the first time in the country. Chlamydospores and sclerotia, both types of fruiting bodies, ultimately produced conidia in culture (Fig. 2). The identity of the fungus was confirmed through PCR using *U. virens* specific primer, US1-5/US3-3 (Fig. 3). The fungus was also identified in seeds from infected fields through PCR.

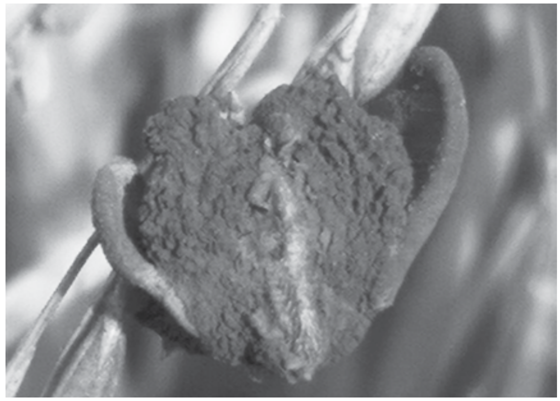
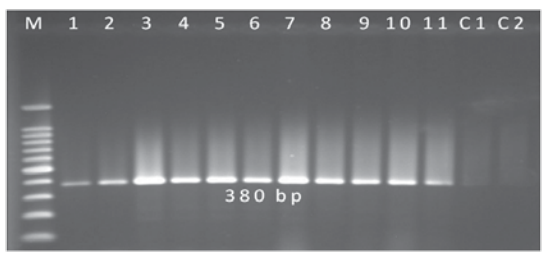


Fig. 1. Sclerotia, the teleomorphic stage of the pathogen.

Fig. 2. Germination of sclerotia in sand culture.




PCR amplification of internal transcribed spacer (ITS) regions of *Ustilaginoidea virens* with specific ITS primer, US 1-5/US3-33. Lane M- 100 BP ladder; Lanes 1 to 11 - *U. virens* isolates; Lane C1- negative control (Pyricularia grisea) and Lane C 2 - water.

Fig. 3. PCR detection of the pathogen.

**Identification of seedling blight pathogens**

Seedling blight infected plant samples were collected and the pathogen was isolated. Pure culture of the fungi was done and investigated under microscope. The fungi identified as *Fusarium* sp. and *Curvularia* sp. based on morphological characteristics.

**Standard differential set of blast isolates (*Magnaporthe oryzae* (Hebert) Barr.)**

A total of 25 blast (*Magnaporthe oryzae* (Hebert) Barr.) isolates were selected primarily as differential isolates from 331 isolates, collected from all over Bangladesh. Depending on the differentiating ability, virulence, rate of sporulation, colony stability and storage potentiality, 11 isolates were selected finally for Bangladesh (Table 1). Several resistance alleles of *Pik* locus had the same reaction patterns and could not be differentiated by these selected blast isolates. No avirulent isolate for *Pi19* was found. This information on pathogenicity of blast isolates will be also useful to understand the differentiation and relationship between blast races and resistance genes in rice germplasm. The monogenic lines as the DVs and the selected 11 blast isolates can be used as

**Table 1. Sporulation and virulence of isolates selected as differential isolates for Bangladesh.**

| Designation | Virulence (%) | Sporulation rate (Spores × $10^4$/ml) | Differentiating ability | *Avir* gene(s) |
|---|---|---|---|---|
| BD346-3p | 88.46 | 176.0 | 0.79 | *Pish*, *Pi9*, *Piz* |
| Ba77a | 69.23 | 106.0 | 0.75 | One of *Pii allele*, *Pi9*, *Piz-5*, *Piat-2*, *Pita* |
| BD576p | 80.77 | 115.0 | 0.74 | *Pi9*, *Piz*, *Pita-2*, *Pita* |
| BD642p | 84.62 | 170.0 | 0.78 | *Piz-5*, *Pita-2*, *Pita* |
| Ba196a | 61.54 | 229.0 | 0.76 | One of *Pii* and *Pik* allele, *Piz-t*, *Pita* |
| Ba1186a | 76.92 | 97.0 | 0.80 | *Pib*, *Pi9*, *Piz*, *Pita-2*, *Pita* |
| Ba46(a) | 80.77 | 180.0 | 0.73 | *Pi9*, *Pita-2*, *Pi12*(t), *Pita* |
| Ba1075 | 69.23 | 160.0 | 0.74 | One of *Pii*, *Pik-p*, *Pi7*(t), *Pi9*, *Piz-t*, *Pita-2* |
| Ba1149 | 76.92 | 258.0 | 0.78 | *Pi1*, *Pi9*, *Pita-2*, *Pita* |
| Ba1210a | 84.62 | 315.0 | 0.68 | *Pi9*, *Pita-2*, *Pita* |
| Ba1189b | 88.46 | 271.0 | 0.76 | *Pi9*, *Pita-2* |

the differential system, which can characterize the resistances of rice varieties and pathogenicities of blast isolates.

**Identification of races and development of differential system of *Xanthomonas oryzae* pv. *oryzae***

An experiment was conducted to identify a standard differential set of isolates of *X. oryzae* pv. *oryzae* (*Xoo*) and to know the diversity of *Xoo* through phenotypic and genetical studies. A total of 125 bacterial (BB) isolates was isolated, purified and preserved for short (PSA slant) and long term (NBY 40% glycerol) from 230 BB diseased samples of T. Aman 2016. To identify the differential BB isolates, 12 NILs and 14 pyramid lines were transplanted to test 80 BB isolates during Boro 2016-17. The isolates of *Xoo* were polymorphic for virulence on 12 NILs. The results showed that a total of eight races of *Xoo* were existed in Bangladesh (Table 2). The gene *Xa1, Xa2, Xa3, Xa4, Xa10, Xa11* and *Xa14* did not show any resistant reactions against all the isolates tested. The result suggests that the resistant gene *xa5, xa13, Xa7, Xa8* and *Xa21* can be used to develop of bacterial blight resistant variety for Bangladesh.

**Moleular detection of rice tungro virus**

Molecular studies were conducted to identify the rice tungro virus using the molecular marker. The presence of rice tungro bacilliform virus (RTBV) on the tungro infected plants was confirmed using linked primers such as ORF-I-F (TGGTATCAGAGCGATGTTCG)/ ORF-I-R (TATGGCCATCATGCCTATATG) and ORF-IV-F (AGCCTACCTTTGAGCATATC)/ ORF-IV-R (CTCACTGACCTGAGCCATT). After confirmation of RTBV, infected plants were kept in the cage for two days for virus acquisition by GLH. After that, infected plant replaced with the healthy seedlings for virus transmission from GLH to healthy seedling. Disease symptom was appeared in the

**Table 2. Pathogenic diversity of 80 *Xoo* isolates based on the reaction of 12 NILs during Boro 2016-17.**

| Race | No. of isolates | % of total isolates | Near isogenic line (NILs) and known resistance genes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | IRBB1 (Xa1) | IRBB2 (Xa2) | IRBB3 (Xa3) | IRBB4 (Xa4) | IRBB5 (xa5) | IRBB7 (Xa7) | IRBB8 (Xa8) | IRBB10 (Xa10) | IRBB11 (Xa11) | IRBB13 (xa13) | IRBB14 (Xa14) | IRBB21 (Xa21) |
| 1 | 51 | 64 | S | S | S | S | S | S | S | S | S | S | S | R |
| 2 | 13 | 16 | S | S | S | S | S | S | R | S | S | R | S | R |
| 3 | 5 | 6 | S | S | S | S | S | S | R | S | S | S | S | R |
| 4 | 3 | 4 | S | S | S | S | S | S | S | S | S | R | S | R |
| 5 | 3 | 4 | S | S | S | S | R | R | S | S | S | S | S | R |
| 6 | 3 | 4 | S | S | S | S | R | S | R | S | S | R | S | R |
| 7 | 1 | 1 | S | S | S | S | R | S | S | S | S | S | S | R |
| 8 | 1 | 1 | S | S | S | S | R | S | R | S | S | S | S | R |

plants 21 days after inoculation. Then, the virus was further detected in the freshly inoculated seedlings using the same primer (Fig. 4).

## DISEASE RESISTANCE AND MOLECULAR STUDIES

### Screening of breeding lines and germplasm against BB, sheath blight and bakanae

A total of 309 materials including 100 rice land races, 209 breeding lines two resistant checks and 13 susceptible checks were screened against bacterial blight. Among the 100 land races, five materials such as, accession no. 523, 553, 578, 586 and 587 were found resistant and accession no. 505 and 561 were found moderately resistant. However, among the 209 breeding materials, 13 showed highly resistant, 15 showed resistant and 25 showed moderately resistant to BB compared to susceptible. Another experiment was conducted to identify new resistant source(s) of sheath blight disease. Among the tested materials, ten genotypes BR8850-20-3-5-1, BR8522-53-1-3, BR8204-5-3-2-5-2, BR8490-5-1-4-4, BR8189-10-2-3-1-5, BR8521-30-3-1,BR8493-4-2-1-1, BR8492-9-5-3-1, BR8492-9-5-3-2 and BR9392-6-2-3B showed moderately susceptible reaction. Hundred germplasm were screened against bakanae of rice. Two accessions (no 363 and 369) were found resistant.

### Screening of rice and wheat germplasm against blast pathogen

An experiment was conducted to investigate the cross infection ability of blast fungus (*Pyricularia oryzae*). All 11 wheat blast isolates showed highly susceptible reaction to 22 BARI wheat varieties and non-pathogenic reaction to 23 blast resistant monogenic rice lines. Conversely 10 rice isolates produce blast symptoms on monogenic rice lines and non-pathogenic to all wheat varieties. Disease reaction data were collected followed by SES scale (SES, IRRI, 2014).

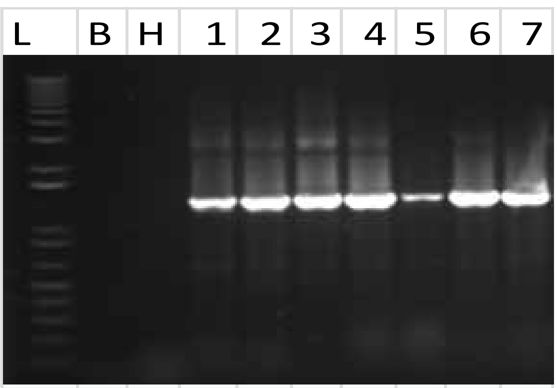



Fig. 4. Detection of rice tungro bacilliform virus through RTBV ORF-I primer. (Here, L=1 kb plus ladder, B=Blank (No DNA), H=Healthy, 1 to 7 tungro infected samples).

### Evaluation of advanced breeding lines against blast disease

In T. Aman, 113 advanced breeding lines along with check materials were screened to identify the resistance sources against blast disease (*Pyricularia oryzae*). Four entries such as BR8515-28-1-1-3-HR3(Com), IR08L181, IR92240-40-2-2-1 and IR64683-87-2-2-3-3 showed moderate resistance to blast. Again, in Boro season, out of 117 materials six materials such as BR8079-19-1-5-1, BR9011-46-2-2, HHZ15-DT4-DT1-Y1, BR9025-50-2-1, BR8776-12-2-2, and BR8784-4-1-2 showed moderate resistance to blast disease.

### Screening and diversity analysis of exotic upland rice germplasm against blast disease

Fifty upland rice genotypes, including one resistant check (Pongsu Seribu-1 (PS-1)), and one susceptible check (MR219), were evaluated to find out new sources of resistance and assess their diversity based on the reactions against *Magnaporthe oryzea*. Resistant reactions were observed with the genotypes Biaw Bood Pae, Blau Noc, Chirikata 2, IPPA, IR5533-50-1-10, IR5533-55-1-11, Ja Hau, Ja No Naq, BR26, BRRI dhan42, and BRRI dhan43.

### Pyramiding of major blast resistant gene(s) in susceptible rice variety/lines

Blast resistant genes *Pish*, *Pita2*, *Pi9* and *Pi40* were introgressed separately in BRRI dhan28, BRRI dhan29, BRRI dhan63, IR64, Kalijira and Nayonmoni. Table 3 shows introgression of different genes in different parents and the no. of produced seeds for each generation. BC3F1 population has confirmed using molecular linked marker (Fig. 5).

### Development of tungro resistant varieties

Seven crosses were made using five parents and four sets of BC2F1 and three sets of F1 seeds were obtained. Table 4 shows number of seeds produced in different crosses at different generations.

**Table 3. No. of seeds produced in different generation of recurrent parents with their introgressed gene.**

| Recurrent parent | Gene introgressed | Progeny | No. of seed |
|---|---|---|---|
| | *T. Aman 2016* | | |
| IR64 | *Pita2* | BC2F1 | 49 |
| IR64 | *Pi9* | BC2F1 | 29 |
| IR64 | *Pi40* | BC2F1 | 55 |
| Nayonmoni | *Pish* | BC2F1 | 36 |
| Nayonmoni | *Pita2* | BC2F1 | 74 |
| Kalijira | *Pi9* | F1 | 18 |
| | *Pita2* | F1 | 16 |
| | *Boro* | | |
| BRRI dhan28 | *Pi9* | BC3F1 | 89 |
| | *Pi40* | BC3F1 | 63 |
| | *Pish* | F1 | 9 |
| | *Pita2* | F1 | 31 |
| BRRI dhan29 | *Pi9* | BC3F1 | 71 |
| | *Pi40* | F1 | 10 |
| | *Pita2* | BC3F1 | 40 |
| | *Pita2* | BC3F1 | 42 |

**Table 4. List of crosses and $F_1$ seeds after crossing the materials during Boro 2016-17.**

| Generation | Cross | No. of seed |
|---|---|---|
| BC2F1 | BRRI dhan71*Matatag-1 | 116 |
| BC2F1 | BRRI dhan71*TW-16 | 107 |
| BC2F1 | BRRI dhan48*Matatag-1 | 55 |
| BC2F1 | BRRI dhan48*IR69705-1-1-1-4-2 | 49 |
| F1 | Swarna*Matatag-1 | 115 |
| F1 | Swarna*IR69705-1-1-1-4-2 | 134 |
| F1 | Swarna*IRBB58 | 164 |

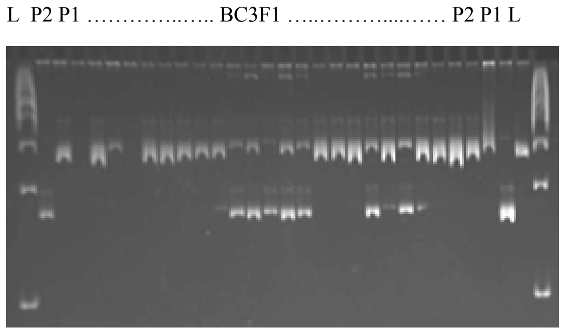



Fig. 5. BC3F1 population of BRRI dhan28 with *Pi9* gene (P1: BRRI dhan28, P2: IRBL-9W).

**Characterization of globally diverse blast-resistant upland rice (*Oryza sativa* L.) germplasms**

An experiment was conducted to elucidate the performances of 27 globally diverse blast-resistant upland rice genotypes. The Chirikata 2, Choke Tang, BRRI dhan43 and Padi Beleong were identified as best genotypes in terms of yield (Fig. 6).

**Transcriptome analysis of blast resistant cultivar BRRI dhan43 through next generation sequencing**

The present investigation was initiated to compare the transcriptome level of blast resistant rice variety BRRI dhan43 control samples with that of its counterpart fungus treated samples to identify the potential variation among them through next generation sequencing platform in gene level. This investigation successfully identified more

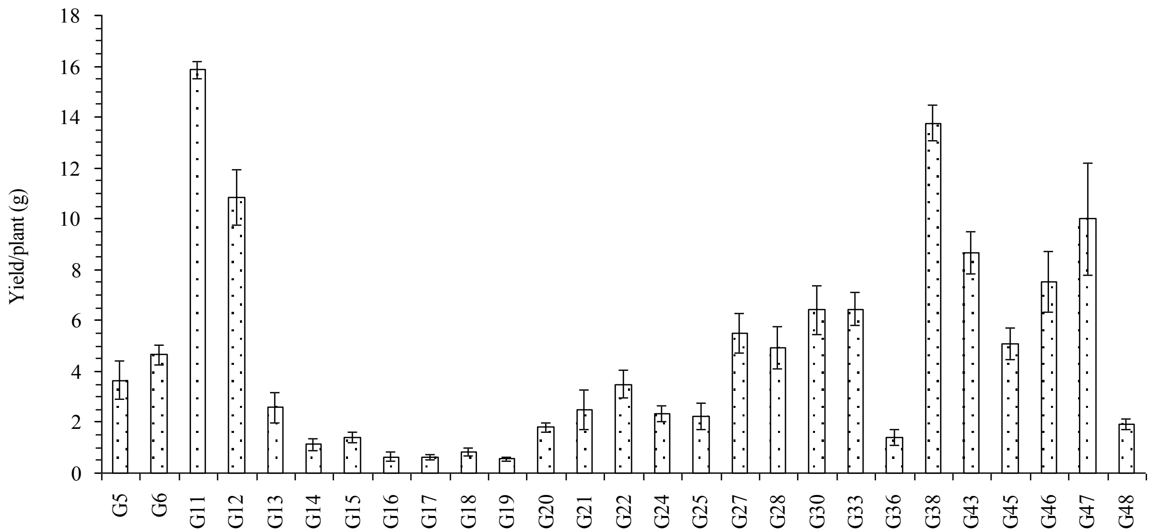



Fig. 6. Yield/plant of 27 blast resistant upland genotypes of rice. Each column represents mean with standard error of each genotype; n=3.

than 30,000 expressed genes shared in the control and treatment samples (Fig. 7); approximately 96 and 88 SNPs from the control and the treatment samples, correspondingly and around one thousand novel transcribed active regions in both samples of rice species (Table 5). The transcriptomes sequence data including gene and isoform expressions, SNPs and indel identification, and novel transcripts were higher in the control sample than its counterpart treated sample, thus revealing the reduction of some metabolic and biological activities in fungus-infected plants attacked by *M. oryzae* pathogen.

**Differentially expressed genes in incompatible interaction between upland rice cultivar BRRI dhan43 and fungus race P7.2 pathosystem**

Differentially expressed genes (DEGs) involved in the disease developmental stages were identified in the upland rice cultivar BRRI dhan43 and fungus race P7.2 pathosystem. Overall, 2,733 of the 30, 436 DEGs were identified as true DEGs during incompatible interactions. A pathway enrichment analysis revealed several blast disease resistant inducible proteins, such as MLA10, L6, disease resistance protein RPS1, probable WRKY transcription factor 52, and disease resistance protein RPS4; other stress inducible factors, such as heat shock protein (HSP90) (Fig. 8). Although functional analysis has not done yet, the DEGs analysis revealed that 151 genes were involved in BRRI dhan43 and race P7.2 patho-system.

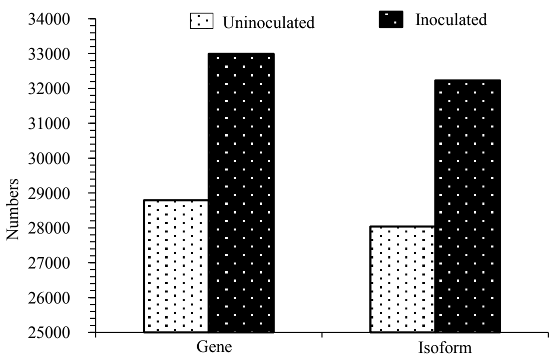



Fig. 7. Gene and isoform expression in uninoculated and inoculated leaves of BRRI dhan43 with fungus race P7.2.

**Table 5. SNP, indel and novel genes in uninoculated and inoculated leaves of BRRI dhan43 with fungus race P7.2.**

| Sample | SNP | Indel | Novel genes |
|---|---|---|---|
| Uninoculated | 95,854 | 4,710 | 1,032 |
| Inoculated | 88,407 | 4,490 | 921 |

**Genetic variation of resistance to blast (*Pyricularia oryzae* Cavara) in rice germplasm**

Genetic variations for blast resistance in 334 Bangladesh rice accessions from four major ecotypes (Aus, Aman, Boro and Jhum) were clarified. These were classified into two cluster groups, I and II, based on polymorphism data of 74 SSR markers. The groups I and II corresponded to Japonica and Indica Groups, respectively. Cluster II accessions were included in all ecotypes with high frequencies, and subdivided into clusters IIa and IIb. The accessions of cluster IIa showed high frequencies in only Aus and Jhum. The accessions of cluster I were grown particularly those in the Aman ecotype. Distinct variations in resistance were found; these were classified into groups A1, A2, B1 and B2, based on the reaction to standard differential blast isolates. The most susceptible group was A2 including susceptible variety Lijiangxintuanheigu and most differential varieties and some accessions in Bangladesh. Groups A1 and B2 were followed it in the order, and B1 was the most resistant. The four ecotypes fell with different frequencies into each of these resistance groups. These results demonstrated that the accessions of Japonica group were found mainly in Aman, and Indica group distributed in all ecotypes. Susceptible accessions were limited in Aus and Aman.

**Estimation of blast resistance gene(s) using differential system and Bulk Segregating Analyses (BSA)**

Clarification of the existing genetic mechanism of blast resistance in Basmati 370 was done using standard differential system, QTL and bulk segregating analyses. $BC_1F_2$ family lines were derived from the crosses between Basmati 370 and US-2 as recurrent parent. A total of 130 polymorphic markers distributed across the 12 chromosomes used for genotyping and linkage map construction. Based on the comparative reaction pattern of Basmati 370 and DVs of 23 known blast resistance genes with 18 Standard Differential Blast Isolates (native and exotic), suggested that *Pib* and one of *Pik* allele (*Pik-s, Pik-m, Pi1, Pik-h, Pik, Pik-p* or *Pi7*(t)) were present in the genetic background of Basmati 370. In addition, comparative reaction patterns of the isolates PHL16 and Ba77a-B reveled that at least one unknown gene was present in the genetic background of Basmati 370.

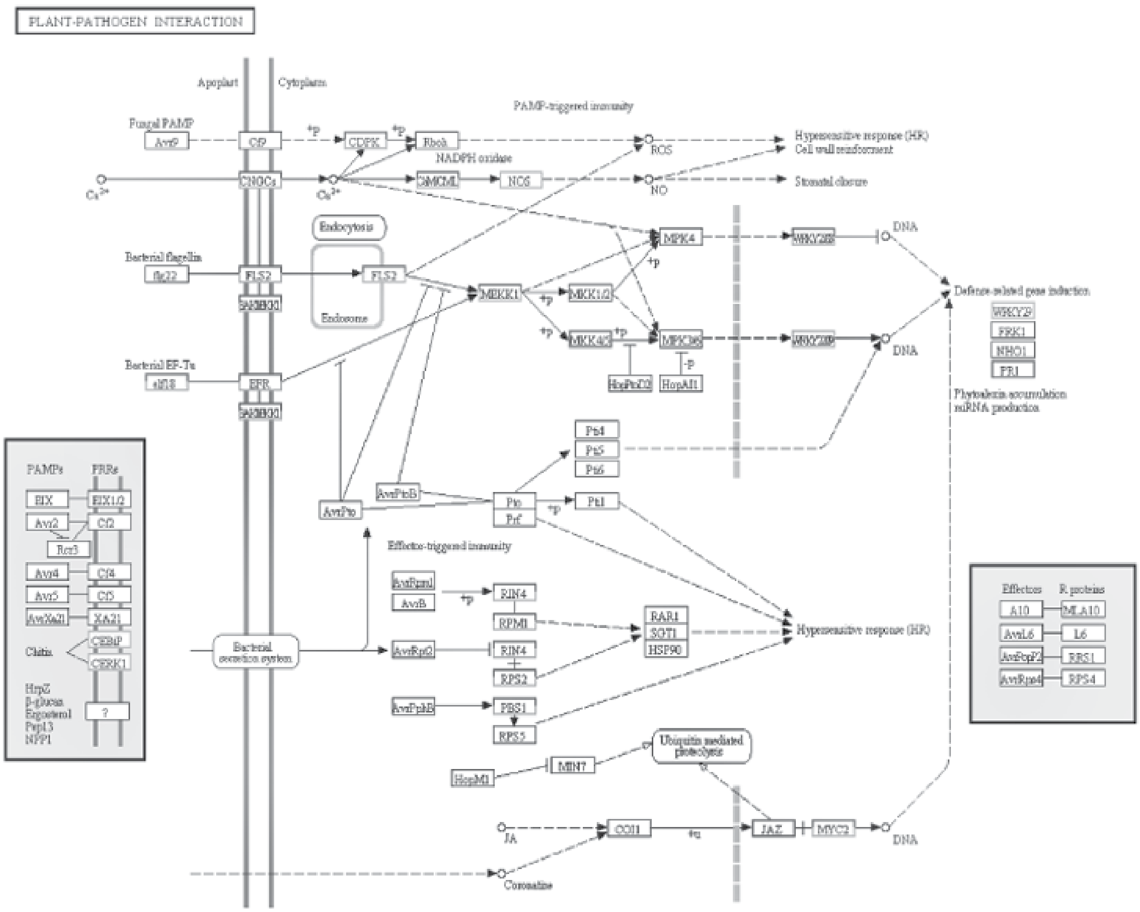



Fig. 8. Analysis of different signal pathways gene expression in BRRI dhan43 and race P7.2 co-evolution.

QTL analysis suggested that Basmati 370 harboured blast resistant genes *Pib* on chromosome 2 and one of the *Pik* alleles on the distal end of chromosome 11. There were some unknown genes on chromosome 4 (Fig. 9). Basmati 370 mostly harboured major QTLs on the regions of *Pik* locus on the longer arm of chromosome11, and *Pib* on chromosome 2. In addition, some minor QTLs were also found on chrs. 4 and 6. None of the resistant genes of *Piz* and *Pita* loci of chromosomes 6 and 12 respectively, and shorter arm of chromosome 11 were found in Basmati 370. Segregation of the resistance against 18 differential blast isolates in these hybrid population (Table 6). These studies established that differential systems for blast are a powerful tool for estimating known blast resistant gene(s) in rice genome.

**Identification of blast resistant QTLs in NERICA-L-19**

Clarification of the existing genetic mechanism of blast resistance in NERICA-L-19, a highly blast resistant variety in Africa and South-East Asia was done using standard differential system, QTL and bulk segregating analyses of BC1F2 family lines (LTH as recurrent parent). Eleven standard differential blast isolates (SDBIs) from Japan (n=8), Africa (n=1) and Bangladesh (n=2), were used for the investigation accordingly. A total of 119 polymorphic markers were used for genotyping and linkage map construction. Resistance spectra of NERICA-L-19 to standard differential blast isolates (SDBIs) were compared with those of 25 differential varieties (DVs). None of the isolates were found virulent against NERICA-L-19. Due

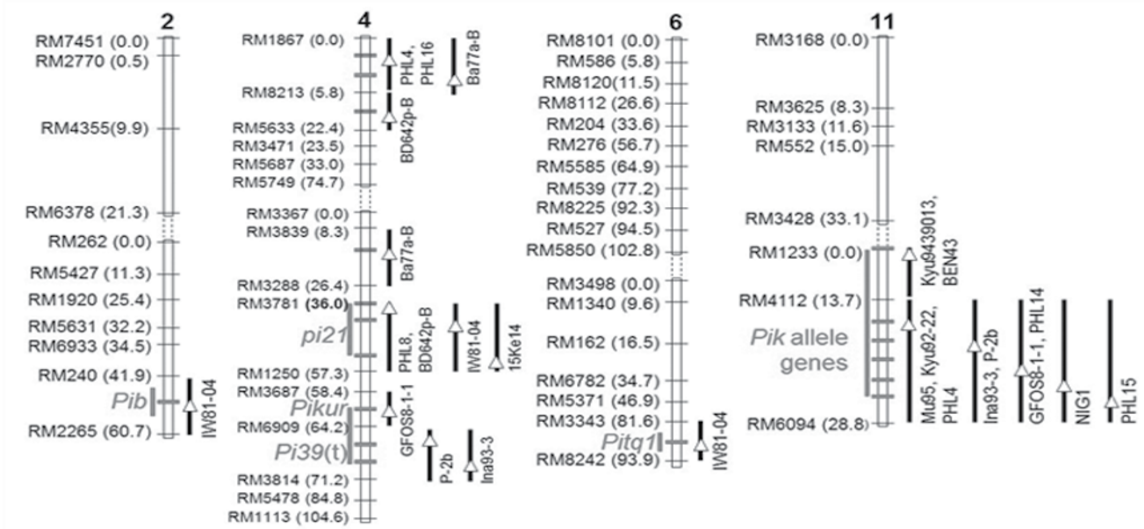



Fig. 9. Chromosomal locations of QTLs for blast resistance in an Indica group rice cultivar Basmati 370 against 18 standard differential blast isolates (SDBLs). The black bars indicated the positions of the QTLs. Basmati 370 has the positive allele for the QTL against specific SDBIs indicated by upper arrow. The estimated genes *Pib* and one of *Pik* allele were indicated on chromosomes 2 and 11, respectively. The red colour indicated the tentative position of the published QTLs/genes on the respective chromosome by other researchers. Some unknown genes were found on the short arm of chromosome 4.

**Table 6. Segregation of the resistance against 18 differential blast isolates in BC1F2 lines derived from the crosses US-2/ Basmati-370//US-2.**

| Differential Blast Isolates | | No. of BC1F2 lines | | | $X^2$ value | | | P (df=1) |
|---|---|---|---|---|---|---|---|---|
| Designation | Origin | Segrigating resistant | All susceptible | Total | 1:1 | 3:1 | 7:1 | |
| BEN43 | Africa | 28 | 27 | 55 | 0.018 | - | - | 0.89 |
| PHL8 | Philippines | 26 | 29 | 55 | 0.164 | - | - | 0.69 |
| PHL14 | Philippines | 26 | 29 | 55 | 0.164 | - | - | 0.69 |
| BD642p-B | Bangladesh | 29 | 26 | 55 | 0.455 | - | - | 0.50 |
| Kyu92-22 | Japan | 41 | 14 | 55 | - | 0.006 | - | 0.94 |
| NIG1 | Africa | 41 | 14 | 55 | - | 0.006 | - | 0.94 |
| Mu95 | Japan | 48 | 7 | 55 | - | - | 0.003 | 0.96 |
| IW81-04 | Japan | 48 | 7 | 55 | - | - | 0.003 | 0.96 |
| Ina93-3 | Japan | 49 | 6 | 55 | - | - | 0.127 | 0.72 |
| P-2b | Japan | 49 | 6 | 55 | - | - | 0.127 | 0.72 |
| GFOS8-1-1 | Japan | 48 | 7 | 55 | - | - | 0.003 | 0.96 |
| PHL4 | Philippines | 48 | 7 | 55 | - | - | 0.003 | 0.96 |
| PHL15 | Philippines | 48 | 7 | 55 | - | - | 0.003 | 0.96 |
| PHL16 | Philippines | 48 | 7 | 55 | - | - | 0.003 | 0.96 |
| Ba77a-B | Bangladesh | 49 | 6 | 55 | - | - | 0.127 | 0.72 |
| Kyu9439013 | Japan | 54 | 1 | 55 | - | - | 5.738 | 0.02 |
| 15Ke14 | Africa | 16 | 39 | 55 | - | - | - | - |
| 15Ke69 | Africa | 0 | 55 | 55 | - | - | - | - |

$X^2$ value fit to 1:1, 3:1 and 7:1 ratio expected for single, double and triple dominant gene control of resistance, respectively.

to this, differential system was not applicable for resistant gene estimation in NERICA-L-19. QTL analysis suggested that NERICA-L-19 harboured blast resistant genes on chrs. 1, 4, 6, 8, 10, 11 and12 (Table 7). These studies suggested that there are some novel QTLs in NERICA-L-19 those were responsible for high resistance potentiality against differential blast isolates of Japan, Africa and Bangladesh.

**Introgression of complete and partial blast resistance genes into popular BRRI varieties**

To develop durable blast resistance popular rice varieties, BRRI dhan28, BRRI dhan29, BRRI dhan34, BRRI dhan63, BRRI dhan64 and Pusabasmati were selected as recurrent parent. As donor, partial resistance gene *Pb-1* and complete resistance gene *Pi9* were selected. Selection of differentiating isolates and polymorphic markers have already done. BC1F1 population has already been confirmed using markers (Fig. 10)

**Development of cold tolerant and short duration blast resistance rice lines for Bangladesh**

To develop cold tolerant and short duration blast resistant rice lines, popular rice varieties: BRRI dhan28, BRRI dhan34 and Pusabasmati were selected as recurrent parent. As donor, Japonica group cultivar 'Mineasahi' harboring partial resistance gene *Pb-1* and *Pi39* was selected. Mineasahi is one of the testy rice variety in Japan and usually growing in mountainous areas of Aichi prefecture where temperature ranges from -0.2°C (January) to 23.5°C (August). $F_1$ population has developed in Boro 2017. For evaluating cold tolerance of 'Mineasahi', we collaborated with Plant Physiology Division, BRRI.

**Evaluation of blast resistant multilines harboring resistant QTLs in Bangladesh**

Blast resistant multilines of IR64 were collected from JIRCAS, Japan. The yield potentiality of these varieties under Bangladesh condition is needed to be determined. Observational yield trial (OT)

**Table 7. QTLs for blast resistance in an Indica Group rice cultivar NERICA-L-19 against 11 Standard Differential Blast Isolates (SDBIs)**

| Differential isolate | Linkage | Chr. no. | Position (cM) | Marker interval | LOD | PVE (%) | Add effect |
|---|---|---|---|---|---|---|---|
| 15Ke69 | 3 | 1 | 18 | RM8129 - RM5497* | 4.582 | 10.5 | 1.34 |
| H05-72-1 | 3 | 1 | 64 | RM8084* - RM7180 | 2.294 | 5.4 | -3.27 |
| 15Ke69 | 3 | 1 | 70 | RM8084 - RM7180* | 2.783 | 6.5 | -0.40 |
| Ina93-3 | 4 | 1 | 36 | RM5310* - RM6840 | 3.123 | 7.3 | 1.25 |
| GFOS8-1-1 | 11 | 4 | 0 | RM6909* - RM1113 | 2.518 | 5.9 | 0.05 |
| P-2b | 15 | 6 | 28 | RM2615* - RM276 | 2.016 | 4.8 | -1.25 |
| P-2b | 19 | 8 | 50 | RM152* - RM6356 | 2.422 | 5.7 | 1.05 |
| BD576p-B | 20 | 8 | 2 | RM5432* - RM5556 | 2.266 | 5.3 | -4.05 |
| GFOS8-1-1 | 20 | 8 | 106 | RM5887 - RM5808* | 3.343 | 7.8 | -0.78 |
| Ina93-3 | 20 | 8 | 106 | RM5887 - RM5808* | 2.264 | 5.3 | 0.15 |
| IW81-04 | 23 | 10 | 2 | RM7545* - RM5271 | 1.857 | 4.4 | 0.40 |
| 15Ke69 | 25 | 11 | 0 | RM1812* - RM552 | 2.448 | 5.8 | -0.08 |
| Kyu9439013 | 27 | 12 | 22 | RM1208 - RM7315* | 2.323 | 5.5 | 0.21 |
| Ba77a-B | 28 | 12 | 24 | RM2529 - RM1036* | 3.143 | 7.3 | -6.06 |
| H05-72-1 | 28 | 12 | 42 | RM1036 - RM7102* | 2.363 | 5.6 | -0.32 |
| H05-72-1 | 28 | 12 | 60 | RM7102* - RM5700 | 2.75 | 6.4 | -0.29 |
| Kyu92-22 | 28 | 12 | 72 | RM7102 - RM5700* | 6.42 | 14.4 | -0.16 |
| Mu-95 | 28 | 12 | 74 | RM7102 - RM5700* | 5.414 | 12.3 | 0.02 |
| BD576p-B | 28 | 12 | 84 | RM7102 - RM5700* | 2.152 | 5.1 | -3.79 |
| Kyu92-22 | 28 | 12 | 90 | RM5700* - RM1986 | 6.021 | 13.6 | 0.13 |
| H05-72-1 | 28 | 12 | 92 | RM5700* - RM1986 | 2.273 | 5.4 | -0.19 |
| IW81-04 | 28 | 12 | 92 | RM5700* - RM1986 | 1.621 | 3.9 | -0.06 |

Chr. No. indicates on which putative QTL detected. * indicates the marker nearest the putative QTL. Add effect is the effect of substituting a NERICA-L-19 allele for a LTH allele. Positive and negetive value of additive effect indicate have the positive allele of NERICA-L-19 and LTH, respectively. PVE (%) indicates phenotypic variation explained by each putative QTL.

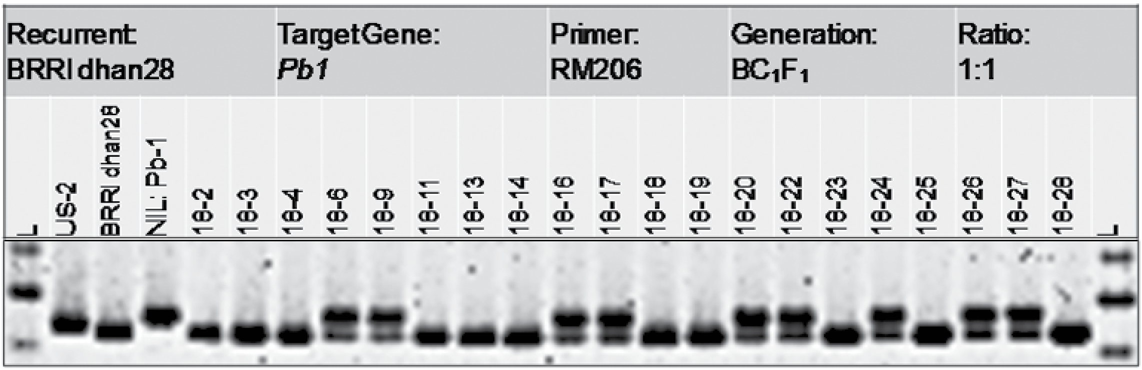



Fig. 10. Partial genotypes of $BC_1F_1$ population developed from BRRI dhan28 x *Pb1*.

was conducted in boro (2016-17) and the seeds were multiplied. Reaction of these lines against differential isolates has been completed under laboratory condition. Multilines, IR64-*Pi9* and IR64-*Pish* were found suitable and effective in Bangladesh in terms of yield and blast reaction.

**Gene pyramiding for bacterial blight (BB) resistance.** In this study, BRRI dhan28, and BRRI dhan29 were used as recipient parents. IRBB57, IRBB58 and IRBB60 were used as donor parents. Phenotyping and genotyping were applied for suitable plant selection. Result is presented in Table 8. Pathogenicity results showed that a number of progenies of $BC_1F_1$ developed from the crosses were resistant to the most virulent BB isolate BXO9.

## EPIDEMIOLOGY AND YIELD LOSS STUDIES

**Density of false smut balls on infected rice panicles and its seasonal variation**

Comparatively more balls formed in 2015 than 2014 or 2016 seasons. As many as 136 smut balls were identified on an infected panicle in 2015, whereas maximum of 67 and 45 balls were recorded in 2014 and 2016, respectively (Fig. 11). There was two-third chance that the maximum of five smut balls would be found on infected rice panicles. When the smut ball number per infected panicle was five or below, 48.1±3.5% (± is 95% confidence interval) of them located at the base, 45.5±3.4% at the mid and only 6.4±1.7% at the apex section of the infected panicles. As the number increased (up to 55), the smut ball formation gradually increased at the mid and decreased at the base section. Compared to potential grain number with this three portions (base, mid and apex) smut balls in a panicle, the proportion accounted for the base ($Y = 1.82 + 0.64 X$; $R^2 = 0.95$; n = 15) and mid ($Y = - 0.48 + 0.74 X$; $R^2 = 0.99$; n = 15) remained almost similar; on the other hand, the proportion in the apex portion was much lower ($Y = - 6.42 + 0.41 X$; $R^2 = 0.84$; n = 15) than base or mid-section. Under natural infection, absolute predominance of distribution of false smut balls on the base and mid portions of the infected panicles indicate that the false smut pathogen might not enter into panicles from air with water droplet through the junction of flag leaf and lodicule.

**Table 8. Development of BB resistant materials from the crosses of BRRI dhan28, BRRI dhan29 and a local improved variety and bacterial blight resistant pyramid lines of IR24.**

| Recipient/Recurrent | Donor | | Present status |
|---|---|---|---|
| | Designation | Target *R* gene | |
| BRRI dhan28 | IRBB57 | *Xa4, xa5, Xa21* | 25 seeds of $BC_1F_1$ |
| BRRI dhan28 | IRBB66 | *Xa4, xa5, Xa, xa13, Xa21* | 40 seeds of $BC_1F_1$ |
| BRRI dhan29 | IRBB57 | *Xa4, xa5, Xa21* | 45 seeds of $BC_1F_1$ |
| | IRBB58 | *Xa4, xa13, Xa21* | |
| BRRI dhan29 | IRBB66 | *Xa4, xa5, Xa7, xa13, Xa21* | 45 seeds of $BC_1F_1$ |

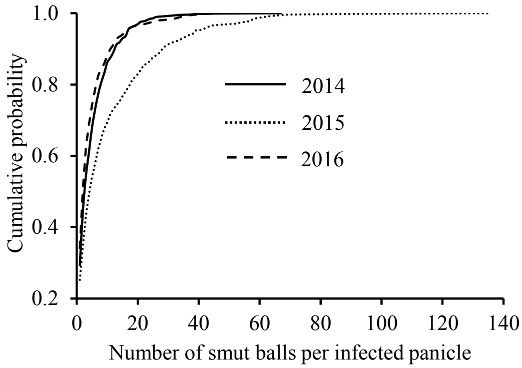



Fig. 11. Density of false smut balls on infected rice panicles and its seasonal variation.

**Evaluation and optimization of neck blast inoculation technique of rice**

Neck blast is one of the major threats to successful rice cultivation in Bangladesh. Usually, scientists are screening rice germplasm against leaf blast. Due to some difficulties in neck blast disease inoculation, optimization of artificial inoculation technique of neck blast disease was investigated under greenhouse condition. Three techniques: cotton wrapping, spray and injection of spore suspension were tested. In spray method, blast symptoms were found in primary and secondary branches and also around the base of panicle. Among the three techniques, disease progress was slow in cotton wrapping technique followed by spray and injection. But disease severity scale was recorded at 7-9 scale (SES, IRRI) after 10 days of inoculation (Fig. 12). Though cotton wrapping technique was slow, it was selected for evaluating large number of segregating population in neck blast disease screening programme.

**A simple but robust artificial inoculation technique of rice false smut disease (*Ustilaginoidea virens* (Cooke) Takah)**

Rice false smut disease is now an emerging disease especially in T. Aman season. Due to the climate change effect, it is becoming major day by day. Isolation, purification, preservation and inoculation technique of rice false smut disease was tried to develop in this study. Water agar and Potato Sucrose Agar were selected for isolation and growing fungi on media. Injection of conidial suspension during late booting stage was found the best for inoculation. Figure 13 shows the details of the process.

DISEASES MANAGEMENT

**Effect of soil and seedling treatment on false smut disease development**

Efficacy of soil and seedling treatment was investigated for controlling false smut disease. Rice variety BRRI dhan49 was used in this study. Treatments were as follows- $T_1$: Root dipping of seedling (Carbendazim); $T_2$: Soil treatment (Carbendazim); $T_3$: Foliar spray (Propiconazole); $T_4$: $T_1 + T_2$; $T_5$: $T_1$ + T3; $T_6$: $T_2 + T_3$; $T_7$: Tilt two spray; $T_8$: Nativo two spray; and $T_9$: Control. Data on disease incidence and severity with different treatments were collected at maturity. Among the nine treatments, root dipping along with twice foliar spray ($T_5$) produced the lowest number of infected tiller (30) followed by $T_8$ (34) and $T_7$ (35). The highest number of infected tiller (125) was found in control (Table 9). The lowest number of infected floret (50.67) was recorded in $T_5$ treatment, followed by $T_8$ and $T_7$. The highest number of infected floret (221.67) was found in control plot. In addition to this, the highest 75.80% disease reduction was detected in $T_5$ plot.

**Efficacy of higher doses of fungicides for controlling false smut disease**

Rice variety BRRI dhan49 was used as a test variety. Treatments were as follows- $T_1$: Propiconazole two spray @ 500 ml/ha; $T_2$: Nativo two spray @ 250 gm/ha; $T_3$: Azoxstrobin two spray @ 500 ml/ha; $T_4$:

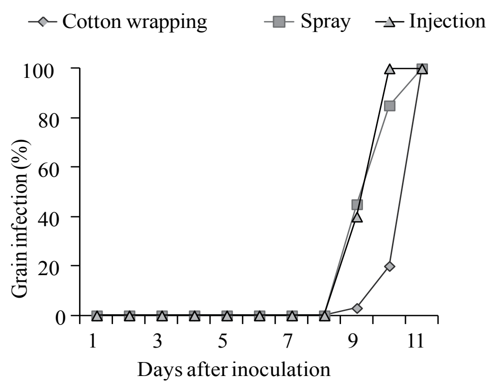



Fig. 12. Disease progress curve of neck blast disease using different inoculation techniques.

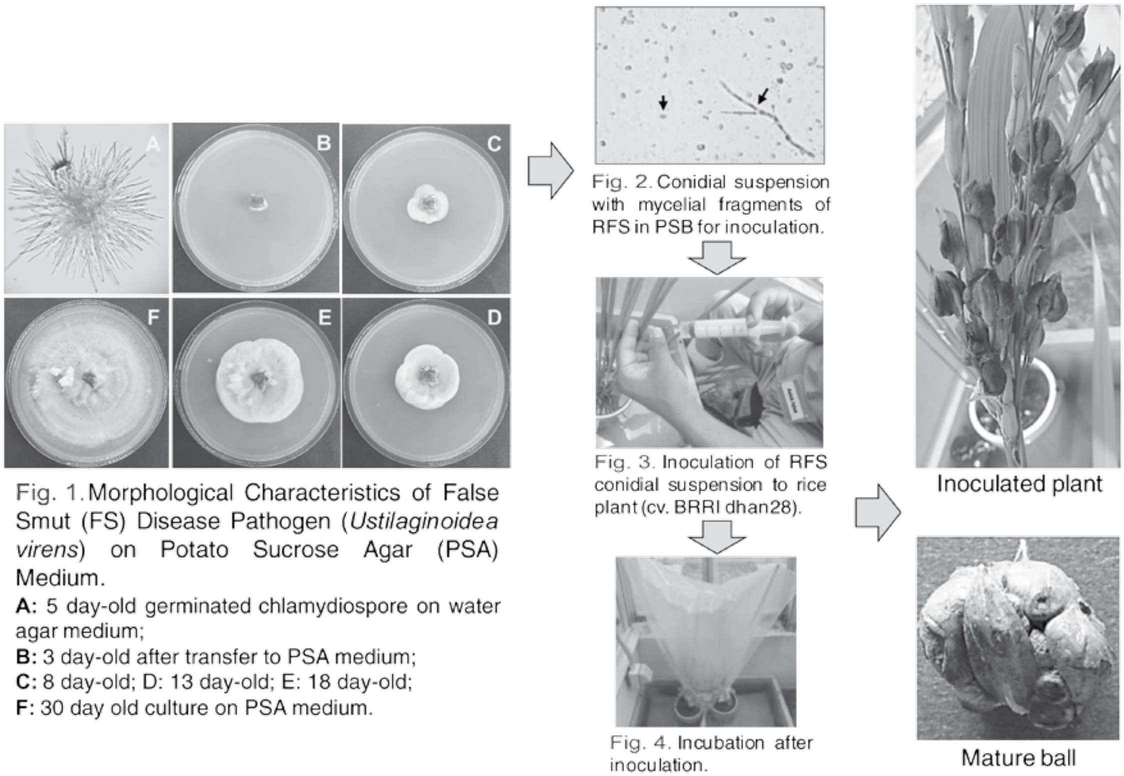



Fig. 13. A Simple but robust artificial inoculation technique of rice false smut disease**.**

Propiconazole two spray @ 1000 ml/ha; $T_5$: Nativo two spray @ 500 gm/ha; $T_6$: Azoxstrobin two spray @ 1000 ml/ha; and $T_7$: Control. Data on disease incidence and severity with different treatments were collected at mature stage of the crop. So far, among the different treatments, $T_5$ produced lowest number of infected tiller (35.67) followed by $T_2$ and $T_6$, and the highest number of infected tiller (159) was recorded in $T_7$ in case of BRRI HQ, Gazipur. While, in case of Rangpur, $T_5$ produced the lowest number of infected tiller (29.67) followed by $T_6$ and $T_2$, and the highest number of infected tiller (151.33) was recorded in control plot ($T_7$). In addition to this, the highest 80.40% disease reduction was observed at Rangpur while 77.57% disease reduction was recorded at BRRI HQ, Gazipur.

**Table 9. Integrated management on rice false smut disease in Gazipur, T. Aman 2016**

| Treatment | Infected tiller | No. of ball | Yield (t/ha) | Disease reduction (%) |
|---|---|---|---|---|
| Root dipping | 43 | 84.00 | 5.17 | 65.69 |
| Foliar spray | 52 | 89.33 | 5.20 | 58.51 |
| Soil treatment | 53 | 95.00 | 5.11 | 57.45 |
| Root dipping +soil treatment | 40 | 85.67 | 5.46 | 67.82 |
| Root dipping+ Foliar spray | 30 | 50.67 | 5.60 | 75.80 |
| Soil treatment + Foliar spray | 42 | 88.00 | 5.28 | 66.49 |
| Tilt two spray | 35 | 81.00 | 5.34 | 71.81 |
| Nativo two spray | 34 | 74.33 | 5.40 | 72.87 |
| Control | 125 | 221.67 | 5.01 | |
| SE | 3 | 11.99 | 0.09 | |
| LSD (p=0.05) | 10 | 35.94 | 0.27 | |

**Efficacy of biopesticides against sheath blight disease of rice**

*In vitro* and pot experiments were conducted to screen out the biopesticides for the control of sheath blight during T. Aman 2016. *In vitro* experiment was conducted three times with different biopesticides along with chemical control (Nativo) and negative control (water). The treatments were *Trichoderma harzianum* (BT1), Microtech1 (*Bacillus. subtilis*), *B. subtilis*, Agroplus, Recharge (*Glomus* spp, *Bacillus* spp. *Trichoderma* spp.), Chitin, Nativo (Tebuconazole+Trifloxystrobin) and control (water). None of the biopesticides was found effective to inhibit fungal and bacterial growth *in vitro*. In pot experiment, artificial inoculation of ShB and BB was conducted and the tested biopesticides were applied by spray method. The results showed that ShB and BB diseases were reduced about 30-50% by spraying the biopesticides.

**Development of novel biopesticides against sheath blight and bacterial blight diseases**

Soil and plant samples were collected from different rice growing areas in Bangladesh to identify suitable biocontrol agents against bacterial blight (BB) and sheath blight (ShB) disease of rice. Twelve *Trichoderma* and eight *Bacillus* isolates were purified from the collected soil and plant samples (rhizosphere/phylloplane) following dilution plate technique using PDA medium. *In vitro* experiment was performed three times following dual culture method on PDA for ShB and PSA for BB media. All those isolates were tested to know the efficacy of these isolates against *Rhizoctonia solani* and *Xanthomonas oryzae* pv. *oryzae*. The treatments were 12 Bangladeshi *Trichoderma* isolates BT1-BT12 @ OD600=0.3, 6 Bangladesh *Bacillus* isolates BDBs1-BDBs8 @ OD600=0.3, Nativo (Tebuconazole+Trifloxystrobin) @ 0.3% w/v as a chemical control and a control (water) as without application of biocontrol agents or chemicals. *R. solani* agar disk (6 mm) isolated from pure culture was disposed at the center of petridishes and incubated at 25°C for 2-3 days. In *in vitro* test, the radial growth of *R. solani* and bacterial growth was significantly inhibited by nine *Trichoderma* and four *Bacillus* strains including chemical control compared to water control treatment. Percent fungal reductions by these isolates and the chemical control were determined about 70 to 90% over control. In pot experiment, sheath blight disease was significantly reduced (about 40-70%) compared to diseased control by one *Bacillus* and two *Trichoderma* isolates and BB disease was reduced about 30-40% over diseased control by two *Trichoderma* isolates. These promising candidates will be further evaluated in the pot experiment and in the field condition.

PESTICIDE EVALUATION (ROUTINE WORKS)

**Evaluation of new chemicals against blast disease**

Among the 23 fungicides, only six such as Pazodi 32.5 SC, Navera, Seltima and Azonli 56 successfully controlled rice blast disease (above 80%) in Gazipur. In Barisal, eight chemicals viz. Metrobin, Royal, Aiker, Sunzoxy, Navera, Seltima, Mcvo and Alivo significantly reduced (84-92%) neck blast and were similar to standard check chemical Nativo (89%). Among the tested eight fungicides, three fungicides namely Gunzim (carbendazim ), Bitavo (Midacloprid 25%+Thiram 25%+Carbendazim 25%) and Topzim-super reduced more than 80% disease. Evaluation of fungicides against sheath blight results 12 effective fungicides eg Ensure, Agronil, Sunchance, Oxyzole, Fajilat, Azonil, Lustre, Trizole, Pair, Royal, Adistar, Aikon among the tested 19 fungicides in Rajshahi. Seven fungicides eg., Ensure 40 EC, Novita 75 WG, Agronil 560SC, Fazilat 30 EC, Trizole 75 WP, Pair 55 WG and Royal 75 WDG were identified as effective against the sheath blight disease among those fungicides tested in Rajshahi. Few bactericides eg Bactrol 50 SP, radi 20WP, BLB stopper 20% EC, autobac 20WP and sunoscar 21.5 wp result was good against bacterial blight disease but the disease incidence was very less.

TECHNOLOGY TRANSFER

**Demonstration on integrated rice disease management of sheath blight and blast**

A total of 20 demonstrations were conducted for blast and sheath blight disease management at farmers' field in four upazilas i.e., Gapalgonj sadar, Nazirpir, Mollahat and Fakirhat of Gapalgonj and Bagerhat districts under PGB in 2016-17. One farmer's field was selected for each demonstration where BRRI recommended practices in a plot and farmers practice in the adjacent plot were demonstrated. BRRI recommend practice showed less disease severity and incidence resulted in higher yield.

**Management of sheath blight disease using *Trichoderma harzianum***

Trichocompost was prepared in Boro season 2016-17 in farmers' home yard. Culture of *Trichoderma* spp. was grown in broken corn seeds in laboratory condition. The culture was mixed with dry water hyacinth, cow dung, and urea solution. Water hyacinth and cow dung were dried under intense sunlight for seven days. The composting materials were placed in layers in a pit (1m × 1m × 1m) in ratio of water hyacinth: Cow dung: *Trichoderma inoculum:* 3: 1: 0.25. Urea solution (10%) was used for rapid decomposing. The pit was covered with polythene sheet to avoid excessive rain water. Water was sprayed with sprinkler in every week up to four weeks and inverted the composting mixtures for better decomposition. Then the composting materials were covered with polythene sheet and locked the outer side of the polythene sheet with mud until compost prepared to use. The compost is prepared within 6-7 weeks and looks black and loose. After compost preparation, it was used in farmers' fields in variety BRRI dhan48 to find the efficacy of this compost in reducing sheath blight disease. Along with composting trial other two trials - farmers' conventional practice and chemical control were set up at the same time adjacent to the compost trial for comparison. All three practices were replicated thrice in RCB design. Data were collected on % RLH and yield (t/ha) in treated plots versus in farmers practice plots. RLH (%) was observed highest at farmer's practice plots (RLH: 41.8 and DI 45.18%) compared to fungicide treated plots (RLH: 10.4%) and DI 11.77%. Trichocompost treated plots showed the RLH 14.06 and DI 14.06 %. Trichocompost was found enriched with NPKSZn respectively as 1, 0.3, 1.13, 0.51, 0.004% content. These might have impact on increase of yield (11.4%). Disease reduction was profound in the second year as compared to the first year probably due to microbial effect on *R solani* as well as nutritional enrichment (Fig. 14).

**Identification of crop damage phenomenon by red eelworm and their management**

Control of eelworm was investigated using fungicide, nematicide, alternate wetting and drying and farmers' practice. Among the treatments used, regent application with alternate waiting and drying water management performed the best to control red eel worm and yield was also increased 12% compared to control (Table 10).

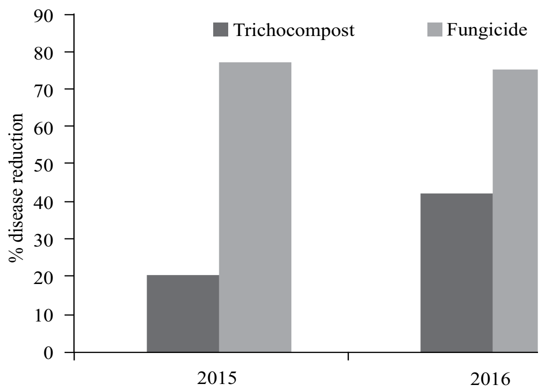



Fig. 14. Comparison of disease reduction over times.

**Table 10. Red eelworm incidence and yield of rice at different treatments**

| Treatment | No. of eel worm (before treatment) | No. of eel worm (after treatment) | Yield (t/ha) | Yield increase (%) |
|---|---|---|---|---|
| Regent (7.5 kg/ha) | 341.67 | 92.67 ab | 6.9 | 4.55 |
| Furadhan (20 kg/ha) | 371.67 | 81.33 bc | 6.9 | 4.55 |
| AWD | 345.00 | 71.67 bc | 7.1 | 7.58 |
| Regent+AWD | 276.33 | 47.33 c | 7.4 | 12.12 |
| Furadhan+AWD | 315.00 | 66.0 bc | 7.0 | 6.06 |
| Control | 360.00 | 130.00 a | 6.6 | |
| LSD (*p=0.05*) | ns | 39.0 | 0.719 | |

AWD = Alternate wetting and drying.

# Rice Farming Systems Division

SUMMARY

Crops and cropping pattern data were collected by using structured questionnaire from all upazilas of Bangladesh through DAE personnel. Data were processed in spread sheet and validated in workshops conducted separately in 64 districts of the country. Finally the verified data were analyzed and the report writing is complete, which will be published soon.

A long term experiment on crop establishment method (EM) and crop residue retention (CRR) in Wheat-Mungbean-Aman cropping pattern was conducted in Kharif-II 2016 to Kharif-I 2017. After completion of the experiment no significant difference of rice equivalent yield (REY) for either crop establishment method or for crop residue retention was observed. But interaction effect of EM and CRR were significantly different at the 5% level of significance. $EM_3$ (25% wheat and rice, 100% mungbean) treatment of CRR gave the highest rice equivalent yield (13.50t/ha) with conventional tillage ($T_3$), which was significantly similar with $EM_5$:$T_3$ (12.35t/ha) and $EM_3$:$T_2$ (12.20 t/ha) combinations.

In a long-term experiment of three cropped cropping patterns conducted at BRRI HQ, Gazipur, the highest REY, 25.22 t/ha and the highest gross margin, 169.20 thousand taka per hectare was obtained from Potato-Boro-T. Aman cropping pattern, which was 107% higher over the check pattern Boro-Fallow-T. Aman. The soil analysis report after six consecutive cycles reveals that organic matter and K were depleted in all the tested patterns, N was also depleted in all the tested pattern except in Maize-Mungbean-T. Aman, where it remained static. P level increased in $T_{1,}$ decreased in $T_2$ and remained static in other cropping patterns.

Fertilizer dose for T. Aman-Mustard-Boro cropping pattern was aimed to determine through omission plot technique. Individual crop-based recommended doses were higher compared to system-based recommendation for all the three tested crops. To fix a complete stable dose for the whole system the experiment needs to repeat.

Among the high intensity cropping patterns tested in Kushtia, the highest REY was obtained from Maize+Potato-T. Aus-T. Aman cropping pattern (18.36 t/ha) followed by Maize+Spinach-T. Aus-T. Aman (15.07 t/ha). Both the values were significantly higher than the REY of the check pattern, Maize-Fallow-T. Aman (10.14 t/ha). In Maize-Sweet gourd-T. Aman cropping pattern, different intercropping options with maize were compared in terms of maize equivalent yield (MEY). Significantly higher MEY was obtained when potato was intercropped with maize.

A study was undertaken at Gazipur and Meherpur during 2016-17 to evaluate proper use of homestead area and increase the diversity of existing agro-forestry system through inclusion of date palm. Two separate date palm gardens were established in 2013-14. At present, there are five hundred date palm plants in BRRI HQ, Gazipur and 1100 plants are in Mujibnagar Complex, Mujibnagar, Meherpur. In 2017, 30 male and 14 female plants were identified. Out of 14 female plants successful harvest was done from six plants.

## FARMING SYSTEMS RESEARCH AND DEVELOPMENT FOR CROSS ECOSYSTEM

**Survey on cropping patterns of Bangladesh**

**Study on cropping pattern and harnessing opportunities for improvement.** A survey was conducted at all upazilas of Bangladesh during January 2015- December 2016 to create database of existing cropping system in different regions of Bangladesh, exploring the scope of improvement in existing cropping patterns and to create cropping pattern map using GIS tools. Crops and cropping pattern data were collected by using structured questionnaire from all upazilas of Bangladesh through DAE personnel. Data were processed in spread sheet and were validated in workshops conducted separately in 64 districts of the country. Finally the verified data were analyzed and the report writing is complete, which will be published soon.

## DEVELOPMENT OF FARMING SYSTEMS TECHNOLOGIES FOR DIFFERENT ECOSYSTEMS

**Resource conservation technologies**

**Evaluation of crop residue retention for minimum tillage in T. Aman-Wheat-Mungbean cropping system.** An experiment was conducted in 2016-2017 at BRRI experimental farm, Gazipur with three crop establishment methods viz, $EM_1$- Strip tilled Aman, strip tilled wheat and mungbean, $EM_2$ - Single pass Aman, strip tilled wheat and mungbean and $EM_3$- Puddled Aman, direct seeded wheat and mungbean (conventional) and five crop residue retention options viz., $T_1$ - 100% wheat, mungbean and rice, $T_2$ - 50% wheat and rice, 100% mungbean, $T_3$ - 25% wheat and rice, 100% mungbean , $T_4$ - 25% wheat and rice, no mungbean and $T_5$ – conventional were evaluated in split plot design with three replications in Wheat-Mungbean-Aman rice cropping pattern. Non-selective herbicide round up 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. Mungbean was 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, T. Aman (BRRI dhan33) rice was transplanted in second week of July and harvested in first to last week of October that was followed by wheat. Recommended management practices were followed for wheat, mungbean and rice cultivation. No significant difference of REY for either crop establishment method or for crop residue retention was observed. But interaction effect of EM and CRR were significantly different at the 5% level of significance. $EM_3$ (25% wheat and rice, 100% mungbean) treatment of CRR gave the highest rice equivalent yield (13.50 t/ha) with conventional tillage ($T_3$), which was significantly similar with $EM_3$:$T_5$ (12.35 t/ha) and $EM_2$:$T_3$ (12.20 t/ha) combinations. $EM_1$:$T_1$ (11.79 t/ha) and $EM_3$:$T_2$ (11.36 t/ha) combinations were significantly similar. $EM_1$:$T_3$, combinations yielded the lowest (8.21 t/ha) which was significantly similar with $EM_2$:$T_4$ (8.95 t/ha). (Table 1)

**Cropping systems and component technologies for favourable environment (Irrigated condition)**

**Long-term effect of three crop cropping patterns on the agro-economic productivity and soil health.** The experiment was conducted in 2015-16 at the BRRI HQ experimental farms, Gazipur to develop farming system technology for diversifying and maximizing productivity using aquatic systems. 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 RCB design with three replications. Each unit plot was isolated by 1 meter space and 0.2 m high and 0.2 m wide levees. The levees were covered with polythene sheet inserting into the soil both sides of levee to prevent movement of irrigation water. The yield of each crop was converted to rice equivalent yield (REY) for comparing the system productivity. Use of resources like labour and inputs was recorded for calculating the variable cost and market price of the output at maturity was collected for determining the economic return.

**Table 1. REY of Wheat-Mungbean-T. Aman cropping system with different crop residue retention treatments under different establishment methods, Gazipur, 2016-17.**

| Crop residue retention | REY (t/ha) | | |
|---|---|---|---|
| | Establishment method | | |
| | Strip tillage | Single pass tillage | Conventional tillage |
| $T_1$ | 11.79 abc | 10.72 abcd | 10.02 bcd |
| $T_2$ | 9.76 bcd | 10.41 bcd | 11.36 abc |
| $T_3$ | 8.21 d | 12.20 ab | 13.50 a |
| $T_4$ | 10.49 bcd | 8.95 cd | 10.31 bcd |
| $T_5$ | 10.99 abcd | 9.94 bcd | 12.35 ab |
| CV (EM) | 31.5% | | |
| CV (CRR) | 14.3% | | |
| F value $_{0.05}$ for EM | 0.59 (NS) | | |
| F value $_{0.05}$ for CRR | 0.35 (NS) | | |
| F value $_{0.05}$ for CRR × EM | 0.021* | | |

NB: REY- Rice equivalent yield, CRR-Crop residue retention and EM- Establishment method.

During Rabi season, grain yield of BRRI dhan29 was 6 t/ha in Boro-Fallow-T. Aman cropping pattern and that of BRRI dhan28 was 5.11, 4.17 t/ha under Boro-T. Aus-T. Aman and Potato-Boro-T. Aman cropping pattern. Potato yielded 19.67 t/ha under Potato-Boro-T. Aman cropping pattern. Maize and mungbean yield was 6.6 t/ha and 0.57 t/ha under Maize-Mungbean-T. Aman cropping pattern. In three rice cropping pattern (Boro-T. Aus-T. Aman.) yield of Aus variety BRRI dhan48 was 4.31 t/ha. Grain yields of Aman rice variety BRRI dhan49 were 4.74, 4.16, 4.05 and 4.94 t/ha under Boro-Fallow-T. Aman, Boro-T. Aus-T. Aman, Maize-Mungbean-T. Aman and Potato-Boro-T Aman cropping pattern. The highest REY (19.84 t/ha) was obtained from Potato-Boro-T. Aman cropping pattern. The second highest REY obtained from Boro-T. Aus-T. Aman (12.15 t/ha) which is statistically similar to Maize-Mungbean-T. Aman (10.51 t/ha) cropping pattern. The lowest REY was obtained from Boro-Fallow-T. Aman (10.26 t/ha) cropping pattern that also statistically similar to Maize-Mungbean-T. Aman cropping pattern (Table 2).

The highest gross margin (72.53 thousand Tk/ha) was found from Potato-Boro-T. Aman cropping pattern followed by Maize-Mungbean-T. Aman and Boro-Fallow-T. Aman cropping pattern. Although, the second hightest REY observed from three rice (Boro-T. Aus-T. Aman) cropping pattern but due to high variable cost against gross return, gross margin was lowest (Table 3).

The soil analysis report after six consecutive cycles reveals that organic matter and K were depleted in all the tested patterns, N was also depleted in all the tested patterns except in Maize-Mungbean-T. Aman, where it remained static. P level increased in $T_1$, decreased in $T_2$ and remained static in other cropping patterns.

**Determination of fertilizer dose for Mustard-Boro-T. Aman cropping patterns**

The experiment was conducted at the experimental farm of BRRI HQ, Gazipur during T. Aman 2016 to Boro 2017 to determine the fertilizer dose for Mustard-Boro-T. Aman cropping pattern through site specific nutrient management (omission plot technique) with the inclusion of mustard in the transition period between T. Aman and Boro rices under T. Aman - Mustard - Boro cropping systems. There were four treatments: i) NPK, ii) -N, iii) - P and iv) - K. The variety BRRI dhan57, Barishoisha-14 and BRRI dhan28 were used for T. Aman rice, mustard and Boro rice respectively. The treatments were arranged in a randomized complete block design with three replications. In T. Aman season, the crop was transplanted in 3rd week of July with 31-day-old seedlings and harvested in 3rd week of October. Mustard was sown in 2nd week of November and harvested in 1st week of February. In Boro season, the crop was transplanted in 2nd week of February with 45-day-old seedlings and harvested in 2nd week of May. The crops were fertilized with N, P and K through urea, TSP and MOP, respectively. Recommended management practices were followed for rice and non-rice crops.

The results showed that the grain yields of T. Aman, mustard and Boro varied from 2.81 to 3.78 t/ha, 0.42 to 1.37 t/ha and 2.79 to 6.44 t/ha, respectively (Table 4). The grain yields of all the tested crops were significantly influenced by the treatments. System based fertilizer recommendation for the tested crops have been calculated from one year completion data (Table 5). The required doses of N, P, K for T. Aman, Mustard and Boro were 42.7, 3.47 and 25 kg/ha; 103, 26 and 39 kg/ha; and 107.9, 8.2 and 23.9 kg/ha, respectively. The experiment will be repeated for several years for valid conclusion.

**Table 2. Yield of rice, potato and mungbean and REY under different cropping patterns, BRRI, Gazipur, 2015-16.**

| Location | Cropping pattern | Grain/Tuber yield (t/ha) | | | | REY (t/ha) |
|---|---|---|---|---|---|---|
| | | Maize/Potato | Boro | T. Aus/Mungbean | T. Aman | |
| Gazipur | Boro-Fallow-T. Aman | - | 6.0 | - | 4.74 | 10.26 |
| | Boro-T. Aus-T. Aman | - | 5.11 | 4.31 | 4.16 | 12.15 |
| | Maize-Mungbean-T. Aman | 6.60 | - | 0.57 | 4.05 | 10.51 |
| | Potato-Boro-T. Aman | 19.67 | 4.17 | - | 4.94 | 19.84 |
| CV (%) | | | | | | 6.5 |
| LSD (0.05) | | | | | | 1.71 |

In case of REY, means followed by common letter(s) are not different at 0.1% level of significance. Potato: 10 Tk/kg, Rice: 18 Tk/kg, Maize: 12 Tk/kg, Mungbean: 65 Tk/kg.

**Table 3. Economic performance of different cropping patterns, BRRI HQ, Gazipur, 2015-16.**

| Cropping pattern | Variable cost ('000' Tk/ha) | Gross return ('000' Tk/ha) | Gross margin ('000' Tk/ha) |
|---|---|---|---|
| Boro-Fallow-T. Aman | 157.75 | 184.73 | 26.97 |
| Boro-T. Aus-T. Aman | 217.24 | 218.82 | 1.58 |
| Maize-Mungbean-T. Aman | 184.55 | 189.12 | 4.57 |
| Potato-Boro-T. Aman | 284.60 | 357.13 | 72.53 |

Price- Potato: 10 Tk/kg, rice: 18 Tk/kg, maize: 12 Tk/kg, mungbean: 65 Tk/kg.

**Table 4. Yields of T. Aman, mustard and Boro under T. Aman - Mustard - Boro cropping system, BRRI, Gazipur, 2016-17.**

| Treatment | T. Aman | | Mustard | | Boro | |
|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | Straw yield (t/ha) | Grain yield (t/ha) | Stover yield (t/ha) | Grain yield (t/ha) | Straw yield (t/ha) |
| NPK | 3.78 | 5.59 | 1.37 | 2.64 | 6.44 | 7.30 |
| -N | 2.81 | 4.23 | 0.42 | 0.62 | 2.79 | 5.06 |
| -P | 3.29 | 5.53 | 1.21 | 2.22 | 6.17 | 6.73 |
| -K | 3.52 | 5.76 | 1.19 | 1.89 | 5.90 | 7.41 |
| CV(%) | 4.4 | 4.5 | 7.9 | 13.4 | 4.7 | 8.0 |
| LSD$_{0.05}$ | 0.29 | 0.47 | 0.17 | 0.49 | 0.50 | 1.06 |
| F-value for treatment | ** | ** | ** | ** | ** | ** |

**Table 5. Cropping system based fertilizer recommendation for T. Aman, mustard and Boro, BRRI, Gazipur, 2016 - 17.**

| Required nutrients (kg/ha) | T. Aman | | Mustard | | Boro | |
|---|---|---|---|---|---|---|
| | RD | CSR | RD | CSR | RD | CSR |
| N | 69 | 42.7 | 138 | 103 | 119.6 | 107.9 |
| P | 10 | 3.47 | 36 | 26 | 19.4 | 8.2 |
| K | 41 | 25 | 50 | 39 | 60 | 23.9 |

ICR= Individual crop seed recommendation, CSR= Cropping systems based recommendation.

**Development of cropping systems and component technologies for deep water ecosystem**

**Improvement of relay cropping.** The experiment was conducted at Bahanga, Faridpur during 2016-17 to increase the total productivity of the Rabi-Jute/Aman (Relay) cropping pattern in deep water rice ecosystem with shallow water depth by adopting appropriate Aman (relay) variety and fertilizer management option. The highest yield (3.29 t/ha) was produced by BRRI dhan39 as relay crop with jute which was similar to that of BRRI dhan49 (3.27 t/ha) and BRRI dhan72 (3.26 t/ha) (Table 6). Among the fertilizer doses 30-14-12-8-1: Urea-TSP-MOP-Gypsum-Zinc sulphate, kg/Bigha produced the highest grain yield of BRRI dhan39. (Table 7).

## FARMING SYSTEMS TECHNOLOGY TRANSFER

**Validation and delivery of cropping systems technology**

**Development of high intensity cropping pattern for greater Kushtia region.** The experiment was conducted during Rabi 2015-16 to Kharif 2016 seasons. Four cropping patterns viz, Mustard (BARI sarisha-14)- Mungbean (BARI Mug-6)-T. Aus (BRRI dhan48)-T. Aman (BRRI dhan56/57), Potato (BARI alu-7)- Mungbean (BARI Mug-6)-T. Aus (BRRI dhan48)-T. Aman (BRRI dhan56/57), Maize (NK40)+Spinach-T. Aus-T. Aman and Potato (BARI alu-7) + Maize (NK40)-T. Aus (BRRI dhan48)-T. Aman (BRRI dhan56/57) were evaluated along with the check Maize (NK40) - Fallow-T. Aman (Swarna) in RCB design with three replications. There was significant REY difference among the four cropping patterns. Potato+Maize-T. Aus-T. Aman gave the highest REY (18.36 t/ha) followed by Maize+Spinach-T. Aus-T. Aman (15.07) in Kushtia and in Meherpur district Potato+Maize-T. Aus-T. Aman gave the highest REY (22.95 t/ha) followed by Mustard-Mungbean-T. Aus -T. Aman (19.95). On the contrary, lowest yield was found from Maize-Fallow-T. Aman (check) cropping pattern which was 10.14 t/ha in Kushtia (Table 8) and 14.16 t/ha in Meherpur district.

**Table 6. Performance of different Aman varieties used as relay crop with jute in Rabi-Jute - Relay Aman cropping pattern in shallow flooded area.**

| Cropping pattern | Yield (t/ha) |
|---|---|
| BRRI dhan39 (check) | 3.29 |
| BRRI dhan49 | 3.27 |
| BRRI dhan57 | 2.92 |
| BRRI dhan71 | 3.08 |
| BRRI dhan72 | 3.26 |
| $LSD_{0.05}$ | 0.359 |
| CV | 6.02 |

**Table 7. Performance of BRRI dhan39 as relay crop with jute in Rabi-Jute-/Relay Aman cropping pattern as affected by different dose of fertilizer in shallow flooded area.**

| Fertilizer dose (Urea-TSP-MOP-Gypsum Zinc sulphate, kg/Bigha) | Yield (t/ha) |
|---|---|
| 30-14-12-8-1 | 4.54 |
| 25-12-10-7-1 | 3.96 |
| 20-10-8-7-1 | 3.83 |
| 20-10-8-0-0 (check) | 3.45 |
| $LSD_{0.05}$ | 0.301 |
| CV | 6.21 |

## Validation of improved cropping patterns for greater Kushtia

A study was undertaken in Meherpur and Kushtia during 2016-17 for validation of improved cropping pattern to increase the system productivity and income of the farmers through introduction of improved cropping patterns. Pulse-Jute-T. Aman pattern was improved through replacing existing low yielding varieties by modern varieties. High yielding variety BARI moshur6 and BRRI dhan39 was introduced. Table shows that 21.27 t/ha rice equivalent yield was produced in improved pattern where farmers pattern produced 17.98 t/ha (Table 9). Judicial fertilizer management practice and intercultural operation reduced production cost which was less than farmers' practice. Consequently gross margin increased 43.27% over farmers practice (Table 10).

Modern high yielding variety was introduced in Pulse-Jute-T. Aman cropping pattern. BARI moshur 7 and BRRI dhan49 was introduced in the improved pattern and REY increased in improved practice (22.67 t/ha), which was more than farmers practice (20.20 t/ha) (Table 11). Gross margin increased 23.80% over farmer's practices (Table 12).

Pulse-Jute-T. Aman was introduced with modern variety BARI moshur 6 and BRRI dhan57 in T. Aman season. As a result REY was increased in improved practices (20.01 t/ha) over farmer's practices (17.28 t/ha) (Table 13). Gross margin was also increased by 37.11% in improved practices over farmer's practices because of judicious fertilizer management and intercultural operations (Table 14).

Boro-Fallow-T. Aman pattern was replaced by Boro-T. Aman/Mastard (Relay) pattern in an experiment at Paikpara, Khoksha. Short duration Aman and Mustard was introduced in improved pattern. Improved pattern produced 12.96 t/ha where farmers pattern produced 10.12 t/ha (Table 15). Gross margin was reduced 52.17% in improved pattern over farmer's pattern (Table 16).

Latest high yielding variety was introduced in Onion-T. Aus-T. Aman pattern to increase the production. Taherpuri variety of onion and BRRI dhan49 were used instead of low yielding variety. As a result 33.18 t/ha REY was found in improved pattern and 31.27 t/ha was found in farmer's pattern (Table 17). Gross margin also increased 10.82% in improved practices over farmer's practice (Table 18).

**Research and development under cross cutting issues Performance of exotic date palm.** The study was undertaken at Gazipur and Meherpur during 2016-17 to evaluate proper use of homestead

**Table 8. Yield performance for different cropping patterns in Kushtia, 2015-16.**

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

Mustard = 50 Tk/kg, Mungbean = 60 Tk/kg, BRRI dhan48 =17 Tk/kg, BRRI dhan57 =20 tk/kg, Potato = 10 Tk/kg, Spinach = 6 Tk/kg, Maize = 14 Tk/kg, Sweet gourd= 10 Tk. /kg.

**Table 9. Performance of improved cropping pattern over existing pattern at Shimulia block, Khoksha, Kushtia.**

| Cropping pattern | Number of farmer | Ave. yield (t/ha) | | | REY (t/ha) |
|---|---|---|---|---|---|
| | | Pulse | Jute | T. Aman | |
| Pulse-Jute-T. Aman (FP)** | 5 | 1.2 | 3.18 | 5.18 | 17.98 |
| Pulse-Jute-T. Aman (IP)* | 5 | 1.72 | 3.52 | 5.29 | 21.27 |
| CV (%) | | | | | 3.6 |
| F for treatment | | | | | ** |
| $LSD_{0.05}$ for treatment | | | | | 1.25 |

**FP-Farmers practice, *IP-Improved practice. Price- BRRI dhan39: 17 Tk/kg and BRRI dhan57: 20 Tk/kg, Lentil: 70 Tk/kg, Jute: 40 Tk/kg.

**Table 10. Economic performance for different practice at Shimulia.**

| Cropping pattern | TVC (Tk/ha) | GR (Tk/ha) | GM (Tk/ha) | % GM increase |
|---|---|---|---|---|
| Pulse-Jute-T. Aman (FP)** | 165900 | 296670 | 130770 | 43.27 |
| Pulse-Jute-T. Aman (IP)* | 163600 | 350955 | 187355 | |

**FP-Farmers practice, *IP-Improved practice.

**Table 11. Performance of improved cropping pattern over existing pattern at Jayontihazra block, Khoksha, Kumarkhali.**

| Cropping pattern | Number of farmer | Yield (t/ha) | | | REY (t/ha) |
|---|---|---|---|---|---|
| | | Pulse | Jute | T. Aman | |
| Pulse-Jute-T. Aman (FP)** | 5 | 1.60 | 3.70 | 4.90 | 20.20 |
| Pulse-Jute-T. Aman (IP)* | 5 | 1.80 | 4.00 | 5.53 | 22.67 |
| CV (%) | | | | | 4.4 |
| F for treatment | | | | | * |
| $LSD_{0.05}$ for treatment | | | | | 1.64 |

**FP-Farmers practice, *IP-Improved practice. Price- BRRI dhan39: 17 Tk/kg and BRRI dhan57: 20 Tk/kg, Lentil: 70 Tk/kg, Jute: 40 Tk/kg.

**Table 12. Economic performance for different practices at Joyantihazra.**

| Cropping pattern | TVC (Tk/ha) | GR (Tk/ha) | GM (Tk/ha) | % GM increase |
|---|---|---|---|---|
| Pulse-Jute-T. Aman (FP)** | 164500 | 343400 | 178900 | 23.80 |
| Pulse-Jute-T. Aman (IP)* | 163900 | 385390 | 221490 | |

(**FP-Farmers practice, *IP-Improved practice).

**Table 13. Performance of improved cropping pattern over existing pattern at Shomospur block, Khoksha, Kushtia.**

| Cropping pattern | Number of farmer | Yield (t/ha) | | | REY (t/ha) |
|---|---|---|---|---|---|
| | | Pulse | Jute | T. Aman | |
| Pulse-Jute-T.Aman (FP)** | 5 | 1.00 | 3.50 | 4.93 | 17.28 |
| Pulse-Jute-T.Aman (IP)* | 5 | 1.30 | 4.03 | 4.40 | 20.01 |
| CV (%) | | | | | 4.1 |
| F for treatment | | | | | ** |
| $LSD_{0.05}$ for treatment | | | | | 1.33 |

*Improved management; **Farmers' management. Price- BRRI dhan39: 17 Tk/kg and BRRI dhan57: 20 Tk/kg, Lentil: 70 Tk/kg, Jute: 40 Tk/kg.

**Table 14. Economic performance for different practices at Shomospur.**

| Cropping pattern | TVC (Tk/ha) | GR (Tk/ha) | GM (Tk/ha) | % GM increase |
|---|---|---|---|---|
| Pulse-Jute-T. Aman (FP)** | 165500 | 293760 | 128260 | 37.11 |
| Pulse-Jute-T. Aman (IP)* | 164300 | 340170 | 175870 | |

*Improved management; **Farmers' management.

area and increase the diversity of existing agro-forestry system through inclusion of date palm. Two separate gardens were established in 2013-14. Five hundred plants in BRRI HQ, Gazipur and 1100 plants in Mujibnagar Complex, Mujibnagar, Meherpur. In 2017, 30 male and 14 female plants are identified. Out of 14 female plants successful harvest was done from six plants.

**Table 15. Performance of improved cropping pattern over existing pattern at Paikpara, Khoksha, Kushtia.**

| Cropping pattern | Number of farmer | Yield (t/ha) | | | REY (t/ha) |
|---|---|---|---|---|---|
| | | Boro | T. Aman | Mustard | |
| Boro- Fallow -T. Aman (FP)** | 5 | 5.90 | 4.45 | - | 10.12 |
| Boro- T. Aman-Mustard (IP)* | 5 | 6.05 | 3.70 | 1.15 | 12.96 |
| CV (%) | | | | | 7.5 |
| F for treat. | | | | | ** |
| $LSD_{0.05}$ for treat. | | | | | 1.52 |

*Improved management; **Farmers' management. Price- BRRI dhan28: 19 Tk/kg, BRRI dhan29: 18.5 Tk/kg, BRRI dhan49: 18 Tk/kg, BR11/Shawrna: 16.5 Tk/kg, Mustard: 50 Tk/kg.

**Table 16. Economic performance for different practice at Paikpara.**

| Cropping pattern | TVC (Tk/ha) | GR (Tk/ha) | GM (Tk/ha) | % GM increase |
|---|---|---|---|---|
| Boro-Fallow-T.Aman (FP)** | 133900 | 192280 | 58380 | 52.17 |
| Mustard-Boro-T.Aman (IP)* | 157400 | 246240 | 88840 | |

*Improved management; **Farmers' management.

**Table 17. Performance of improved cropping pattern over existing pattern at Dasha, Kumarkhali, Kushtia.**

| Cropping pattern | Number of farmer | Yield (t/ha) | | | REY (t/ha) |
|---|---|---|---|---|---|
| | | Onion | T. Aus | T. Aman | |
| Onion-T. Aus-T. Aman (FP)** | 5 | 12.00 | 5.10 | 5.00 | 31.27 |
| Onion-T. Aus-T. Aman (IP)* | 5 | 12.50 | 5.30 | 5.50 | 33.18 |
| CV (%) | | | | | 2.7 |
| F for treatment | | | | | * |
| $LSD_{0.05}$ for treatment | | | | | 1.54 |

*Improved management; **Farmers' management.Price- BRRI dhan48: 17 Tk/kg, BRRI dhan39: 17 Tk/kg, BRRI dhan49: 18 Tk/kg, Onion: 30 Tk/kg.

**Table 18. Economic performance for different practice at Dasha.**

| Cropping Pattern | TVC (Tk/ha) | GR (Tk/ha) | GM (Tk/ha) | % GM increase |
|---|---|---|---|---|
| Onion-T. Aus-T. Aman (FP)** | 221500 | 531590 | 310090 | 10.82 |
| Onion-T. Aus-T. Aman (IP)* | 220400 | 564060 | 343660 | |

Latest high yielding variety was introduced in Onion-T. Aus-T. Aman pattern to increase production. Taherpuri variety of onion and BRRI dhan49 were used instead of low yielding variety. As a result 32.15 t/ha REY was found in improved pattern and 30.82 t/ha was found in farmer's pattern (Table 19). Gross margin also increased 8.05% in improved practices over farmer's practice (Table 20).

**Table 19. Performance of improved cropping pattern over existing pattern at Jaduboira, Kumarkhali, Kushtia.**

| Cropping pattern | Number of farmer | Yield (t/ha) | | | REY (t/ha) |
|---|---|---|---|---|---|
| | | Onion | T. Aus | T. Aman | |
| Onion-T. Aus-T. Aman (FP)** | 5 | 12.20 | 4.25 | 5.04 | 30.82 |
| Onion-T. Aus-T. Aman (IP)* | 5 | 12.40 | 4.87 | 5.10 | 32.15 |
| CV (%) | | | | | 1.8 |
| F for treat. | | | | | * |
| $LSD_{0.05}$ for treat. | | | | | 0.97 |

*Improved management; **Farmers' management Price- BRRI dhan48: 17 Tk/kg, BRRI dhan39: 17 Tk/kg, BRRI dhan49: 18 Tk/kg, Onion: 30 Tk/kg.

**Table 20. Economic performance for different practice at Jaduboira.**

| Cropping Pattern | TVC (Tk/ha) | GR (Tk/ha) | GM (Tk/ha) | % GM increase |
|---|---|---|---|---|
| Onion-T. Aus-T. Aman (FP)** | 223100 | 523940 | 300840 | 8.05 |
| Onion-T. Aus-T. Aman (IP)* | 221500 | 546550 | 325050 | |

# Agricultural Economics Division

SUMMARY

BRRI dhan28 and BRRI dhan29 were the leading varieties as being grown in nearly 62% of rice lands in the Boro season. The adoption of modern varieties was more than 99% and among them, the coverage of the BRRI varieties was about 71% in this season. In T. Aman season, BRRI dhan49 (11%) and BR11 (7%) occupied about 18% areas, and the coverage of the BRRI varieties in this season was about 48%. In Aus season, the adoption of modern varieties was about 90% and the BRRI varieties covered almost 67% areas. BRRI dhan48 ranked the topmost (17%) by the area adoption as followed by BRRI dhan28 (15%). BRRI dhan29 was the utmost yielder (6.41 t/ha) followed by BRRI dhan58 (5.98 t/ha) as well as BRRI dhan63 (5.73 t/ha) in Boro season. Average yield of hybrids were 7.23 t/ha whereas BRRI developed hybrids were 7.58 t/ha in Boro season. In T. Aman season, BRRI dhan49 was the top yielder (4.60 t/ha) as followed by BRRI dhan52 (4.55 t/ha). On the contrary, BRRI dhan48 was found the outyielder (4.04 t/ha) in Aus season. BRRI dhan51 (1.63%) and BRRI dhan52 (4.30%) were, submerged tolerant varieties in T. Aman season, cultivated in 6% of rice land in the study area in 2014. Moreover, BRRI dhan51 (2.84%) and BRRI dhan52 (5.93%) are rapidly getting farmer acceptance in flood affected area. On the contrary, BRRI dhan56 and BRRI dhan57 are introduced to combating with the drought stress in the same season. For Aus season, BRRI dhan42, BRRI dhan43, and BRRI dhan55 are more suitable for the drought condition. Unexpectedly, these varieties are not adopted enormously at farm level. In Aman season, most of the drought area is dominated by the Indian rice varieties such as Swarna, Ranjit and Jamaibabu, etc. In salt affected areas, BRRI dhan40 and BRRI dhan41 perform very well in T. Aman season. In Boro season, BRRI dhan47 is still widely grown variety, even though it has a disadvantage of shattering. Yield of stress resilient rice cultivars in all seasons were lower than conventional MV type. Higher yield potential with stresses tolerant would widely be adopted and made more profitable at the farm level.

In the preference analysis, the check variety BR11 and Sowarnagota were the most preferred T. Aman varieties in Dacope and Amtoli, respectively which are more typically risk escaping for small farmers in coastal regions. In addition to quantity of grain and straw, quality and stem strength, other phenotypic traits like growth duration substantially influenced to vote in favour of BRRI dhan73 and BRRI dhan66 in Dacope. Similarly, BRRI dhan53 and BRRI dhan66 were voted in Amtoli because these varieties could escape the occurrence of water stagnation in the fields. Besides, farmers could establish most DS crop within optimum seeding windows. Farmers rejected BRRI dhan62 and BRRI dhan54 in part because of high susceptibility to water lodging and infestation of vertebral pests. The preference analysis implied that environmental adaptability of a variety especially at maturity stage is more crucial consideration of farmers to select a new variety along with higher yield, plant height, strong stem, tillers per hills, panicle length, and grain size.

Wet season (WS) rice farming is found as a better option for livelihood other than off-farm waged activities. Gross income of rainfed wet season rice is significantly varied due to seasonal dispersion of yield and market uncertainty. In some of case, under farmer's practice the chance of occurring negative net income of MV WS rice is also significant. However, economic viability (profitable and less risky) of the rainfed WS rice under research managed plot is tremendously higher than farmer's practice. The key insight of modern technology introduction (variety and agronomic management) is associated with reduction of the risk of the rainfed crop cultivation along with profitability.

In response to huge credit demand, Rajshahi Krishi Unnayan Bank (RAKUB) continues to fulfill about 75% of credit requirement of farmers in the study villages during Boro, 2016. Although, there was large gap between the need and receipt of credit for small farmers (33%) as followed by medium (25%) and large (18%), small farmers used 48% of their credit for MV Boro rice cultivation higher than medium (35%) and large (23%) farmers. Insufficient amount of loan, higher non-interest cost and complicated credit rules were the major constraints as reported by 93, 85, and 75% farmers, respectively.

Total production capacity of seven surveyed rice bran oil mill was 147000 ton/year, during 2016 and they produced 97,900 tons of oil (67% capacity utilization) of which about 55% was supplied in internal market and the remaining 45% were

exported in foreign countries like, India, China and Japan. Total cost of rice bran oil production including by products was Tk 176,206/ton. After deducting the returns from by products; actual cost of bran oil was Tk 87019/ton. Two dominant chains were found for the value chain of rice bran oil in Bangladesh. Value additions by miller, dealer and retailer of the supply chain were 14.92, 10.00 and 10.91% and gross margin obtained by those actors were 37.11, 28.59 and 34.30%, respectively. The key problems of RBO were unavailability of adequate rice bran and lack of promotional activities at consumer level.

In Southern Coastal Bangladesh, farmers' adaptation strategies could be referred by the adoption of modern varieties, shifting of planting time, providing supplementary irrigation, growing dry-season rice and other crops, rice/fish/shrimp culture, homestead gardening, raising livestock, receiving credit, and carrying out off/non-farm work. The constraints of cropping system intensification included inadequate access to fresh-water for irrigation, soil salinity, excess soil moisture at sowing time of Rabi crops, inadequate access to suitable technologies at local level, lack of stress tolerant varieties, technologies and extension supports and price fluctuation. There exists great prospect to increase cropping intensity in the area through judicious use and management of reserved fresh-water, improving farmers' knowledge on crop management and increasing adoption of stress tolerant variety.

Government procurement programme has positive impacts on both participant farmers and millers. Farmers obtained about 30% higher returns through selling paddy at procurement center than selling paddy at local market. Incremental margin per quintal paddy rice and clean rice of farmers and miller were Tk 462 and Tk 451, respectively. Inadequate quota, undue expectation of procurement staff, strict regulation about quality of paddy, husked rice, and payment system would be reported as major limitations of inefficient procurement systems. Farmers of old enclaves were familiar with modern rice production technologies through private companies and NGOs. They did not face problems in selling output in Bangladesh market. Adequate institutional credit is needed to smooth rice production at these areas.

## FARM LEVEL ADOPTION AND EVALUATION OF MODERN RICE CULTIVATION

Rice is the main diet packed with protein and calorie for the people in Bangladesh and enormously contributes to 17% of the country's GDP. In addition, more than 75% of the country's cropped area is devoted to rice cultivation. However, Bangladesh Rice Research Institute has developed as much as 85 MVs including 5 hybrids for different production environments. Most of the varieties have been practiced by the farmers. The adoption rate of these MVs differs to greater extent in the different regions as well as seasons. The study has been accomplished with the specific objectives such as: to determine the region-wise adoption rate of different rice varieties in different seasons; and to estimate the yield of different modern and local varieties. To collect the required dataset, multistage random sampling technique was adopted. Thus, the total sample size was 4,140 rice farmers under Aus (1,356), T. Aman (1,328), and Boro (1,456), respectively.

### Season-wise adoption of modern rice varieties

In Boro season, BRRI dhan28 and BRRI dhan29 were the dominant rice varieties covering 62% of total Boro area during 2016-17 (Table 1), which is consistent with the national average (BBS, 2016). The overall adoption of modern varieties (MVs) in this season was about 99% of which total BRRI varieties' coverage was 71%. Among BRRI varieties, BRRI dhan28 and BRRI dhan29 were grown in all the regions of Bangladesh. The area coverage of hybrids (15%) remained unchanged. On the other hand, Indian varieties (11%) increased compared to previous year (8%), showing these varieties are particularly Zirasail getting popularity among the farmers.

In T. Aman season, BRRI dhan49 (11%) and BR11 (7%) appeared as the most prominent rice varieties covering 18% areas in T. Aman season. The area coverage of BRRI varieties was about 48% in this season which was 47% in last year, indicating slight increasing trend. On the other hand, adoption of Indian variety was (21%), which was 23% in the last year, indicating that these varieties were

**Table 1. Adoption (%) of different Boro rice varieties by agricultural regions of Bangladesh, 2016-17.**

| Variety | Reg1 | Reg2 | Reg3 | Reg4 | Reg5 | Reg6 | Reg7 | Reg8 | Reg9 | Reg10 | Reg11 | Reg12 | Reg13 | Reg14 | BGD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BRRI dhan28 | 46.2 | 37.4 | 24.3 | 24 | 46.3 | 55.2 | 10 | 16.9 | 43.1 | 38.5 | 30.9 | 34.3 | 28.6 | 35.6 | 35.3 |
| BRRI dhan29 | 19.4 | 23.7 | 25.8 | 7.8 | 2.5 | 1.1 | 14.3 | 38.4 | 32.4 | 35.9 | 11.5 | 10.3 | 62.6 | 38.9 | 26.5 |
| BRRI dhan58 | 1.8 | 1.1 | 2.9 | 0.2 | 0.5 | 0.2 | 5.9 | 2.3 | 1.9 | 9.2 | 1.3 | 0.5 | 1.4 | 2 | 2.2 |
| Other BRRI varieties | 3.9 | 6.6 | 3.8 | 4.4 | 15 | 3.6 | 11.8 | 5 | 6.6 | 6.4 | 20.8 | 13.2 | 2.2 | 4.8 | 6.7 |
| All BRRI varieties | 71.3 | 68.9 | 56.9 | 36.4 | 64.2 | 60.2 | 42 | 62.5 | 83.8 | 90.1 | 64.5 | 58.3 | 94.9 | 81.2 | 70.6 |
| All hybrid | 27.7 | 12 | 8.9 | 4.4 | 7.9 | 36.1 | 21.7 | 27.1 | 14.4 | 9.2 | 28.5 | 39.4 | 4.3 | 17.6 | 15.1 |
| All MVs | 99.6 | 100 | 99 | 100 | 100 | 99.5 | 94.5 | 97.1 | 99.8 | 99.9 | 100 | 100 | 99.3 | 99.2 | 99.4 |
| All LVs | 0.4 | 0 | 1 | 0 | 0 | 0.5 | 5.5 | 2.9 | 0.2 | 0.1 | 0 | 0 | 0.7 | 0.8 | 0.6 |
| All varieties | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

slightly losing popularity (Table 2). However, overall adoption of modern varieties (MVs) in T. Aman season was about 80%. Therefore, the area coverage could be expanded toward MVs in order to feed upcoming generation.

In Aus season, the overall adoption rate of modern rice varieties in Aus season was about 90% of which the coverage of BRRI varieties was about 67%. Among all BRRI varieties, BRRI dhan48 ranked the top position (17%) in terms of area coverage followed by BRRI dhan28 (15%) and BR26 (7%). In Aus season, coverage of other MVs, Indian and hybrid were about 14, 5, and 4%, respectively (Table 3). Results revealed that, area coverage of traditional varieties was about 10% in this season.

### Yield of modern rice varieties

An attempt was also made in the present study to explore the yield performance of modern rice varieties in Boro, T. Aman and Aus seasons in different agricultural regions of Bangladesh. In Boro season, among all BRRI varieties, BRRIdhan29 was the top yielder (6.41 t/ha) followed by BRRI dhan58 (5.98 t/ha), BRRI dhan63 (5.73 t/ha) and BRRI dhan28 (5.70 t/ha)). Average yield of hybrid was 7.23 t/ha whereas BRRI hybrid was 7.58 t/ha in this season (Table 4). The average yield of Indian varieties was 5.65 t/ha and the overall yield of modern varieties in Boro season was about 6.20 t/ha. In T. Aman season, Among BRRI varieties, BRRI dhan49 was the top yielder (4.60 t/ha), followed by BRRI dhan52 (4.55 t/ha) and BR11 (4.53 t/ha) in

**Table 2. Adoption (%) of different T. Aman rice varieties by agricultural regions of Bangladesh, 2016-17.**

| Variety | Reg1 | Reg2 | Reg3 | Reg4 | Reg5 | Reg6 | Reg7 | Reg8 | Reg9 | Reg10 | Reg11 | Reg12 | Reg13 | Reg14 | BGD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BR11 | 14.4 | 0.3 | 3.7 | 1 | 0.6 | 6.6 | 6.4 | 2.5 | 7.3 | 2.3 | 7.9 | 25.4 | 10.1 | 22.5 | 7.3 |
| BR22 | 0 | 0 | 0.7 | 0 | 0.5 | 1 | 3.3 | 0 | 1.4 | 27 | 9.7 | 4 | 5.7 | 6.6 | 3.7 |
| BR23 | 0 | 0 | 0 | 0 | 1.1 | 16.4 | 5.9 | 0 | 0.4 | 2.8 | 6 | 0.3 | 0.2 | 1.7 | 2.7 |
| BRRI dhan49 | 3.6 | 4.5 | 17 | 8.9 | 11.3 | 7.8 | 0.9 | 6.5 | 21.9 | 10.2 | 9.6 | 14.2 | 36.9 | 16.4 | 10.9 |
| BRRI dhan52 | 7.3 | 1.7 | 1.4 | 1.1 | 1.2 | 2 | 6.6 | 2.9 | 2.6 | 1.4 | 3.7 | 0.9 | 1.5 | 3.6 | 3.3 |
| Other BRRI varieties | 11.8 | 25.2 | 15.8 | 17 | 22.7 | 22.4 | 12.2 | 55.9 | 22.2 | 19.2 | 27.4 | 35.5 | 13.6 | 23.4 | 20.4 |
| BRRI varieties | 37 | 31.8 | 38.6 | 27.9 | 37.4 | 56.2 | 35.4 | 67.8 | 55.9 | 62.9 | 64.4 | 80.6 | 67.8 | 73.9 | 48.1 |
| All hybrid | 5.1 | 5.3 | 1.6 | 0.1 | 3.9 | 1.4 | 0 | 1.7 | 1.3 | 0 | 0.6 | 0.8 | 0.2 | 0 | 1.7 |
| All Indian | 48.2 | 56.3 | 40.7 | 53.4 | 43.7 | 6.6 | 2.2 | 1.2 | 1.5 | 0.9 | 2.4 | 1.4 | 2.5 | 3.4 | 21.2 |
| Other MVs | 4.4 | 4.5 | 15.6 | 10.8 | 14 | 5.6 | 3.7 | 14.4 | 16.2 | 2.3 | 9.7 | 11.5 | 16.4 | 2.7 | 8.7 |
| All MVs | 94.7 | 97.9 | 96.4 | 92.2 | 99.1 | 69.9 | 41.3 | 85.1 | 74.9 | 66.2 | 77.1 | 94.2 | 86.9 | 80.1 | 79.7 |
| All LVs | 5.3 | 2.1 | 3.6 | 7.8 | 0.9 | 30.1 | 58.7 | 14.9 | 25.1 | 33.8 | 22.9 | 5.8 | 13.1 | 19.9 | 20.3 |
| All varieties | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

**Table 3. Adoption (%) of different Aus rice varieties by agricultural regions of Bangladesh, 2016-17.**

| Variety | Reg1 | Reg2 | Reg3 | Reg4 | Reg5 | Reg6 | Reg7 | Reg8 | Reg9 | Reg10 | Reg11 | Reg12 | Reg13 | Reg14 | BGD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BR21 | | | 4.7 | 15.6 | 0.9 | | 0.1 | | | 0 | 2.1 | 1.4 | 9.2 | 4.5 | 4.3 |
| BR26 | 0.7 | 0.1 | 1.7 | 4.6 | 10.1 | 8.8 | 2.2 | 4.4 | 17.1 | 6.1 | 7.7 | 1.8 | 22.3 | 11 | 6.9 |
| BRRI dhan28 | 47.6 | 61.2 | 4.9 | 19 | 11.2 | 9.9 | 0 | 0.5 | 21 | 27.6 | 7 | 2.1 | 17.9 | 19.9 | 15.3 |
| BRRI dhan48 | 18.6 | 0.3 | 31.5 | 8.9 | 28.8 | 14.1 | 12.9 | 9.5 | 23.4 | 14.8 | 9.4 | 2.4 | 17.2 | 30.8 | 17.2 |
| Other BRRI varieties | 7.5 | 2.4 | 6.4 | 9.2 | 7.2 | 10.6 | 44.9 | 3.8 | 10.9 | 37.5 | 40.7 | 10.2 | 29.8 | 27.6 | 23.2 |
| All BRRI varieties | 74.4 | 64.1 | 49.1 | 57.3 | 58.4 | 43.2 | 60.2 | 18.2 | 72.4 | 86.1 | 66.9 | 17.8 | 96.4 | 93.7 | 66.8 |
| BRRI hybrid | 0.1 | | | | | | | | | | | | | | 0 |
| All hybrid | 22.1 | 20.6 | 3.5 | 2.8 | 13.8 | 4.3 | 0.3 | 1.7 | | 4.6 | 4.4 | 4 | 0.2 | 0.1 | 4.5 |
| All Indian | | 1.1 | 9.6 | 12.5 | 10.1 | 7.4 | 0.1 | | | 0.2 | 8.1 | 0.8 | 0.3 | | 5 |
| Other MVs | 1.9 | 13.9 | 9.1 | 20.8 | 16.3 | 7.5 | 39.4 | 0.3 | 25.1 | 8.2 | 2 | 1.4 | 0.7 | 3.7 | 13.5 |
| All MVs | 98.3 | 99.6 | 71.3 | 93.4 | 98.6 | 62.4 | 100 | 20.2 | 97.5 | 99 | 81.3 | 24.1 | 97.5 | 97.5 | 89.9 |
| All LVs | 1.7 | 0.4 | 28.7 | 6.6 | 1.4 | 37.6 | | 79.8 | 2.5 | 1 | 18.7 | 75.9 | 2.5 | 2.5 | 10.1 |
| All varieties | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Classification of region by districts Reg1 (Rangpur). Rangpur, Kurigram, Lalnonirhat, Gaibandha and Nilphamari; Reg2 (Dinajpur): Dinajpur, Panchagar, and Thakurgoan; Reg3 (Bogra): Bogra, Sirajgonj, Joypurhat and Pabna; Reg4 (Rajshahi): Rajshahi, C. Nawabganj, Naogoan, and Natore; Reg5 (Jessore): Khustia, Meherpur, Chuadanga, Jessore, Jhenaidah, and Magura; Reg6 (Khulna): Khulna, Satkhira, Narail, and Bagerhat; Reg7 (Barisal): Barisal, Patuakhali, Barguna, Jhalokhati, Pirojpur and Bhola; Reg8 (Faridpur): Rajbari, Gopalganj, Shariotpur, Madaripur, and Faridpur; Reg9 (Mymensing): Jamalpur, Mymenshingh, Sherpur, Netrakona and Kishorganj; Reg10 (Comilla): Comiila, B.Baria, and Chandpur; Reg11 (Chittagong): Feni, Noakhali, Cox's Bazar, Laxmipur and Chittagong; Reg12 (Rnagamati): Khagrachari, Bandarban and Rangamati; Reg13 (Dhaka): Dhaka, Tangail, Manikganj, Narshingdi, Munshiganj and Gazipur; Reg 14 (Sylhet): Habiganj, Sylhet, Moulivibazar, and Sunamganj.

**Table 4. Yield (t/ha) of different Boro rice varieties by agricultural regions of Bangladesh, 2016-17.**

| Variety | Reg1 | Reg2 | Reg3 | Reg4 | Reg5 | Reg6 | Reg7 | Reg8 | Reg9 | Reg10 | Reg11 | Reg12 | Reg13 | Reg14 | BGD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BRRI dhan28 | 5.2 | 5.6 | 6 | 6.2 | 6.1 | 5.8 | 5.9 | 6 | 5 | 5.5 | 5.3 | 5.4 | 5.9 | 4.9 | 5.7 |
| BRRI dhan29 | 6.7 | 6.3 | 6.9 | 7.1 | 6.7 | 6.1 | 6.3 | 6.8 | 6 | 6.1 | 5.8 | 5.8 | 6.8 | 5.1 | 6.4 |
| BRRI dhan58 | 5.5 | 6.2 | 6.3 | 6.7 | 6.4 | 5.7 | 6.2 | 6.3 | 5.4 | 5.9 | 5.7 | 5.4 | 6.4 | 5 | 6.0 |
| Other BRRI varieties | 4.64 | 3.60 | 5.88 | 3.88 | 3.00 | 4.95 | 4.40 | 4.50 | 4.60 | 4.78 | 5.48 | 5.30 | 5.04 | 4.35 | 5.55 |
| BRRI varieties | 5.4 | 5.9 | 5.8 | 6.3 | 6.2 | 5.7 | 5.9 | 6.1 | 5.3 | 5.6 | 5.5 | 5.4 | 6 | 4.9 | 5.7 |
| BRRI hybrid | 7.6 | 0 | 0 | 7.6 | 0 | 7.2 | 7.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7.6 |
| All hybrid | 7.2 | 6.9 | 7.6 | 7.5 | 7.3 | 7.1 | 7.5 | 7.6 | 7 | 7.2 | 7 | 6.8 | 7.5 | 5.7 | 7.2 |
| All Indian | 5.2 | 5.7 | 5.8 | 6.3 | 5.9 | 5.8 | 4.6 | 4.5 | 4.5 | 5.1 | 4.7 | 5.1 | 4.5 | 0 | 5.7 |
| Other MVs | 5.3 | 5.5 | 5.6 | 5.9 | 6.1 | 5.7 | 5.8 | 6 | 5.2 | 5.3 | 5.3 | 4.9 | 5.8 | 5 | 5.6 |
| All MVs | 5.8 | 6 | 6.2 | 6.5 | 6.3 | 6.1 | 6 | 6 | 5.5 | 5.8 | 5.6 | 5.5 | 6 | 5.2 | 6.0 |
| All LVs | 3.2 | 0 | 3.1 | 3.8 | 0 | 2.9 | 2.6 | 2.5 | 2.8 | 2.7 | 0 | 0 | 2.9 | 2.7 | 2.8 |
| All varieties | 6.5 | 6.4 | 6.6 | 6.8 | 6.6 | 6.4 | 6.5 | 6.3 | 5.9 | 6 | 6.1 | 6.2 | 5.9 | 5 | 6.2 |

T. Aman season whereas average yield of hybrid was 5.70 t/ha. Overall yield rate of modern varieties (MVs) was 4.56 t/ha and the average yield of BRRI varieties was 4.30 t/ha (Table 5). In addition, the productivity of Indian variety was 4.27 t/ha.

In Aus season, BRRI dhan48 produced the highest yield (4.04 t/ha) and BRRI dhan28 and, BRRI dhan55 ranked the second and third position with an average yield of 3.93 t/ha and 3.84 t/ha, respectively. The yield rate of hybrid rice was also higher in BRRI varieties (5.97 t/ha) than other hybrid varieties (5.33 t/ha) in this season (Table 6). Average yield of all MVs in Aus season was 4.20 t/ha.

**Table 5. Yield (t/ha) of different T. Aman rice varieties by agricultural regions of Bangladesh, 2016-17.**

| Variety | Reg1 | Reg2 | Reg3 | Reg4 | Reg5 | Reg6 | Reg7 | Reg8 | Reg9 | Reg10 | Reg11 | Reg12 | Reg13 | Reg14 | BGD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BR11 | 4.4 | 4.7 | 4.9 | 4.7 | 4.7 | 4.7 | 4.3 | 4.6 | 4.6 | 4.4 | 4.5 | 4.5 | 4.3 | 4.5 | 4.5 |
| BR22 | 4 | | 4.2 | | 4.6 | 4.5 | 4.4 | | 4.5 | 4.2 | 4.4 | 4.1 | 4.1 | 4.2 | 4.3 |
| BR23 | 3.6 | | | 4.7 | 4.2 | 4.6 | 4.4 | 3.5 | 4.3 | 4.1 | 4.4 | 3.9 | 3.9 | 4.3 | 4.2 |
| BRRI dhan49 | 4.1 | 4.5 | 5 | 4.9 | 4.9 | 4.5 | 4.5 | 4.9 | 4.6 | 4.5 | 4.5 | 4.6 | 4.6 | 4.4 | 4.6 |
| BRRI dhan52 | 4.3 | 4.5 | 5.1 | 5 | 4.7 | 4.5 | 4.5 | 4.8 | 4.4 | 4.2 | 4.5 | 4.6 | 4.4 | 4.3 | 4.5 |
| Other BRRI varieties | 3.4 | 2.4 | 3.2 | 3.5 | 3.1 | 4.0 | 4.2 | 4.6 | 4.1 | 3.4 | 4.2 | 4.3 | 3.8 | 4.1 | 4.2 |
| BRRI varieties | 4 | 4.3 | 4.6 | 4.6 | 4.4 | 4.4 | 4.3 | 4.5 | 4.2 | 4.1 | 4.3 | 4.3 | 4.2 | 4.2 | 4.3 |
| BRRI hybrid | 5.1 | | 6 | | | | | 6 | | | | | | | 5.7 |
| All hybrid | 5.1 | 5 | 5.7 | 6 | 5.7 | 5.3 | 5.5 | 5.8 | 5.3 | 5.7 | 5.8 | 6.4 | 5.4 | | 5.5 |
| All Indian | 4.3 | 4.5 | 4.9 | 4.9 | 4.4 | 4.2 | 3.5 | 4.2 | 3.8 | 3.2 | 4.3 | 3.8 | 3.2 | 4 | 4.3 |
| Other MVs | 3.9 | 4 | 4.7 | 4.1 | 4.6 | 4.5 | 4.1 | 4.6 | 3.9 | 4 | 4 | 4 | 4 | 4.1 | 4.1 |
| All MVs | 4.3 | 4.4 | 5 | 4.9 | 4.8 | 4.6 | 4.3 | 4.8 | 4.3 | 4.2 | 4.6 | 4.6 | 4.2 | 4.1 | 4.6 |
| All LVs | 2.6 | 3 | 2.7 | 2.9 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2 | 2.5 | 2.6 | 2.4 | 2.6 | 2.5 |
| All varieties | 3.9 | 4.3 | 4.4 | 4.4 | 4.3 | 3.4 | 3.2 | 3.9 | 3.6 | 2.9 | 3.7 | 4.1 | 3.5 | 3.5 | 3.7 |

**Table 6. Yield (t/ha) of different Aus rice varieties by agricultural regions of Bangladesh, 2016-17.**

| Variety | Reg1 | Reg2 | Reg3 | Reg4 | Reg5 | Reg6 | Reg7 | Reg8 | Reg9 | Reg10 | Reg11 | Reg12 | Reg13 | Reg14 | BGD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BR21 | | | 3.9 | 4.2 | 3.8 | | 3.4 | | | 3.9 | 3.3 | 4.1 | 3.9 | 3.5 | 3.7 |
| BR26 | 3.7 | 3.7 | 3.6 | 3.9 | 3.9 | 3.6 | 3.6 | 3.5 | 3.6 | 3.7 | 3.8 | 3.5 | 3.9 | 3.3 | 3.7 |
| BRRI dhan28 | 4.1 | 4.1 | 3.8 | 4.3 | 4 | 3.7 | 3.6 | 3.2 | 3.8 | 4.1 | 3.7 | 4.7 | 4.3 | 3.3 | 3.9 |
| BRRI dhan48 | 4.2 | 4 | 4.2 | 4.6 | 4.2 | 3.8 | 3.8 | 3.3 | 4 | 4.4 | 4.1 | 4.2 | 4.1 | 3.9 | 4 |
| Other BRRI varieties | 4 | 3.7 | 3.5 | 4.2 | 3.8 | 3.3 | 3.3 | 3.3 | 3.2 | 3.8 | 3.8 | 4 | 4.1 | 3.4 | 3.8 |
| BRRI varieties | 4.1 | 3.9 | 3.7 | 4.2 | 4 | 3.6 | 3.4 | 3.4 | 3.7 | 3.9 | 3.7 | 4 | 4 | 3.5 | 3.8 |
| BRRI hybrid | 6 | | | | | | | | | | | | | | 6 |
| All hybrid | 5.5 | 4.6 | 4.3 | 5.5 | 4.7 | 4.4 | 5 | 4.6 | | 4.5 | 5.6 | 5.4 | 4.5 | 4.8 | 5.3 |
| All Indian | | 4.2 | 3.7 | 4.2 | 4 | 4.2 | 3.8 | | | 3.6 | 3.7 | 3.7 | 3.6 | | 3.9 |
| Other MVs | 3.8 | 3.8 | 3.7 | 3.9 | 3.9 | 3.4 | 3.1 | 3.5 | 3.8 | 3.5 | 3.8 | 3.8 | 4.3 | 3.3 | 3.6 |
| All MVs | 4.5 | 4.1 | 3.8 | 4.5 | 4.1 | 3.9 | 3.8 | 3.8 | 3.8 | 3.9 | 4.2 | 4.2 | 4.1 | 3.9 | 4.2 |
| All LVs | 2.3 | 2.9 | 2 | 2.3 | 1.9 | 2 | | 1.9 | 2.1 | 2.3 | 1.9 | 2.2 | 2.2 | 1.7 | 2 |
| All varieties | 4.7 | 4.2 | 3.5 | 4.1 | 4.1 | 3.4 | 3.5 | 2.7 | 3.3 | 3.6 | 3.4 | 3.3 | 3.8 | 3 | 3.6 |

### Trend of changes in adoption and yield level

The overall adoption of modern varieties in Aus season increased from 25.57 to 89.86% (i.e., 64.29% during the period from 1990-91 to 2016-17). In T. Aman season, the adoption increased to 45.67%. In case of modern Boro varieties, the adoption was 88.93% in 1990-91 and peaked to 99.39% in 2016-17. The increase of yield was much higher in Aus (135.03) compared to that in T. Aman (38.60) and Boro season (36.96) (Table 7).

## INPUT USE PATTERN AND PROFITABLITY

Input use–the number of labour use (87 man-days/ha) was higher in MV Aus season than in both MV Boro (82 man-days/ha) and MV T. Aman (72 man-days/ha). The seed rates for MV Aus, MV T. Aman, and MV Boro rice were 37, 43, and 41 kg/ha respectively depicting that farmers' use was largely higher than the BRRI rate (25 to 30 kg/ha). More noteworthy, majority of the farmers used the lower quantity of urea fertilizer in both T. Aman (140 kg/

**Table 7. Changes in the level of adoption and yield of modern rice varieties over the years, 1990/91-2016/17.**

| Season/Item | Period | | Differences |
|---|---|---|---|
| | 1990-91* | 2015-16 | |
| Aus: Adoption (%) | 25.57 | 89.60 | 64.29 |
| Yield (kg/ha) | 1770 | 4160 | 2390 (135.03) |
| T. Aman: Adoption (%) | 34.00 | 79.67 | 45.67 |
| Yield (kg/ha) | 3290 | 4560 | 1270 (38.60) |
| Boro: Adoption (%) | 88.93 | 99.39 | 10.46 |
| Yield (kg/ha) | 4410 | 6040 | 1630 (36.96) |

Figures in parentheses indicate the percent. *National average.

ha) and Boro rice (216 kg/ha). In addition, the rate of MP and gypsum fertilizer in the Aus (65 and 15 kg/ha), T. Aman (60 and 20 kg/ha) and Boro rice (87 and 50 kg/ha) were also lower than BRRI rate. Per unit cost in Aus season was slightly lower (18.47 Tk/kg) than Aman season (19.41Tk/kg), but per unit cost in Boro season (22.18 Tk/kg) is the largest in all seasons. In the profitability–per hectare gross margin of MV Boro rice (Tk 43,178) was higher than MV T. Aman (Tk 39,493). To compare with the former, that of MV T. Aus rice was lower (Tk 21,660). It is noted that even though return per unit investment in all seasons (Aus 1.06 and Boro 1.09) was more than one as indicated to be profitable, that in Aman season (1.14) is more promising for the investment. However, the farmers happily received 38% of the gross income as profit in Aus season; 51% in T. Aman season as well as 46% in Boro season.

## TRACKING OF CLIMATE RESILIENT RICE VARIETIES AND ITS ECONOMIC PERFORMANCE AT THE FARM LEVEL

Bangladesh is the most vulnerable country to climate change and repeatedly reported that the consequence of climate change hampers the speed of the expected development activities. However, more than 18 districts of Bangladesh are regularly affected by flash floods. In addition, northwestern part of Bangladesh is treated as severe drought affected area; that causes a substantial reduction in crop yield. Large areas in the coastal belt are also being affected by the water salinity. Bangladesh Rice Research Institute (BRRI) has developed as much as 21 varieties that could survive in different climatic stresses. Cultivation of these stress-tolerant rice varieties in various climatic shocks has already been introduced to mitigate the yield losses. However, the adoption of a variety not only depends on its quality but also on various social and environmental issues. Thus, the present study has been designed to explore the overall performance of stress tolerant rice varieties in different environments; and identify the constraints and suggest policy measures. The study was carried out in three specified areas of Bangladesh namely, submergence, saline and drought environments. A total of 300 respondents for Aus and Aman for 2014/2015 and that of Boro for 2015/16 for Aus, T. Aman and Boro seasons were interviewed more specifically 100 from each location. The supporting information was also collected from DAE. Finally, descriptive statistical tool were employed to produce the expected result.

**Adoption status of stress tolerant rice varieties**

**Submergence prone area.** In T. Aman season of 2014, on average the area coverage of submergence tolerant rice varieties was 5.94%, among them BBRI dhan52 (4.30%) and BBRI dhan51 (1.63%) were dominant. During 2015, total area coverage of submergence tolerant varieties was 8.82%, which was higher compared to previous year.

**Drought prone area.** BRRI dhan56 and BRRI dhan57 are the two varieties for combating the drought situation in T. Aman season (Table 9). For Aus season, BRRI dhan42, BRRI dhan43 and BRRI dhan55 are suitable to grow under drought condition. But the adoption rate of these varieties was not satisfactory at all both in T. Aman and Aus season during the study periods (2014-15).

**Saline environment.** On average, the adoption of saline tolerant rice varieties in T. Aman season was 6.14% during 2014, and slightly increased to 7.66 % in 2015. BRRI dhan41 covered highest area (5.53%) among all stress tolerant rice varieties in Patuakhali district during Aman season of 2014 (Table 11).

In Boro season of 2015, highest area coverage of BRRI dhan47 was 22.09%, and also increased to 23.45% during 2016 in Patuakhali district among all other saline tolerant varieties. However, on an average adoption rate of saline tolerant rice varieties was 3.79% in 2015, and 4.40% during 2016.

**Yield of stress tolerant rice varieties**

**Yield of submergence tolerant rice varieties.** During 2014, average yield of stress tolerant rice varieties was3.65 t/ha, among them BRRI dhan52 yielded highest (3.84 t/ha) in submergence prone area. During 2015, yield of stress tolerant rice varieties was almost similar as in 2014 (Table 13).

**Yield of drought tolerant rice varieties.** During 2014, average yield of drought tolerant rice varieties was 3.75 t/ha in T. Aman season, among them BRRI dhan56 produced highest yield in Kushtia (4.09 t/ha) followed by Natore (3.96 t/ha) district. In 2015, yield of BRRIdhan56 and BRRI dhan57 was a bit lower compared to 2014, as a result average yield (3.14 t/ha) decreased a bit compared to 2014 in Aman season. In Aus season, BRRI dhan42 was the highest yielder (2.76 t/ha) followed by BRRI dha55 (2.65 t/ha) and BRRI dhan43 (2.61 t/ha) in drought prone area during 2014, and the average yield was 2.66 t/ha. In 2015, it was BRRI dhan55 (2.72 t/ha) and BRRI dhan42 (2.60 t/ha) as the top yielder and the next one, respectively. Average yield was 2.52 t/ha in this season.

**Yield of salinity tolerant rice varieties.** BRRI dhan40 was produced the highest yield (3.85 t/ha) in Bagerhat and Khulna district averaging 3.67 t/ha, followed by Satkhira (3.50 t/ha) in T. Aman season, and on average, stress tolerant rice varieties' yield was estimated to be 3.74 t/ha during 2014 and 3.43 t/ha in 2015. BRRI dhan47 yielded 5.33 t/ha and BRRI dhan55 yielded4.73 t/ha in Khulna region during Boro season of 2015, and average yield of stress tolerant varieties was 4.55 t/ha in the study area during 2015, which was (4.59 t/ha) almost similar to the yield of non-stress tolerant MVs. During 2016, although average yield of different stress tolerant rice varieties was mostly similar, performance of BRRI dhan55 and BRRI dhan61 appeared to be better yield and area coverage.

**Profitability and constraints of stress tolerant rice cultivation**

The yield of Boro (4.27 t/ha) was higher than T. Aman and Aus season in all environments. As yield was higher, consequent gross return was also higher compared to other seasons. Per hectare costs of production was found higher (Tk 96,309) in saline prone environment in Boro season compared to that in other seasons (Aman and Aus) and environments (drought (Tk 64,720/ha) and submergence (Tk 68,949/ha). Benefit cost ratio (BCR), on cash cost basis in all environments of Aman season was positive and higher compared to Aus and Boro. Furthermore, on full cost basis, net return was negative in all other environments with except for submergence prone area (Table 8). Benefit cost ratio (BCR), on cash cost basis in all environments of Aman season was positive and higher compared to Aus and Boro. Furthermore, on full cost basis, net return was negative in all other environments with except for submergence prone area (Table 8).

The major constraints of enhancing rice production in the stress prone regions can be viewed in Table 9. Global worming leading to climatic and environmental change such as soil and water salinity, droughts and submergence along with the erratic rainfall pattern were the key constrains of rice cultivation in the stress prone regions. In

**Table 8. Per hectare costs and returns of different stress tolerant rice varieties in Bangladesh, 2015-16.**

| Item | Submergence | Drought | | Salinity | |
|---|---|---|---|---|---|
| | Aman | Aman | Aus | Aman | Boro |
| Yield (kg/ha) | 3266 | 3554 | 3094 | 3312 | 4279 |
| Paddy price (Tk/kg) | 18.52 | 17.54 | 17.20 | 17.50 | 17.24 |
| Return from paddy (Tk/ha) | 60486 | 62337 | 53217 | 57960 | 73770 |
| Return from straw (Tk/ha) | 5,000 | 5,500 | 5,000 | 5,000 | 4,000 |
| Gross return (Tk/ha) | 65,486 | 67,837 | 58,217 | 62,960 | 77,770 |
| Variable costs (Tk/kg) | 49,749 | 53,704 | 53,923 | 48,432 | 78,914 |
| Gross margin (Tk/kg) | 9,312 | 12,612 | 4,212 | 9,355 | 666 |
| Total costs (Tk/kg) | 64,720 | 68,949 | 69,250 | 65,147 | 96,309 |
| Net return (Tk/kg) | 766 | -1,112 | -11,033 | -2,187 | -18,539 |
| BCR (cash cost basis) | 1.32 | 1.26 | 1.08 | 1.30 | 0.99 |
| Unit cost (Tk/kg) | 19.82 | 19.40 | 22.38 | 19.67 | 22.51 |

**Table 9. Major constraints faced by the stress tolerant rice growers in Bangladesh.**

| Constraint | Rank | Respondent (%) |
|---|---|---|
| Salinity | 1 | 77 |
| Drought and erratic rainfall | 2 | 71 |
| Flashflood | 3 | 69 |
| Unavailability of stress tolerant seed, extension service, and adulteration | 6 | 65 |

addition, inadequate excess to extension services (training, demonstration and information about modern technologies), higher wage rate and lack of availability of quality stress tolerant seeds were also the major problems in the study areas.

## PREFERENCE ANALYSIS OF T. AMAN RICE VARIETIES IN THE COASTAL AREAS

Preference analysis (PA) is the most updated tool to identify the more suitable new varieties for target locations or groups. In the process, farmers could choose the most preferred varieties for their location from a researcher's managed trial. Both the quantitative and qualitative data were generated through PA which might guide the extension workers and other stakeholders to disseminate the right varieties in the target area. The specific objective of the study was to identify the most preferred T. Aman rice varieties in the study areas. Dacope Sub-district of Khulna under Polder 30 and Amtali Sub-District of Barguna under Polder 43/1, were selected for this study. This is because BRRI conducted trials on different T. Aman rice varieties under ACIAR and KGF funded a collaborative project. The preference polls were conducted on 6 November, 2016 in Pankhali and 7 November, 2016 in Sekandarkhali. Farmers were briefed regarding the entire procedures how to vote in favour of varieties selection. Eleven varieties including four checks and six varieties including two checks were included for preference analysis in Dacope and Amtali, respectively. Correlation analysis was performed to test if there are significant correlations between the preference scores of male and female farmers, and the preference scores of farmers and researchers. In Pankhali, total participants were 34 farmers (59% male and 41% female), scientists, extension personnel and project field staff attended in the preference poll. The similar numbers of participants were present in Sekandarkhali site. Average year of schooling of the participants voters was higher in Pankhali than in Sekandarkhali. In contrast, the average farm size of Sekandarkhali was greater than that in Pankhali village.

### Preference outcomes: Pankhali, Dacope

Table 10 shows preference score of T. Aman rice varieties in Pankhali. BR11 which was voted to the top by the farmers. Despite having somewhat sterility problem and longer life compared to newly released BRRI varieties, farmers still like to practice BR11 because of better cropping traits such as more tillering capacity, medium panicle lengthtextured with more grains, higher yield, bold grain, good taste, mdeium plant with height strong stem protecting crops from lodging at maturity stage, needless fertilizer, less disease and pest infestation, shorter growth duration compared to BR23 and Baral, suitable for high to medium high land. In addition crop could be harvested when stagnant water could be drained out from the plots.

**Table 10. Preference score for wet season rice varieties in Pankhali, Dacope.**

| Variety | Preference score | | | |
|---|---|---|---|---|
| | Male | Female | Scientist | Total |
| BR10 | 0.013 | -0.083 | -0.107 | -0.041 |
| BR11 | 0.150 | 0.233 | 0.000 | 0.151 |
| BR23 | -0.013 | -0.067 | -0.071 | -0.041 |
| BRRI dhan53 | -0.088 | -0.050 | -0.036 | -0.064 |
| BRRI dhan54 | -0.125 | -0.100 | -0.107 | -0.110 |
| BRRI dhan62 | -0.125 | -0.150 | -0.143 | -0.134 |
| BRRI dhan66 | 0.100 | 0.083 | 0.250 | 0.116 |
| BRRI dhan73 | 0.113 | 0.100 | 0.286 | 0.134 |
| Baral | -0.025 | 0.033 | -0.071 | -0.012 |

The preference scores indicated that BRRI dhan73 was chosen as second most preferred T. Aman rice variety but the most preferred one among newly released rice varieties tested (Table 10). Farmers voted for the variety because of less/no lodging (strong stem) despite torrential rain and stormy winds at ripening stage, more tillering capacity, expecting higher yield due to long panicle with more grains and less number of unfilled grains, less/medium fertilizer intensive, more tolerant to major diseases and pest, medium growth duration which may facilitate to establish dry season (DS) crop on time and expected to be matured after draining out the stagnant water from the fields, medium bold grain might be tasted good to eat, medium plant height so that may survive in moderate flood and produce more straw for livestock feed. BRRI dhan66 ranked second among tested newly released varieties but ranked third among all varieties (Table 10). Despite somewhat higher fertilizer responsive and susceptible to pests, farmers prefer BRRI dhan66 due mainly to medium height of rice plant, less or no lodging despite heavy rain with strong wind at advance stage of the crop growth, long panicle with good number of grains, shiny color of grains and medium growth duration that would facilitate establishment of DS crops in time. BRRI dhan62 ranked the least preferred T. Aman rice variety in Pankhali (Table 10). Although its early maturity favours access to food availability to people and feed to livestock during scarce period (mid-October to mid-November) and land availability for DS crop establishment in time, farmers have not preferred this variety because of coincidence of its maturity with water stagnant fields in October/November. Moreover, severe infestation of vertebral pests including birds and rats, germination in the fields, less number of tillers per hill, shorter panicle length with less number of grains and low grain yield.

BRRI dhan54 ranked second least preferred T. Aman rice variety in Pankhali (Table 10). Farmers reported that stem of this variety is less strong, while the plants are so tall that it lodges most of the time. Moreover, length of panicle is medium with some unfilled grains so that farmers expect low yield. The variety matured early when rain water still remains stagnant in the fields.

**Preference outcomes: Sekandarkhali, Amtali**

Swarnogota was chosen as most preferred T. Aman rice variety by the farmers (Table 11). The key drivers of choosing Swarnogota included a good number of tillers per hill and grains per panicle, medium long panicle, bold grains, good eat quality, higher price (21% higher than locally available other varieties), less sensitive to abiotic and biotic stress, suitable to cultivate in medium low to medium low land, long duration so that matured after drainage out of stagnant water and produce more straw which is main feed for livestock. BRRI dhan53 was ranked second among all varieties but ranked first among introduced varieties (Table 11). Farmers voted for BRRI dhan53 due to its homogeneous plant growth, medium plant height, strong stem, less/no lodging, medium growth duration which may facilitate establishment of DS crop in time, medium grain size, might be tasted good to eat, higher number of tillers per hill and long panicle with more grains per panicle and less or no unfilled grains. Some of the participants reported that this variety is somewhat salinity tolerant as well. Voting for BRRI dhan66

**Table 11. Preference score for wet season rice varieties in Sekandarkhali, Amtali.**

| Variety | Preference score | | | | |
|---|---|---|---|---|---|
| | Male | Female | Farmers | Scientist | Total |
| BR11 | -0.011 | -0.045 | -0.022 | 0.000 | -0.018 |
| BR23 | 0.033 | -0.023 | 0.015 | -0.071 | 0.000 |
| BRRI dhan39 | -0.011 | -0.045 | -0.022 | 0.071 | -0.006 |
| BRRI dhan53 | 0.087 | 0.045 | 0.074 | 0.214 | 0.098 |
| BRRI dhan54 | -0.054 | -0.023 | -0.044 | 0.000 | -0.037 |
| BRRI dhan62 | -0.152 | -0.068 | -0.125 | -0.286 | -0.152 |
| BRRI dhan66 | 0.054 | 0.068 | 0.059 | 0.179 | 0.079 |
| Swarnogota | 0.098 | 0.182 | 0.125 | 0.000 | 0.104 |
| Vajon | -0.043 | -0.091 | -0.059 | -0.107 | -0.067 |

Source: Authors' calculation.

was depended on long and bold grains, higher plant height might help to survive under moderate flood pressure and increased straw production as cattle feed or fuel, medium growth duration which may help timely establishment of DS crops in medium high to high land, medium long panicle with good number of grains per panicle.

Drought tolerance with high protein contain was also reported as voting criteria for this variety. Less number of tillers per hill and shorter growth duration were reported as shorting coming of this variety because it will mature when filed might be remain water stagnant. BRRI dhan62 was the least preferred variety to farmers (Table 11). Shorter growth duration was noted as most important factor of not choosing the variety as infestation of vertebral pest was severe, crop mature when fields are under water. Besides, less or no dormancy (germinate in fields and at home-yard after harvest) period, unattractive crop growth including shorter plant height and less number of tillers per hill, higher number of unfilled grains, lower expected yield and shorter plant height having less potential for straw yield also acted as negative points. Vajon was another less preferred variety mainly because of low yields, shorter panicle length and long life cycle which delays establishment of DS crops. Farmers mainly cultivate the variety in the low-lying areas. Table 12 showsthat there is a significant correlation on the preference scores between male and female farmers as well as between farmers and scientists/ researchers in Pankhali and Sekandarkhali.

## UTILIZATION PATTERN OF AGRICULTURAL CREDIT ON MV BORO RICE CULTIVATION IN CHAPAINAWABGANJ DISTRICT

Modern agriculture is more input intensive venture, which requires huge amount of investment. As majority of the farmers in Bangladesh are small and marginal; they cannot afford such a big investment due to limitation of working capital (Hossain, 1985). To boost up the farming yield, farmers of Chapainawabganj area have to take loan from Rajshahi Krishi Unnayan Bank (RAKUB) in Boro season of 2016. However, the present study has been designed to know how the credit is obtained, utilized and what were the impacts of credit on MV Boro cultivation. To investigate the impact of credit of the target groups, the study is proceeded with the following objectives. Such as to assess the demand and supply situation of credit for MV Boro rice cultivation; to evaluate the costs of getting agricultural credit and its utilization pattern; and; and to identify the major constraints of credit at farm level.

Five villages (e.g., Kamar Jogdail, Purba Nizampur, Pashim Nizampur and Kalkadighi) of sadar and Nachol upazila of Chapainawabganj district was selected purposively for this study as 120 farmers of the villages received credit from respective branch of RAKUB. In total 60 borrower farmers were selected randomly from the listed 120 borrower of RAKUB through stratified random sampling technique. A structured pre-tested questionnaire was for collecting required data through direct interview during 2016-17 Boro season. Descriptive statistics was used to analyze the data.

### Credit demand and supply

Table 13 shows the demand-supply situation of credit by three farm categories for MV Boro rice cultivation in the survey villages. On average requirement of credit of Boro rice farmers was Tk 66,667 while the demand of credit of large farm type (Tk 100,000) was largely higher than that for small (Tk 35,000) and medium (Tk 65,000). Similarly, large farm received higher amount of

**Table 12. Correlation analysis of preference scores for Pankhali, Dacope, 2016.**

| Item | Pankhali, Dacope | | Sekandarkhali, Amtali | |
|---|---|---|---|---|
| | Male farmer vs. Female farmer | Famer vs. Scientist | Male farmer vs. Female farmer | Famer vs. Scientist |
| Correlation coefficient (r) | 0.89 | 0.69 | 0.87 | 0.71 |
| P-value | 0.001 | 0.041 | 0.003 | 0.031 |
| Sig. | *** | ** | *** | ** |

***Significant at 1% and **Significant at 5%.

**Table 13. Demand supply situation of credit of different farm types in Chapainawabganj.**

| Farm type | Credit requirement (Tk) | Credit received (Tk) | Gap (Tk) |
|---|---|---|---|
| Small | 35,000 | 23,400 | 11,600 |
| Medium | 65,000 | 48,900 | 16,100 |
| Large | 1,00,000 | 81,800 | 18,200 |
| All | 66,667 | 51,367 | 15,300 |

Source: Field Survey, 2016.

credit (Tk 81,800) compared to small (Tk 23,400) and medium (48,900) farm. The important finding is that RAKUB can meet more than 75% of total credit requirement of Boro rice farmers in the survey villages. However, the average gap between the requirement and credit delivery was about 23%, indicating that sanction of credit is inadequate to smoothly carry out the Boro rice cultivation.

## Cost of credit

Farmers mentioned that fulfilling an undue demand of brokers and/or some unscrupulous bank officials cover significant percent of the sanctioned credit which itemized as entertainment cost in the analysis. Besides, traveling cost to bank, foods cost (lunch and tiffin) of farmers and labour cost (spend labour hours to sanction credit) also accounted as cost of credit because farmers visit Bank for number days to get sanction of the credit. The significant difference was not found in receiving the credit among different categories of farmers. On average cost per hundred taka loan receiving from RAKUB was Tk 12.18. Among the major cost items, official cost (e.g., application fee, 7%) was adequately lower than unofficial costs (other than application, 93%). The entertainment cost of brokers and bank officials was (58%) of total unofficial costs.

## Credit use pattern

Table 14 presents item wise credit utilization pattern of Boro rice farmers in Chapainawabganj. On average three-fifth of total credit used for purchasing inputs and hired labour for rice and non-rice crop production in the survey villages. There was a large difference between the credit utilization patterns of three farm types for both the rice and non-rice crop production and even for the other purposes. Small farmers used about half of total credit for Boro rice, deceased to 35% for medium farm and 23% for small farm. On the other hand, medium farmers used two-fifth of total credit for non-rice crop production, decreased to 32% for large farm and 17% for small farm. On average 11% and 27% of total credit used for maintaining family expenses and reimbursement of previously received credit respectively. The rate of utilization of credit for bearing family expenses was higher for small farmer (16%) while the large farmers used two-fifth of the total credit for reimbursement of previously received.

## Constraints

About 93% borrowers mentioned that allocation of institutional credit for each farmer was insufficient to meet up cost of input intensive crop like Boro rice. Higher non-interest cost of institutional credit such as - application fees; stamp and documents required in support of loan; form filling and writing; cost of

**Table 14. Credit use pattern (in BDT) of Boro rice farmers in Chapainawabganj.**

| Activity | Small farmer | Medium farmer | Large farmer | All farmers |
|---|---|---|---|---|
| Purchase of seed /Seedling | 450 (2) | 560 (1) | 1,800 (2) | 937 (2) |
| Purchase of fertilizer | 1,150 (5) | 1,400 (3) | 2,400 (3) | 1,650 (3) |
| Paying wage | 3,110 (13) | 8,700 (18) | 8,550 (10) | 6,787 (13) |
| Land mortgaged in | 2,375 (10) | - | - | 792 (2) |
| Power tiller | 1,045 (4) | 1,140 (2) | 900 (1) | 1,028 (2) |
| Buying insecticides | 775 (3) | 1,350 (3) | 1,500 (2) | 1,208 (2) |
| Purchase of manure | 545 (2) | 1,250 (3) | 1,100 (1) | 965 (2) |
| Paying irrigation charge | 1,800 (8) | 2,700 (6) | 2,650 (3) | 2,383 (5) |
| Rice production | 11,250 (48) | 17,100 (35) | 18,900 (23) | 15,750 (31) |
| Non-Rice production | 4,050 (17) | 19,250 (39) | 26,550 (32) | 16,617 (32) |
| Family expenditure | 4,200 (18) | 8,000 (16) | 5,000 (6) | 5,733 (11) |
| Others (Repayment of old loan, investment, bribe etc.) | 3,900 (17) | 4,550 (9) | 31,350 (38) | 13,267 (26) |
| Total | 23,400 | 48,900 | 81,800 | 51,367 |

Source: Field Survey, 2016.

traveling for loan negotiation and undue demand of unscrupulous bank officials/brokers as entertaining cost for the small farmers act as a hindrance to the development of their productive forces reported by 85% of total respondents. About 82% farmers mentioned that strong need for collateral in institutional sources in turn imposes many types of formalities on credit seekers that make them finally penchant for taking loan from semi-institutional and non-institutional sources though their interest rate is quite higher. About 53% farmers think that long institutional procedure as another impediment in securing loans from institutional source. Farmers reported (63%) that lengthy process of sanctioning credit was not only the barrier to get credit, but also they lost interest to receive credit next time.

## COMPARATIVE ECONOMIC VIABILITY OF MODERN AND LOCAL VARIETY T. AMAN RICE IN THE COASTAL AREA

Rice occupies nearly 95% of cropped areas among the major crops (rice, wheat, maize and jute) in the coastal land. Farmers in these regions used to mostly grow (75%) local varieties in both Aman (75%) and Aus (75%) season. In addition, the modern variety is enormously practiced in the Boro (80%) season (BBS, 2015) in the region. The cropping intensity in the area (150%) (SFYP, 2011) was lower than national average (179%) (BBS, 2015). The productivity and profitability of the crops has partially and frequently been affected by extreme weather events and market uncertainty, soil and water salinity, and lack of water supply in the dry season (Kabir *et al.,* 2016). Therefore, assessment of profitability and risk of the major crop like rice is tremendously important. The study is accomplished with the specific objectives such as to assess the relative economic viability (profitability and risks) of modern and local variety rice under farmers' practice and research managed plot. Farm level data was collected in both Kulna and Borguna during February to April 2017. Developed representative enterprise budgets under farmers' practice were referred to the key informant farmers for validation. The key informants agreed with the results and suggested to change in the labour use pattern and yields of the rice crops in different seasonal conditions. Various ways could be used to specify the costs and returns of farm enterprises; this study used Heart (1978) method specifying the important distinction between paid-out cost of purchase inputs and unpaid cost of home-supplied inputs. The monte - carlo simulation software version 7.5 was applied in order to simulate the risk of seasonal rice cultivation under farmers practice and research managed plots.

### Input use patterns and yield

Input use pattern for T. Aman rice cultivation in Pankhali and Sekandarkhali village is delineated in the following. Seed rate per ha under farmers' practice was higher than that in research managed. Furthermore, fertilizer rate per ha under farmers' practice was lower than research managed ones. It was noticed that in Sekandarkhali, only a small dose of phosphorous fertilizer was applied as basal and in Pankhali, farmers applied both the phosphorous and potash fertilizers as basal. The applied dose was found subsatantially smaller than research managed plots. Table 15 shows seasonal variability of T. Aman rice yield in farmers' fields under research management and farmers' practice and rice prices in Dacope and Amtoli. The typical-case yields per ha under research management in farmers' fields were over half a ton higher than typical-case yield of BR23 under farmers' practice. It was also the case that the worst-case yield under research management in farmers' fields was consistent with the typical-case yield of BR23 under farmers' practice. It may be due to variation in varietal potentiality (newly released

**Table 15. Seasonal variability of T. Aman rice yield and price in Dacope and Amtali.**

| Seasons | Yield (t/ha) | | | | | | Price (Tk/kg) | |
|---|---|---|---|---|---|---|---|---|
| | Dacope | | | Amtoli | | | MVs | LVs |
| | Trial plot | BR23 | LVs | Trial plot | BR23 | LVs | | |
| Good/high | 5.4 | 4.2 | 3.5 | 5.2 | 4.3 | 3.8 | 22.5 | 25 |
| Typical/average | 4.4 | 3.7 | 3.1 | 4.2 | 3.5 | 3.1 | 18.75 | 20.5 |
| Bad/low | 3.8 | 3 | 2 | 3.4 | 2.8 | 2.1 | 16 | 16 |

varieties are more potential) and crop management practice in particular time of transplanting, and time and dose of fertilizer application (farmers apply less or lower dose of basal fertilizer). On the other hand, typical-case yield of LVs was largely lower than typical-case yield of BR23. The findings indicated that there is a scope for increasing rice production through improving cultural practice and adoption of modern technologies.

**Costs and returns**

Per ha cost of inputs utilization, hired labour and land rent (about 35% of total cultivated land is rented in land) are accounted as paid-out cost. Per ha imputed cost indicated family supplied inputs such as seed, family labour and land use cost. Paid-out cost was ranges between 52-56% of total cost (TC) under different practices. Hired labour cost was most dominant item of paid-out cost cover 16-18% of TC followed by land rent (11-12% of TC), fertilizer (5-8% of TC) and tillage (7-8% of TC). Total cost per ha of T. Aman rice under research management was higher than farmers' practice is mainly the representation of variation in fertilizer dose (farmers apply less fertilizer) and cost of power thresher (higher for trial plots due to higher yield). Net income (NI) per ha indicates that T. Aman rice is not an economically attractive farm enterprise under farmers' practice. Nevertheless, farmers still grow rice in WS as major food source for subsistence farming in this country. Besides, returns to land (GI per hectare) and labour (gross income per work-day) indicated that T. Aman rice is a profitable farm enterprise at typical-case yield and average price even under the farmers' current practice. The GI work-day of family was two times higher than wages of off-farm work (BDT 300/ work-day) in the village. The result indicates that Aman rice cultivation was more profitable than off-farm wage-work. The finding is consistent with the reality as a large number of small and some landless farmers rented in land in order to grow WS rice. Despite cost per hectare being higher, T. Aman rice cultivation under research management was not only gave higher returns to land and labour than farmers' practice but also gave a reasonable net income per hectare. The discussion indicated that there is an opportunity to increase return of WS rice cultivation through improving management and adopting stress tolerant rice varieties.

**Risk**

The enterprise budget in T. Aman rice farming was a profitable farm enterprise at typical-case yield and current average price. However, the key informant farmers said that returns to land and labour of T. Aman rice has varied significantly due to seasonal fluctuation on rain-fed WS rice yield. The consequent variation is happened because of abiotic (weather) and biotic (insect and pest) stress and uncertain market price. Therefore, a stochastic budget was constructed to evaluate the magnitude of risk associate with T. Aman rice, based on farmers' perceived variability and estimated research management plots in yield (best, typical and worst) and prices (high, average and low (Table 15).

Figure 1 presents cumulative probability distribution curves (CDF) for gross income per ha of T. Aman rice cultivation. The lower benchmark is (BDT 36,800) based on the imputed costs for BR23 under farmers' practice, while the upper benchmark (BDT 50,000) was selected randomly. The CDF shows that T. Aman rice under research management has about 50% chance of exceeding upper benchmark of gross income per ha. Conversely, BR23 has over 50% chance of GI per ha of exceeding lower benchmark and 96% chance of GI per ha below the upper benchmark. The chance of receiving a negative net income (net income lower than imputed cost) for LV T. Aman under farmers' practice was about 67%, but decreased to about 47% for BR23, and about 10% for MV T. Aman rice under research management (Fig. 2). This means that T. Aman rice (MVs and LVs) under farmers' practice not only have the higher risk of receiving

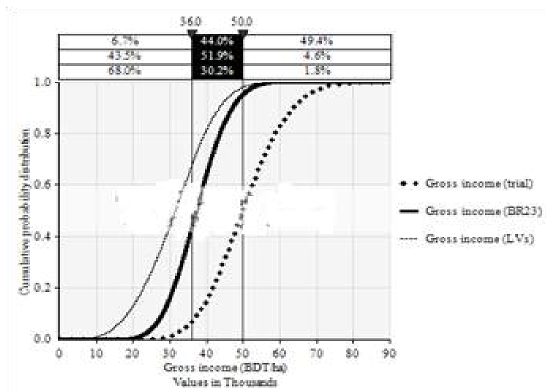



Fig. 1. Cumulative probability distribution of gross income of T. Aman rice, Dacope and Amtali.

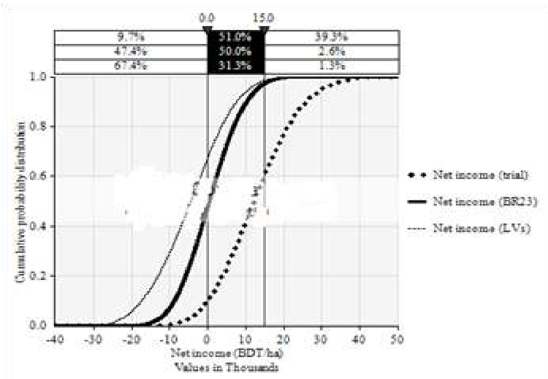



Fig. 2. Cumulative probability distribution of net income of wet season rice, Dacope and Amtali.

a low GI/ha, but also has a higher risk of receiving a negative NI/ha than research management, due likely to differences in crop management. The risk analysis confirmed the informants' observations that the T. Aman rice is economically viable at current prices and a typical seasonal yield, but seasonality can affect the profitability of the crop.

Figure 3 presents the CDFs for GI per work-day of family labour. The lower benchmark (BDT 350) was the average daily off-farm wage rate in the village during the last wet-season, while the upper benchmark (BDT 500) was the average non-farm wage rate in the urban centres. The CDF analysis indicates that the MVs (BR23) and LVs T. Aman rice under farmer's practice has nearly a 81-99% chance of exceeding the lower benchmark. In contrast, the MVs rice under research management has a 96% likelihood of exceeding upper benchmark which is nearly equal to the labour wage in the urban

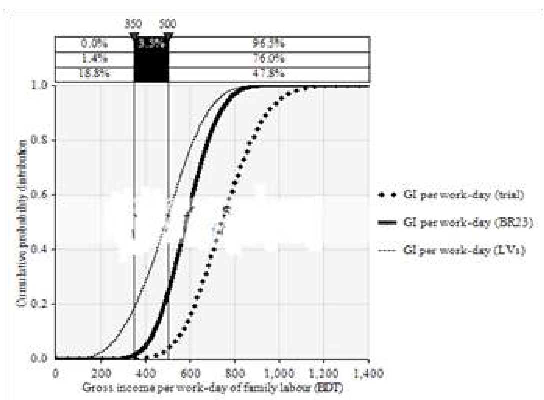



Fig. 3. Cumulative probability distribution of gross income per work-day of family labour of wet season rice, Dacope and Amtali.

centres. However, farming T. Aman rice represents a better livelihood option, even for the farmers current practice, than labouring work, because the simulated mean GI/day of T. Aman rice of LVs is consistent with the daily wage rate of labouring work in the urban centres, while the probability of receiving a GI/day lower than daily local off-farm wage/work-day is a few for MVs rice even under farmer's practice. With other variables remaining constant, the fluctuations in MV rice yield (51% of total variation in GI) and price (49% of total variation in GI) that nearly equally contributed to the variability in the GI/ha (Fig. 4).

This finding indicates that that climatic stress and market uncertainty have consistent effect on the profitability of rain-fed rice in the coastal areas of the country. On the other hand, the fluctuation in LV rice yield (57% of variation in GI) that that mostly contributed to the variability in the GI/ha, with the second most influential factor being the fluctuation in the price of the LV paddy rice. This finding indicates that that climatic stress has a large effect on the profitability of rainfed LV rice in the coastal areas of the country.

## VALUE CHAIN ANALYSIS OF RICE BRAN OIL IN BANGLADESH: AN ECONOMIC INVESTIGATION

The brown outer layer of rice kernel that contains protein, fat and dietary fiber is the source of rice bran oil (Singh *et al.*, 2013). The bran oil is widely used as edible oil in the several countries namely Japan, India, Korea, China and Indonesia due to less

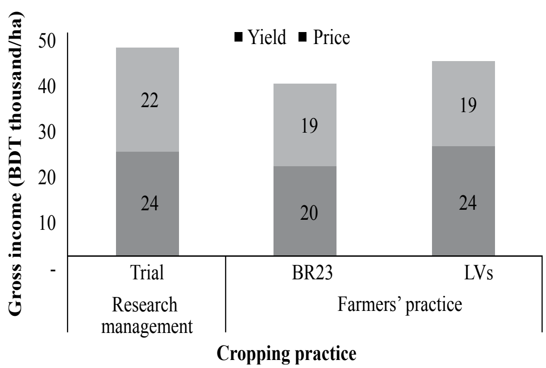



Fig. 4. Inputs ranked by effect on output mean of T. Aman rice, Dacope and Amtali.

cloistral content. The demand of rice bran oil has been increasing in Bangladesh due to its beneficial impact on human health. Therefore, rice bran oil has emerged as an emerging potential sector for the economy of Bangladesh since 2009. Currently, fifteen mills used to produce rice bran oil in the country and continue to fulfill about 2.5% of total demand of edible oil (i.e., 1.44 million tons) in the country. More recent days, daily production of rice bran oil is about 250-300 tons in Bangladesh while its demand is increasing by 5-10% per year (BBS, 2013). Thus, the present study evaluated the production and value chain of rice bran oil in Bangladesh with the specified objectives such as to know the production capacity and total production of rice bran oil in Bangladesh; to estimate cost of rice bran oil production at the mill level; to outline supply system of rice bran oil in domestic and foreign market; and to estimate the share of margin of different actors in the value chain. Owners of seven rice bran oil mills namely Rashid Oil Mills Ltd, Mazumder Products Ltd., Ali Natural Oil Mills & Ind. Ltd., Mazumder Bran Oil Mills Ltd, Agrotech International, Tamim Agro Ind. Ltd., and Krishani Rice Bran oil were interviewed for this study using. In addition, 13 dealers and 30 retailers were of Jamalpur, Sherpur and Mymensingh district were interviewed for this study. Data were collected during 2016-17 using structured interview schedules.

**Rice bran and bran oil production**

Table 16 shows the availability of rice bran and bran oil in Bangladesh since 2009/10 to 2014/15. It revealed that from 2009/10 to 2014/15 production of rice was almost static, so the availability of rice bran was also more or less static, as there is a direct relationship between supply of paddy and rice bran. In 2005, there were only 200 semi-automatic and automatic rice mills but now (2015) the figure is almost tripled (600). So, it can be noted that if all the rice mills were to be converted into auto and semi-automatic mill, then there is possibilities to obtain around 3.62 million tons of rice bran and would produce about 0.72 million tons of rice bran oil which is half of the total demand of domestic edible oil.

**Disposal pattern of rice bran oil in domestic and foreign market**

Most of the surveyed mills "Rashid Oil Mills Ltd, Ali Natural Oil Mills & Ind, and Krishani Rice Bran Oil Mills" supplied their total products in the domestic market. Mazumder Products Ltd, Mazumder Bran Oil Mills, Agrotech International and Tamim Agro Ind. Ltd supplied about 20, 43, 29 and 62% of their bran oil in domestic market respectively. It was also revealed that about 45% was exported to the foreign countries.

**Production cost of rice bran oil**

The variable cost covered about 89% of manufacturing cost of rice bran oil whereas share of rice bran to main input cost was estimated to be about 81%. Per ton manufacturing costs of rice bran oil were Tk 176,206 and Tk 87019, respectively before and after subtraction of byproduct of rice bran oil from the production cost (Table 17).

**Value chain of rice bran oil in domestic market**

Figure 5 shows supply chain of rice bran oil in Bangladesh. Miller to the selected dealer, the dealer to the retailer and the retailers to the consumers were the major supply chain of refined rice bran oil in the domestic market. On the other hand, some companies like Pran, ACI, Pusti and

**Table 16. Production of rice bran and rice bran oil in Bangladesh.**

| Item | % of share | Year and production (million ton) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2009-10 | 2010-11 | 2011-12 | 2012-13 | 2013-14 | 2014-15 |
| Paddy: | 100 | 49.86 | 50.06 | 50.58 | 50.5 | 51.28 | 51.64 |
| Rice | 67 | 33.4 | 33.54 | 33.89 | 33.83 | 34.36 | 34.6 |
| Husk | 24 | 11.97 | 12.01 | 12.14 | 12.12 | 12.31 | 12.39 |
| Broken rice | 2 | 1 | 1 | 1.01 | 1.01 | 1.03 | 1.03 |
| Rice bran (RB) | 7 | 3.49 | 3.5 | 3.54 | 3.54 | 3.59 | 3.62 |
| Crude rice bran oil (CRBO) | 22 of RB | 0.77 | 0.77 | 0.78 | 0.78 | 0.79 | 0.8 |
| Rice bran oil | 94 of CRBO | 0.69 | 0.69 | 0.7 | 0.7 | 0.71 | 0.72 |

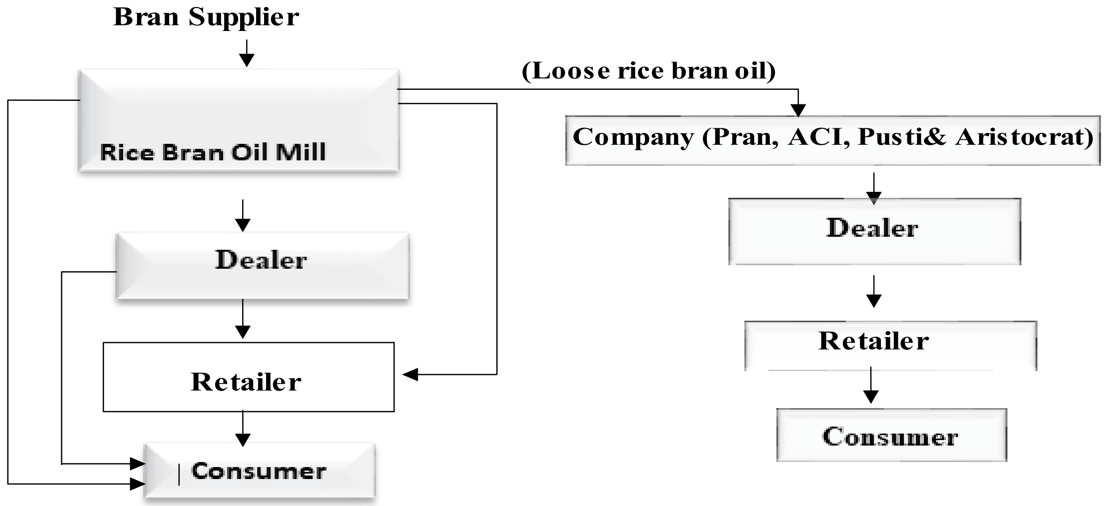



Fig. 5. Supply chain of rice bran oil.

Aristocrat the purchased loose rice bran oil from some mills, and marketed to dealers and retailers as their own brand name.

**Value addition of different actors involved in the chain**

Table 18 shows that total value addition of per ton rice bran oil was Tk 34,981 at different level of actors. The value addition was respectively, 37, 29 and 340% at miller, dealer and retailer level.

## Quality of the rice bran oil

Most rice millers stored the rice bran in the open air for a week or more before shipment of the bran to oil mills because they have no adequate preservation facilities. However, the quality of the rice bran is increasingly decreased due to exposure to open air that happens the hydrolysis reaction and subsequently, the fatty acid get released by 10-20%. Nevertheless, rice bran oil millers collected the bran with lesser fatty acid by 13% at the mill gate. According to expert opinion, the rice bran that contains the fatty acid could be made possible to maintain the level of 3-8% through ensuring systematic and efficient preservation of rice bran. Similarly, magnitude of fatty acid should not be more than 3% in the edible oil or 8% in the crude oil for human consumption.

Problems and limitations of bran oil production were addressed by the lack of adequate supply of quality rice bran; and relatively, higher price of rice bran oil than other oils that leads to lower demand of rice bran oil at consumer level. Lower demand is also influenced by the inadequate information regarding brand and quality as well as benefit on health. In addition, the frequent disruption of power and gas supply increased the costs of production resulting to higher market price.

**Table 17. Costs of bran oil production (Tk/ton).**

| Item | Amount (Tk) |
|---|---|
| Total variable cost (Tk/ton) | 156,375 (88.75) |
| Total fixed cost (Tk/ton): | 10,801 (6.14) |
| Marketing cost (Tk/ton)* | 9,029 (5.12) |
| Total costs (A+B+C) | 176,206 |
| Returns from by-products (Tk/ton RBO production)* | 89,187 |
| Production cost of rice bran oil deducting revenue from byproducts (D - E) | 87,019 |
| Per kg production costs of rice bran oil | 87.02 |

Value in parenthesis indicate percentage of total cost.

**Table 18. Value addition of different intermediaries of rice bran oil (Tk/ton).**

| Particular | Sale price | Purchase price | Value addition | Value addition (%) |
|---|---|---|---|---|
| Miller | 100000 | 87019 | 12981 | 37.11 |
| Dealer | 110000 | 100000 | 10000 | 28.59 |
| Retailer | 122000 | 110000 | 12000 | 34.30 |
| Total value addition | | | 34981 | 100.00 |

Source: Feld survey 2016.

## FARMERS' PERCEPTION OF CLIMATE AND ENVIRONMENTAL CHANGE AND ADAPTATION PRACTICES IN SOUTHERN AREAS

The coastal region covers 19 districts and 32% of total areas in Bangladesh (47,551 sq. km.) (BBS, 2015; Mondal *et al.*, 2010) and arable area in this region is commonly utilized for crops production more particularly rice. Farmers used to cultivate the traditional low yield varieties in T. Aman season. Integrated fresh water prawn-fish-rice farming is intensively practiced to reduce the risk of farming and reduce the environmental hazards (Ahmed and Garnett, 2010). Moreover, the intensification of crops production is constantly hampered by much vulnerability such as cyclones, salinity, land erosion, and lack of necessary infrastructure, irrigation access, and suitable technologies. However, there are many opportunities for crop intensification through the improvement of the aforesaid limitation (CDS, 2006, Bala and Hossain, 2010, Uddin 2016). The study is progressed with the specific objectives to delineate farmers' perception toward climate change and adaptation practice; and to document the cropping system intensification and their suggestions. To accomplish this challenge, nnecessary data were generated through village census and Farmers Group Discussion (FGD) as well as transact walk through the selected villages of Dacope upazila in Khulna and Amtoli upazila in Borguna during December 2016-February 2017. The basic data analysis was also validated by the key informant farmers.

### Climate and environment change and farming risk

Table 19 presents farmers' perceived changes in the climate in the study villages. Farmers observed increased temperature and decreased rainfall during the mid-November-January. Farmers' perceived increased temperature and decreased rainfall with increased extreme events (sudden torrential rainfall and lack of rainfall/droughts) during February-mid May. Some of the key informants perceived more rainfall occurred in the pre-monsoon month (mid-May - mid-June) and some are said decreased rainfall in the period. Key informant said that wet-season shifted delay nearly a month. Farmers observed that rainfall in Asher (mid-June - mid-July) i.e., first month of bangla monsoon month has deceased notably but increased erratic rainfall (sudden torrential rainfall) and temperature. Farmers perceived that more rainfall occurred during mid-July-mid-September. Key informants observed that rainfall during Bangla month Ashin and Kartik locally known as Kaitan Bristy (rainfall during mid-September - mid-November) has decreased significantly and temperature has increased.

**Table 19. Farmers' perceived climate change in the different seasons in Dacope and Amtoli.**

| Month | Temperature | Rainfall |
|---|---|---|
| Mid Nov-Jan | Increase | Decrease |
| Feb-mid May | Increase | Decrease |
| Mid May-mid Jun | Increase | Decrease/ Increase |
| Mid Jun-mid Jul | Increase | Decrease |
| Mid Jul-mid Sep | Increase | Increase |
| Mid Sep-mid Nov | Increase | Decrease |

Source: FGD 2016 and 2017.

Key informants observed that soil salinity of arable lands has decreased significantly after stopping shrimp culture since 2009 in Pankhali and Khatail Fakirpara. Similarly, farmers in Sekenderkhali perceived that soil salinity in arable areas has significantly decreased because of stopping inundation of arable areas by saline tidal river water after construction of WAPDA embankment on bank of Bandra river. According to key informant elevation of arable areas has increased significantly over the last four decades because of gathering alluvium, damp and debris of tidal water. On the other hand, most farmers viewed that fresh-water reserve in the drainage canal has decreased substantially because of heavy siltation on the bottom of canal. Most farmers in Pankhali and Khatail Fakirpara mentioned that fertility and/or productivity of land has increased substantially after stopping shrimp culture. However, most farmers in Sekenderkhali and some farmers in Pankhali and Khatail Fakirpara viewed that land fertility has decreased because of less organic fertilizer application, less access to alluvium of tidal water and monotonous cropping pattern. Table 20 presents farmers perceived risk to farming in Dacope and Amtoli. Extreme weather events in particular torrential rain and droughts significantly influenced productivity of the crops, ranked first by the key informant. Seasonal variability in price of rice and non-rice crops and low price at harvesting season is mostly

**Table 20. Farmers' perceptions of risks to farming in Dacope and Amtoli.**

| Risks factors | Rank |
|---|---|
| Extreme weather events | 1 |
| Seasonal variability of output price | 2 |
| Erraticism of rainfall pattern | 3 |
| Low price at harvesting season | 4 |
| Wide spread pest and diseases infestation | 5 |

Source: FGD 2016 and 2017.

responsible for seasonal fluctuation of returns of farm enterprises, ranked respectively second and fourth by the farmers in the discussion group.

## Farmers' adaptation strategies

Table 21 presents farmers' adaptation practice through cropping in Dacope and Amtoli. It was found that that adoption of modern rice varieties ranges between 65-80% of total T. Amna rice area. Farmers in the study villages adapted a short duration, stress tolerant (e.g., salinity plus drought) and late planting suitable modern rice variety in Aman season. Some farmers irrigate pond water in nursery for raising rice seedling when delay the wet season rain. In addition, some farmers (10-12% of total) apply 1-2 supplementary irrigation during flowering/grain filing stage of rice crop in relatively higher topography 4-7% of total areas have lack of access to tidal water. In Sekenderkhali, majority farmers stopped growing Aus rice due mainly to changes in climate, higher wages and low price of paddy rice. Farmers in the village decreased area of growing stress susceptible rabi crops chillies and mungbean due to changes in climate. Some faremrs grow grass pea, sweet potatoes and groundnut in small. Both in Khatail Fakirpara and Pankhali, the most areas remain fallow for grazing cattle in the rabi seasons. Some farmers grow Boro rice in some areas in Pankhali. Some farmers culture shrimp in *gher* during February-July in Khatail Fakirpara. Farmers in the village irrigate underground water in the *gher* in DS for shrimp culture. It was found that cropping intensity in the villages is low as most areas remain fallow in Rabi season and Kharif-1 season. Thus, there is opportunity to increase cropping intensity in the village through improving cultural practice and increasing production of rabi and Kharif-1 crop production. In addition, growing vegetables and planting fruits and timber trees in home-yard and/or dike of ponds is the most widely practiced farming adaptation strategies in the trial villages. Farmers in the discussion group also mentioned that aquaculture in home-yard pond and rearing cattle are commonly practiced adaptation strategies in the villages.

## Constrains and suggestions of cropping systems

Key informant viewed that environmental problem in particular lack of fresh-water for irrigation, soil and water salinity is the most crucial bottleneck of cropping system intensification in the villages. Firstly, farmers' in the group discussion in Pankhali village in Dacope said that despite two canals (*Gater* canal and *Hatkhola* canal) run across the

**Table 21. Current cropping systems in Dacope and Amtoli.**

| Village | Rabi | Kharif-1 | Kharif-2 | T. Aman rice yield (t/ha) | % of total area |
|---|---|---|---|---|---|
| Khatail: | Fallow | Fallow | LV rice | 2.8 | 20 |
| | Fallow | Fallow | MV rice (BR23) | 3.9 | 35 |
| | Fallow | Fallow | MV rice (others) | 3.3 | 20 |
| | Fallow | Fallow | **MV rice (BR23)/fish | 2.9 | 20 |
| | Shrimp | Shrimp | **MV rice (BR23)/fish | 2.9 | 5 |
| Pankhali: | Fallow | Fallow | MV rice (BR23) | 3.5 | 50 |
| | Fallow | Fallow | MV rice | 3.3 | 22 |
| | Fallow | Fallow | LV rice | 2.8 | 19 |
| | Rice | Fallow | MV rice | 3.3 | 7 |
| | DS corps | Fallow | MV rice | 3.3 | 2 |
| Sekenderkhali: | Grass pea | Fallow | MV rice (BR23) | 3.8 | 30 |
| | Fallow | Fallow | MV rice (BR23) | 3.8 | 20 |
| | Fallow | Fallow | LV rice | 3.2 | 20 |
| | Grass pea | Fallow | LV rice | 3.2 | 15 |
| | Grass pea | LV rice | MV rice (BR23) | 3.3 | 10 |
| | DS crops | Fallow | MV rice (other) | 3.3 | 5 |

Note: BDT. 39,500= 2.2 t/ha rice, *BR11 and BR10 and **BR23. Source: FGD 2017.

village. There was a lack of freshwater for irrigation in the dry season crops in the village. It is due to (i) decreased depth of the canals due to siltation in the canals and (ii) admits saline water from Jopjophis river because of broken sluice gates and some people admits tidal saline water from Jopjophis river for catching fish in the canals. Therefore, farmers in the group suggested that re-excavation of the canals, repairing the sluice gate between *Jopjapia* river and the canals and farmers' friendly sluice gates may ensure adequate reserve of fresh-water for irrigation in rabi crops and kharif-one crop. Secondly, farmers' in the Khatail Fakirpara village in Dacope said that a big canal (e.g., *Khatalia Dawania* canal) (tributary of *Moravodra* river) parallelly runs on the western site of the village and a medium size flows across the eastern site of arable lands of the village. However, there is a lack of fresh-water for irrigation in the village as there is no sluice gate between (i) *Khatalia dawania* canal and *Moravodra* river and (ii) the sluice gate between the *Khatalia Dawania* canal and *Jopjapia* river is broken. Therefore, re-excavation of some part of the *Srimonto Katakhali* canal, establishment a sluice gate between *Moravodra* and *Khatalia dawania* canal, repairing the sluice gate between *Maukhali* and *Jopjapia* river and farmers' friendly management of the sluice gates may create a profuse reserve of fresh-water for irrigation in DS crops and early wet season crop for over thousands of farm families in the areas.

Thirdly, farmers' in the Sekenderkhali Doshgoria in Amtoli said that two kilometers long four connecting canals flow across the village (*Ghater* canal flows to *Hapamarar* canal, the canal flows to Bandarer canal and the Bandarer canal (0.5 km) flows to Bandra river. However, farmers' in the village cannot use the water for irrigation. It was due to (i) siltation in the canal runs across the crop fields (ii) broken the sluice gates between *Bandra* river and *Bandarer* canal, and *Hapamarar* canal and *Ghater* canal. Key informant suggested that re-excavation of canal runs across the crop fields, repairing the sluice gate between *Bandra* river and *Bandarer*, *Hapamarar* canal and *Ghater* canal and farmers' friendly sluice gates may ensure adequate reserve of fresh-water for irrigation in DS crops and early wet season crop for the farm families of the villages.

Besides, climate change in particular changes in rainfall pattern and erratic rainfall (untimely and unpredictable rainfall) is a crucial constraint of increasing production of rabi crops and Aus rice in the villages. Moreover, farmers in the discussion group mentioned that pest infestation including rat and grazing cattle is a problem for cropping Rabi crops and Aus rice in the villages. Besides, lack of farmers' knowledge on modern cultural practice, salinity management, information about adaptation options and modern technologies are the major problem for cropping systems intensification in the villages. Key informant in Sekenderkhali and Khatail Fakirpara said that lack of access to stress tolerant crop variety seeds, extension services (e.g., training and demonstration) and market (quality seed and low price farm output). Farmers suggested that dissemination of seeds of stress tolerant crop varieties, stress management technologies and modern cultural practice through increasing extension supports may reduce the problem. Key informant viewed that socioeconomic features of the farm households such as lack of availability of power operated tiller low level of education, decreasing number of family labour and poor resource-base are the barrier of cropping system intensification in the villages. Majority of farmers have low adaptive capacity and lack of money for capital investment in particular developing infrastructure and purchasing farm machineries for farming but they have poorer access to credit facilities. Thus, policy supports for ensured access to soft agriculture credit and a favourable crop insurance policy may reduce the problem in greater extent.

## EFFECTIVENESS OF BORO RICE/PADDY PROCUREMENT PROGRAMME IN SOME SELECTED AREAS

Government of Bangladesh has introduced various policies to provide more incentives to farmers in order to increase rice production. The main objective of these policies is to enhance farm productivity by reducing input cost and improving the marketing system of paddy and rice. Paddy/rice procurement is one of the programmes to ensure fair price to the growers which will enhance the productivity. The present study is an attempt to assess the effectiveness of the programme with the following objectives.

- Examine structure, functions and performance of the public paddy and rice procurement program;
- Observe farmers' and millers' perception of public procurement system; and
- Evaluate impacts of procurement systems on farm and its drawbacks.

Five millers, ten participant farmers and fifteen non-participant farmers were selected randomly from Mymensingh and Naogaon district. In total, 50 farmers and 10 millers were interviewed using a structured questionnaire in May-June, 2017. The participant farmers were selected from the listed procurement farmers of Local Storage Depot (LSD).

**Government paddy and rice procurement system**

The ministry of food (MoA) determined procurement price and time of rice and paddy. Government procurement centers located in the different locations in the country procures paddy directly from the farmers and rice from the millers in a 'first come first serve" basis through. The procurement staffs issue weight, quality and stock certificate (WQSC) based of the features presented in Table 22 as well as issue payment cheque to farmers for collecting money from selected national commercial bank. Similarly, procurement staffs issue WQSC based of the features presented in Table 23 as well as issue payment cheque to miller for collecting money from selected national commercial bank.

**Procurement price and cost of production of Boro rice**

Figure 6 presents procurement price and production cost of per kg paddy rice over the last ten years. Both the production cost and procurement price of paddy rice has increased with a notable year to year fluctuation in the procurement price of the paddy rice. It indicates that there was an inconsistency between

**Table 22. Features of paddy rice to be qualified for selling at procurement center.**

| Feature | Specification |
|---|---|
| Humidity | Max. 14% |
| Foreign matter | Max. 0.5% |
| Admixture of varieties | Max. 8% |
| Immature and damaged kernels | Max. 2% |
| Unfilled grain | Max. 0.5% |

Source: DG Food, 2015.

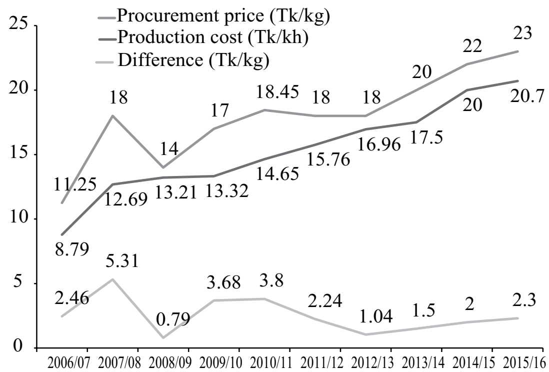



Fig. 6. Procurement price and production cost of paddy rice over the last ten years. Source: FPMU, Ministry of Food

**Table 23. Key features of husked rice to be qualified for selling at procurement center.**

| Criteria | Specification | |
|---|---|---|
| | Boiled | Unboiled |
| Humidity | Max. 14% | Max. 14% |
| Large broken kernels | Max. 4% | Max. 8% |
| Small broken kernels | Max. 1% | Max. 5% |
| Admixture of varieties | Max. 8% | Max. 8% |
| Damaged kernels | Max. 1% | Max. 1% |
| Dead kernels | Max. 1% | Max. 1% |
| Milling | Good | Good |

Source: DG Food, 2015.

the rate of production cost and procurement price increase. The difference between procurement price and production cost decreased to low in 2012/13, indicates that farmers received low returns from paddy rice. On the other hand, the price margin increased to high in 2015/16, indicates that farmers' obtained higher returns.

**Impact of procurement programme on farm returns**

Farmers' paid slightly higher cost (Tk 13/quantal) of selling paddy rice at procurement center than local market because they were to pay some money to scruples procurement staffs and carrying cost of moving paddy rice to procurement center was higher. However, the incremental benefit of selling per quintal paddy at procurement center was Tk 462 which much higher than the additional cost (Table 24).

**Farmer's perception about procurement system**

Farmers' perception about procurement systems are collected and explained here. About 42% of total farmers including participant and non-

**Table 24. Impact of procurement system on farm returns in 2016/17.**

| Item | Taka |
|---|---|
| Paddy sold to procurement center (quintal/farm) | 24.35 |
| Value of the paddy (Tk/farm) sold to procurement center (PC) at PC (Tk 2300/quintal) | 56,005 |
| Value of paddy (Tk/farm) sold to PC at market price (Tk1825/quintal) | 44438.75 |
| Cost of selling paddy to PC (Tk/quintal) | 61.50 |
| Cost of selling paddy to nearby market (Tk/quintal) | 48.50 |
| Total cost (a × d) of selling paddy to PC (Tk/farm) | 1497.525 |
| Total cost (a × e) of selling paddy to nearby market (Tk/farm) | 1180.975 |
| Net margin (b - f) of selling paddy to PC (Tk/farm) | 54507.475 |
| Net margin (c - g) of selling paddy to nearby market (Tk/farm) | 43257.775 |
| Incremental margin (h - i) of selling paddy to PC (Tk/farm) | 11249.70 |
| Incremental margin (j / a) of selling paddy to PC (Tk/quintal) | 462.00 |

Source: Field survey 2016.

participant recognized the procurement price of boro paddy (23 Tk/kg) was reasonable in 2015/16, while 21% of the total respondents said that procurement price was low. Some farmers (24%) opined that allocated amount of paddy per farmers was adequate. Majority of the farmers (61-64%) satisfied with the timing of procurement and locations of the procurement center. About 35% of respondents stated that they had to pay some money and/or some paddy for per quintal paddy to sale at procurement center. Therefore, 61% of total farmers mentioned that the procurement system is not free from corruption and about 40% were not satisfied with the procurement payment system.

**Millers' costs and returns**

Millers purchase paddy from farmers and traders, convert them into rice and finally sell rice to the procurement center as per fixed amount allotted to them. They are also engaged in crushing procurement centers' paddy. Carrying paddy rice from market to mills and processing of paddy were the major cost items of supplying husked rice to the procurement center. In addition, undue payment to procurement staff was notable. Net profit of per quintal paddy was Tk 451 (Table 25).

**Table 25. Costs and return for supplying rice to procurement center.**

| Item | Cost (Tk/quintal) |
|---|---|
| Purchase price of paddy | 1825 |
| Carrying cost of paddy to mill gate | 45.04 |
| Bags | 11.65 |
| Processing cost of paddy to rice | 95.50 |
| Undue payment to procurement staff | 32 |
| Transportation cost of rice to procurement center | 16 |
| Other cost | 8.50 |
| Total cost | 2033.69 |
| Gains from by product | 325 |
| Price received from rice obtained from one quintal of paddy | 2160 |
| Net profit | 451.31 |

Field survey 2016.

**Perception of millers about the procurement programme**

About 50% of total millers said that procurement price of husked rice was low in 2015-16. Some millers (43%) were not happy with the procurement system but some (38%) recognized the system as reasonable. Nearly (53%) half of the millers said that procurement systems was not free from corruption.

## RICE CULTIVATION IN NEWLY INDEPENDENT ENCLAVES OF BANGLADESH: A FIELD LEVEL INVESTIGATION

Modern rice cultivation requires timely availability of inputs and selling outputs at reasonable price. The inhabitants of old enclaves were out of the mainstream for a long time and they could not get due facilities to adopt the modern rice production technologies released by BRRI. They are now the dwellers of Bangladesh and different organizations from GOs and NGOs are extending their endeavors to rehabilitate them. As BRRI is the pioneer of rice sector in Bangladesh, so it is essential to know the existing status of rice production practices and what kind of support need to adopt modern rice production technologies in the enclaves. So, a field level investigation was designed to explore the rice production scenarios of the study location; to examine the adapted rice production practices and technologies including variety ; to investigate the process of getting inputs and selling outputs; as well as to identify major constraints of rice production in the enclaves. Two upzillas namely Patgram of

Lalmonirhat and Fulbaria of Kurigram District was selected purposively for this study as the old enclaves were located in the areas. Data were collected from 30 farmers from the each upazila using a pre-designed questionnaire during the year 2016-17.

**Access to market and extension services**

Farmers of both the locations purchased rice seed from dealers at local market. Farmers purchased fertilizers from black market at Fulbaria while the farmers in Patgram purchased fertilizers from the authorized traders Farmers in both the location relied on seed dealers, fertilizer trades and neighbouring farmers for sources in information about modern rice production technologies. Farmers noted that demand of rice in the local market was ensured in both the local. Farmers mainly relied on Grameen Bank and some NGOs (RDRS, ASA) for agricultural and non-agricultural credit.

**Problems and probable suggestions**

Farmers reported that higher irrigation cost, inputs price, disease infestation and occurrence of natural calamities (e.g., droughts and floods) were the major problems of rice production in the areas. Farmers suggested that ensuring access to irrigation through developing irrigation infrastructure (e.g., DTW and Pucca canal), agricultural credit and other inputs at reasonable price and extension services.

# Agricultural Statistics Division

SUMMARY

In T. Aman season, BRRI dhan49 was found as the stable, while BR4, BR10, BR11, BR22, BR23, BR25, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan66, BRRI dhan71, BRRI dhan72, BRRI dhan73 and BRRI hybrid dhan4 were found having average stability and the other remaining varieties appeared to below average stable among T. Aman varieties.

BRRI hybrid dhan5 was the most stable variety and BR14, BRRI dhan28, BRRI dhan29, BRRI dhan55, BRRI dhan58, BRRI dhan60, BRRI dhan68, BRRI dhan69, BRRI dhan74, BRRI hybrid dhan2 and BRRI hybrid dhan3 appeared to be average stable in Boro season.

The genotype G1 (BR21), G2 (BR22), G3 (BR26) and G4 (BRRI dhan27) were more responsive to the environment since they were away from the origin whereas the genotypes G5 (BRRI dhan42), G6 (BRRI dhan43), G7 (BRRI dhan48) and G8 (BRRI dhan65) were close to the origin and hence they were less sensitive to environmental interactive forces. Among the environment E2 (Kushtia) and E3 (Rajshahi) and among the genotypes G8 (BRRI dhan65), G7 (BRRI dhan48) and G6 (BRRI dhan43) had positive IPCA1 score and registered above average yield, hence these genotypes were identified as specifically adapted to cultivate in Rajshahi and Kushtia environment and those were considered suitable for these genotypes due to stable yields.

Throughout the Aus season all weather conditions for all four locations were more or less similar pattern. Rajshahi has the most extreme weather condition, high temperature and low rainfall and humidity. High rainfall was in Gazipur. July is the month of highest rainfall and low temperature and May is the month of highest temperature and low rainfall. Among the four locations, BRRI recommended management practice based on weather forecasting may be recommended for all locations in rice cultivation for BRRI dhan48 in Aus season having similar environment as that of experimental site.

Maximum temperature have positive effect on yield of all the BRRI varieties except BR4 and the other climatic factors (Minimum temperature, humidity, rainfall and sunshine) have negative effect on yield of most of the varieties. BR25, BRRI dhan57 and BRRI dhan62 have shown the significant positive effect for maximum temperature but for the minimum temperature they have no significant effect. For humidity only BRRI dhan62 showed the significant positive effect. Rainfall has the negative significant effect on BRRI dhan39, BRRI dhan57 and BRRI dhan62. Finally BR4 has shown significant negative effect for the climatic parameter sunshine.

In southern and western regions, Jessore, Satkhira, Khulna, Bhola, Barisal and its surroundings; central regions, Dhaka, Faridpur, Feni, Tangail and its surroundings; eastern regions, Chittagong, Rangamati hill tract areas and most of the northern region were more vulnerable to meteorological drought. Major finding of this study was that Pre-Kharif and Rabi seasons are the most vulnerable to meteorological drought that indicates high Rainfall anomaly seasons in most of the regions of Bangladesh.

Northern side is suitable for cultivation of BRRI dhan62 and BRRI hybrid dhan4. But, south and eastern side are not suitable for both BRRI dhan62 and BRRI hybrid dhan4 cultivation.

Based on groundwater level condition for Boro cultivation, Natore district is divided into three main areas like suitable area which is central part of Natore, moderate suitable, which is eastern and top northern part of Natore district and not suitable area, which is the western side of Natore district.

Primary and secondary data on rice and other important crops were collected periodically from various sources of Bangladesh and included at BRRI website and existing databases have been updated regularly.

Mobile apps of RKB (Rice knowledge Bank) was designed and developed under ICT cell of Agricultural Statistics Division.

The scientists of this division were also engaged in helping scientists of other disciplines in planning experiments, statistical data analysis and interpretation of results. A total of 55 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, the ICT cell

of Agricultural Statistics Division provides ICT related support services to other divisions such as hardware, software and troubleshooting related problems.

## STABILITY ANALYSIS OF BRRI VARIETIES

The main objectives of the study were to determine the stability index of BRRI released varieties, maintain season, year and location-wise database and identify the bio-physical and socio-economic factors causing instability. Experiments are being conducted in T. Aman and Boro seasons with BRRI released rice varieties since T. Aman 2002-15 in Gazipur and different regional stations. The collaborative regional stations in the T. Aman season are Rajshahi, Rangpur, Comilla, Sonagazi, Barisal, Satkhira and Kushtia and in the Boro season Rajshahi, Rangpur, Comilla, Habiganj, Barisal, Bhanga, Satkhira and Kushtia. In T. Aman season, the number of varieties is 30 and in Boro it is 36. The design is RCB with three replications and the effective plot size (harvest area) is 5-×-2 $m^2$ leaving the boarder. Recommended crop management practices are followed. Stability analysis of the experimental data was performed by using a newly developed model. The model deals with the performance of the genotypes across the geographical locations differing in land, soil and other biotic and abiotic factors over the years characterizing fluctuation of weather variable, floods, drought etc.

**Results and discussion**

Among T. Aman varieties, BRRI dhan49 were found stable while BR3, BR5, BRRI dhan32, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan70, BRRI dhan75, BRRI dhan76 and BRRI dhan77 appeared to be below average stable. BR4, BR10, BR11, BR22, BR23, BR25, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan66, BRRI dhan71, BRRI dhan72, BRRI dhan73 and BRRI hybrid dhan4 were found having average stability among T. Aman varieties.In Boro season, this year the stable variety was BRRI hybrid dhan5 and BR14, BRRI dhan28, BRRI dhan29, BRRI dhan55, BRRI dhan58, BRRI dhan60, BRRI dhan68, BRRI dhan69, BRRI dhan74, BRRI hybrid dhan2 and BRRI hybrid dhan3 appeared having average stability. All other Boro varieties (BR1, BR2, BR3, BR6, BR7, BR8, BR12, BR15, BR16, BR17, BR18, BR19, BR26, BRRI dhan27, BRRI dhan35, BRRI dhan36, BRRI dhan45, BRRI dhan47, BRRI dhan50, BRRI dhan59, BRRI dhan61, BRRI dhan63, BRRI dhan64, and BRRI dhan67) appeared having below average stability.

## STABILITY AND ADAPTABILITY ANALYSIS OF BRRI DEVELOPED AUS VARIETIES

The objectives of this study is to identify high yielding Aus rice varieties having wide adaptation and/or specific adaptation to environment and also assess the environmental interaction for their yield stability and adaptability across different environments. Multi environment trials on eight Aus rice varieties were conducted at four environmental conditions; Gazipur (E1), Kushtia (E2), Rajshahi (E3) and Rangpur (E4). BRRI developed Aus varieties will be evaluated in these experiments. The experiments were carried out in a randomized complete block design, with three replications. Each experimental plot was comprised of 5 × 5 m. Standard agronomic practices were followed and plant protection measures were taken as required following the BRRI recommendation. Two border rows were used to minimize the border effects and yield data were recorded. The combined analysis of variance was proceed to look at G × E of the genotypes across all environments. The AMMI model, which combines standard analysis of variance with PC analysis, was used to investigate of G × E interaction. In AMMI model the contribution of each genotype and each environment to the GEI is assessed by use of the biplot graph display in which yield means are plotted against the scores of the IPCA1. The AMMI stability value (ASV) also used for this experiment.

**Results and discussion**

Tables 1 and 2 present the results, The AMMI analysis of variance for rice grain yield (t/ha) of eight genotypes tested in four environments showed that

12.08% of the total sum of squares was attributed to environmental effects, only 26.13% to genotypic effects and 47.65% to genotype × environment interaction effects. The environments were diverse and caused the greatest variation in grain yield. The genotype × environment interaction sum of squares was about 1.82 times larger than that for genotypes, which determined significant differences in genotypic response across environments. The higher the IPCA score, either negative or positive, the more specifically adapted a genotype is to certain environments. Lower ASV scores indicate a more stable genotype across environments. The IPCA1, IPCA2 and IPCA3 explained 78.50, 14.30 and 7.20% of the GEI sum of square respectively, which recommended that the most accurate model for AMMI can be predicted using the first two IPCAs.

The AMMI1 biplot (Fig. 1) clearly indicates that all the eight genotypes studied differed from each other and not only for mean yields, but also for their interaction effects. The genotypes G6 (BRRI dhan43), G7 (BRRI dhan48) and G8 (BRRI dhan65) had IPCA1 score near zero and hence had small interaction effects indicating that these varieties were less influenced by the environments. From these five genotypes G8 (BRRI dhan65), G7 (BRRI dhan48) and G6 (BRRI dhan43) were found to have above average yield. On the other hand, the genotype G2 (BR24) gave lower yield along with the IPCA1 score close to zero, it was adjudged as the stable genotype. G × E interaction hardly affect the genotypes G8 (BRRI dhan65), G7 (BRRI dhan48) and G6 (BRRI dhan43) and thus will perform well across a wide range of environments. Locations, such as E2 (Kushtia) and E3 (Rajshahi) could be regarded as a good selection site for rice improvement due to stable yields.

The AMMI2 biplot (Fig. 2) indicates that E2 (Kushtia) environment were found to be closest to the origin that represent stable environment. This environment showed the smallest scores, thus it has smallest GE interaction effect and were non-sensitive to change in different genotypes and environmental interactive factors. E1 (Gazipur) environment showed a specific GE interaction in IPCA2 scores that have a negative sign similar to G3, G6, G7 and G8 and opposite to E4 (Rangpur). The environment E4 (Rangpur) situated large

**Table 1. AMMI analysis of variance for rice grain yield of eight genotypes tested in four environments.**

| Source of variation | df | Sum.Sq | Mean.Sq | Explained SS (%) |
|---|---|---|---|---|
| ENV | 3 | 14.116 | 4.7053*** | 12.08 |
| REP(ENV) | 8 | 1.856 | 0.2319 | 1.59 |
| GEN | 7 | 30.536 | 4.3623*** | 26.13 |
| ENV:GEN | 21 | 55.686 | 2.6517*** | 47.65 |
| PC1 | 9 | 43.69576 | 4.855084*** | 78.50 |
| PC2 | 7 | 7.968465 | 1.138352*** | 14.30 |
| PC3 | 5 | 4.022054 | 0.804411 | 7.20 |
| Residuals | 56 | 14.661 | 0.2618 | 12.55 |
| Total | 95 | 116.855 | | |

**Table 2. Grain yield performance, PCA scores of eight genotypes and four locations.**

| Genotype/location | Code | Type | Yield (t/ha) | PC1 | PC2 | PC3 |
|---|---|---|---|---|---|---|
| BR21 | G1 | GEN | 3.59 | 0.498 | 0.499 | -0.174 |
| BR24 | G2 | GEN | 3.58 | -0.059 | 0.730 | 0.234 |
| BR26 | G3 | GEN | 3.55 | 0.469 | -0.467 | 0.544 |
| BRRI dhan27 | G4 | GEN | 3.12 | -1.766 | -0.078 | -0.028 |
| BRRI dhan42 | G5 | GENs | 3.76 | 0.275 | 0.396 | 0.071 |
| BRRI dhan43 | G6 | GEN | 4.39 | 0.038 | -0.269 | 0.218 |
| BRRI dhan48 | G7 | GEN | 4.58 | 0.277 | -0.587 | -0.014 |
| BRRI dhan65 | G8 | GEN | 4.85 | 0.268 | -0.224 | -0.851 |
| Gazipur | E1 | ENV | 3.33 | 0.235 | -1.030 | -0.313 |
| Kushtia | E2 | ENV | 4.10 | 0.305 | 0.033 | 0.916 |
| Rajshahi | E3 | ENV | 4.37 | 1.057 | 0.687 | -0.440 |
| Rangpur | E4 | ENV | 3.91 | -1.597 | 0.310 | -0.162 |

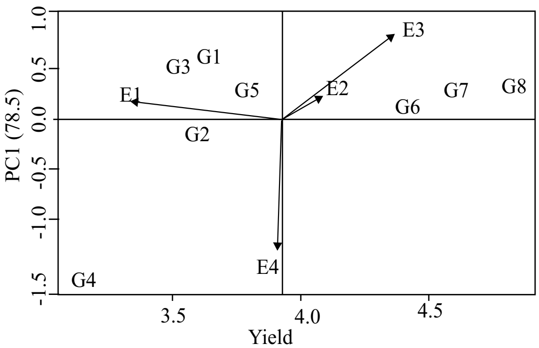



Fig. 1. Interaction principal component analysis yield.

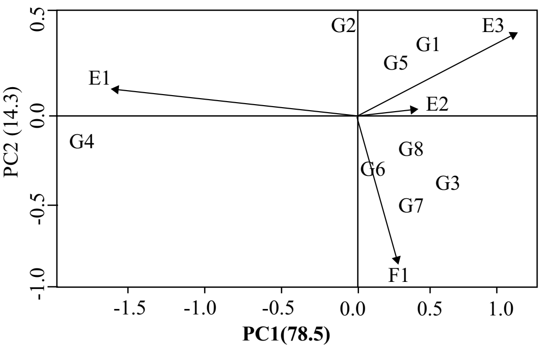



Fig. 2. PCA1 versus PCA2 for grain yield of versus grain genotypes

distance from the origin with high negative scores for IPCA1 axes. Also, E3 (Rajshahi) situated moderate distance from the origin and showed both positive scores of IPCA1 and IPCA2. Thus E1, E3 and E4 had the highest distance from the origin so these are sensitive to genotypes changes and have a large interaction based on AMMI2 biplot. Among them E1 and E4 environment with mean yields are less than the average yield and accordingly can be regarded as the most unstable environment.

## PROSPECTS OF BRRI DHAN62 CULTIVATION

The study was undertaken to evaluate the acceptability, regional yield performance, major problems of cultivation and farmers preference for cultivation of zinc enriched BRRI dhan62 in Bangladesh. A multi-stage random sampling procedure was applied to determine the farmer's preference for rice variety cultivation. Firstly, 10 districts were selected purposively based on wide adaption area of BRRI dhan62 by the concern of expert opinion and using suitability map of BRRI dhan62. Then 10 upazilas were selected from those ten districts that is first sample unit. Then 10 villages were selected from 10 upazilas, which was second sample unit. Finally by using simple random sampling 40 farmers were selected in each village. Information was collected on the choice of varieties for production and consumption using a pre-designed questionnaire. Statistical analysis was used for analysis. SPSS, MS Excel, Programming R were used for completing analysis. For this study a questionnaire has been developed with the help of HarvestPlus. For the study, BRRI dhan62 and farmer's information and study area have been selected as per suggestions of the Country Manager of HarvestPlus and one research officer of HarvestPlus helped us to collect information from farmers in BRRI dhan62 disseminated areas. Ten districts of Bangladesh namely Jessore, Meherpur, Bogra, Rangpur, Dinajpur, Panchagarh, Faridpur, Rajbari, Gopalganj and Barisal have been selected to collect information against the questionnaire.

## MAINTENANCE OF RICE DATABASE

Secondary data on rice and other important crops are collected periodically from Bangladesh Bureau of Statistics (BBS), Agricultural Marketing Directorate, Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB), Bangladesh Agricultural Development Corporation (BADC) and other sources periodically and computerized. Existing databases have been updated and included at BRRI website.

## SEASONAL WEATHER FORECASTING FOR RICE PRODUCTION

The experiment was conducted in T. Aus, 2016 season at BRRI HQ, Gazipur and three BRRI RS: Rangpur, Rajshahi and Barisal which were located between 88°66′E-90°41′E and 23°99′N-25°70′N. Main climate characters are dry, scarce and concentrated precipitation, strong winds, abundant sunshine, strong solar radiation, and a large temperature difference between day and night. BRRI dhan48 was tested under two different treatments

($T_1$ = BRRI recommended management practice i.e. general practice) and $T_2$ = BRRI recommended management practice based on weather forecasting). Full dose of P, K and S were applied at final land preparation. The experimental design was RCB with three replications and each experimental plot was comprised of 5 × 2 m. At maturity, 5.0 $m^2$ areas were harvested for grain yield. it was adjusted to 14% moisture content. All other agronomic and pest management practices were followed when necessary. Combined analysis of variance was performed for four locations to estimate the mean yield, mean square error and coefficient of variation. The weather research and forecasting (WRF) model was used to generate atmospheric simulations based on real data (observations, analyses) or idealized conditions.

**Daily maximum and minimum temperature, rainfall and humidity**

Maximum temperature curve of May 2016 for all four locations shows more or less similar pattern, most of the values are lying 30°C to 40°C. Surprisingly, 21 May had the lowest maximum temperature for all locations. Among them Barisal and Gazipur had the highest low maximum temperature and the value was approximately 23°C. In May Rajshahi had the highest maximum temperature and Barisal had the lowest maximum temperature (Fig. 3). Minimum temperature curve of May 2016 for all four locations are showing more or less similar pattern, most of the values are lying 24°C to 30°C. Surprisingly, in May Rajshahi had the high minimum temperature and Rangpur had the lowest minimum temperature and minimum temperature of Rangpur was significantly lower than that of others locations (Fig. 4). May was mainly low rainfall month. For days there were significant rainfall. On 21 May there was abnormally highest rainfall in Gazipur (172 mm) and Barisal (96 mm). It is noticeable that 21 may had the highest low maximum temperature for all four locations. Throughout the May month Rajshahi was the most low rainfall area and Gazipur was the highest rainfall area (Fig. 5). Relative humidity curve of May 2016 for all four locations is showing more or less similar pattern. Most of the values are lying 50 to 80%. First half of May relatively had low humidity and the last half had high relative humidity. Throughout the May Rajshahi had the most low relative humidity area and Barisal had the highest relative humidity area (Fig. 6). Similarly, June, July and August had maximum and minimum temperature, rainfall and humidity.

In case of management practice, we can conclude that the different levels of management practice are significantly affected the yield of BRRI dhan48. Analysis of variance also shows that there was significant difference between the interaction of location with BRRI han48 and different levels of management practices. So, we can conclude that the yield of BRRI dhan48 in different locations depends on different levels of management practices.

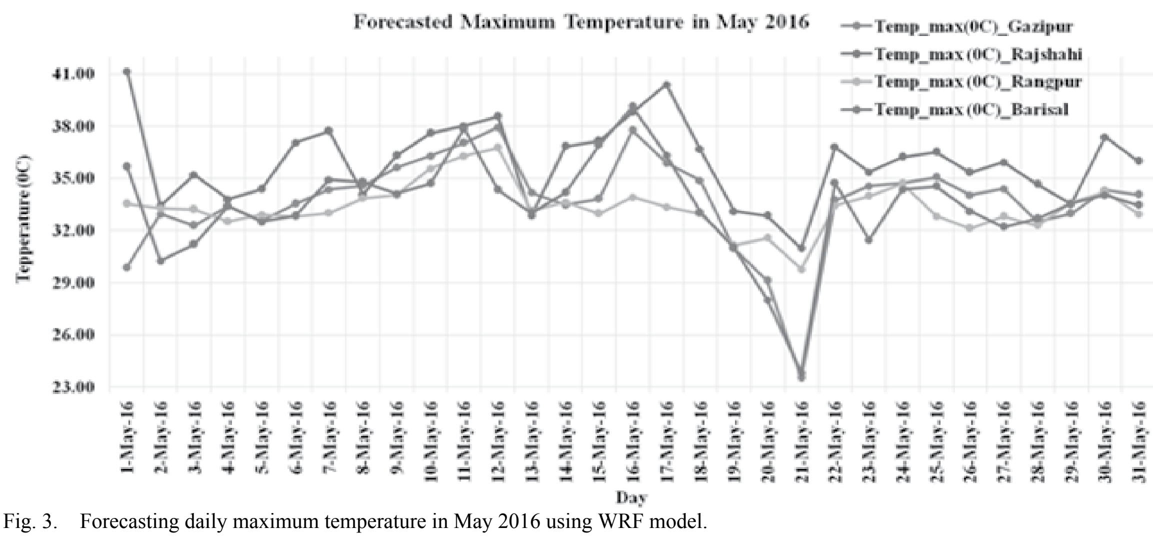



Fig. 3. Forecasting daily maximum temperature in May 2016 using WRF model.

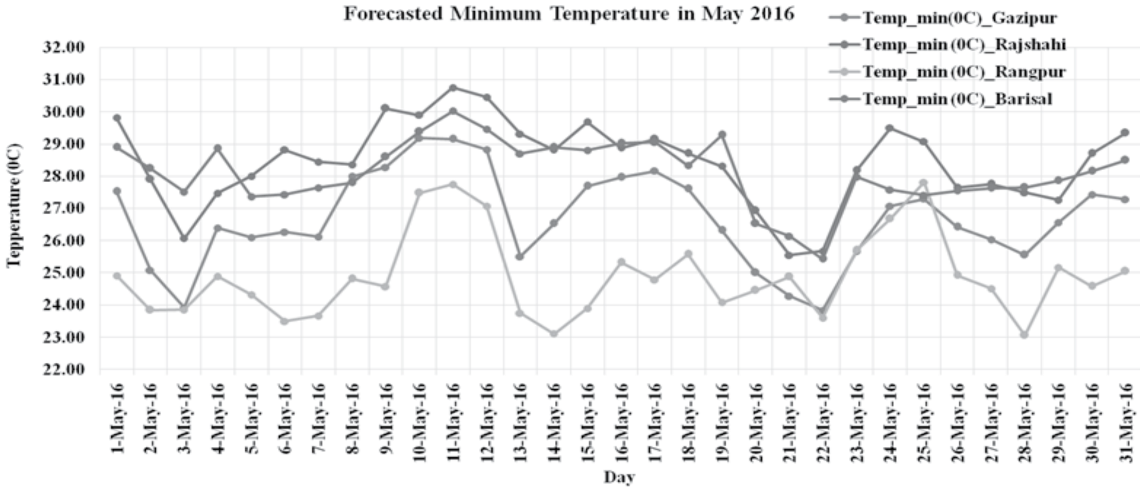


Fig. 4. Forecasting daily minimum temperature in May 2016 using WRF model.

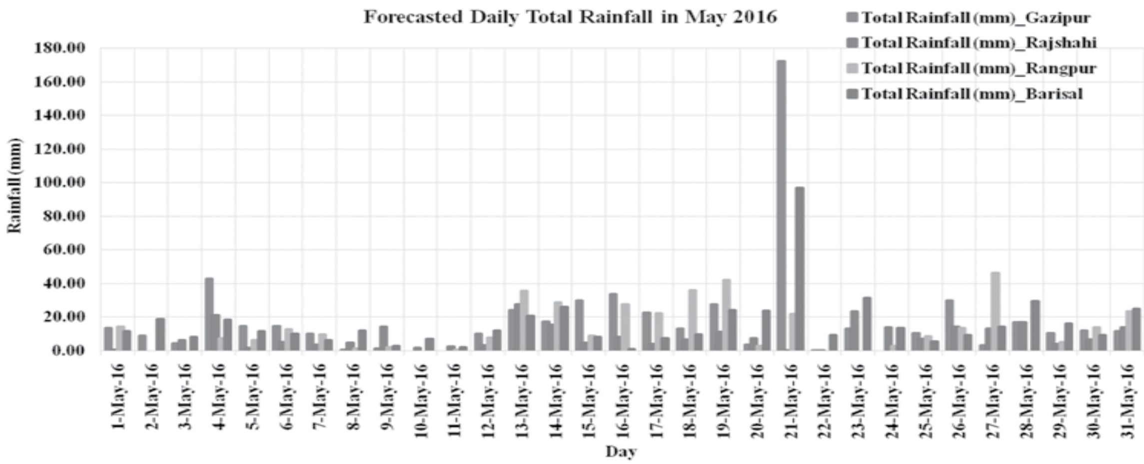


Fig. 5. Forecasting daily total rainfall in May 2016 using WRF model.

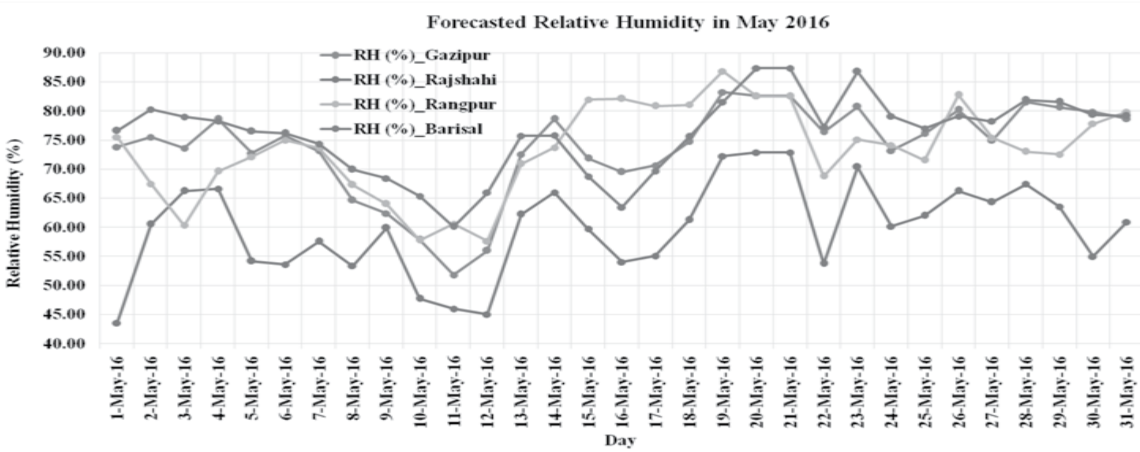


Fig. 6. Forecasting daily relative humidity in May 2016 using WRF model.

The mean separation test of interaction between location and management practice for the variety BRRI dhan48, we can conclude that $T_2$ (BRRI recommended management practice based on weather forecasting) produces higher yield for all locations than $T_1$ (BRRI recommended management practice i.e. general practice). The yield of BRRI dhan48 the case of $T_1$ (BRRI recommended management practice i.e. general practice) for all locations Rajshahi yielded highest (4.17 t/ha), significantly higher than that of two other locations but statistically similar with Gazipur and also Barisal, Gazipur and Rangpur show statistically similar yield performance for BRRI dhan48. Hence, among the four locations and two management practices, BRRI recommended management practice based on weather forecasting may be recommended for all locations in rice cultivation for BRRI dhan48 in Aus season having similar environment as that of experimental site.

## EFFECTS OF THE EDAPHIC AND THE CLIMATIC FACTORS ON THE YIELD OF BRRI RELEASED VARIETIES

The objectives of this study is to identify the most effective BRRI released rice varieties growing location wise in Bangladesh and to Assessment of possible change in yield of BRRI released rice variety due to different factors using regression model. These studies were conducted at all the regional station and the headquarters of Bangladesh Rice Research Institute (BRRI) in the country from T. Aman 2015 season. BRRI released rice varieties were evaluated in this study. The BRRI released rice yield data were collected performing an experiment. The experiment was carried out in a randomized complete block design, with three replications. Each experimental unit was comprised of 5 × 2 m. Standard agronomic practices (BRRI recommended) were followed and plant protection measures were taken as required. Yields of varieties, climatic factors, location etc were recorded. To quantify the effect of different factors (Varieties, location) the ANOVA model of combined analysis and regression model (RM) were used to identify the factors that affect rice yield. The weather data (daily maximum and minimum temperature, relative humidity, rainfall and sunshine) from 1st June 2015 to 31st December 2015 were collected from the Bangladesh Meteorological Department (BMD). From Table 3, we found BR11 as the highest yielding variety in BRRI HQ, Gazipur and the lowest yielding variety is BR23 in Rangpur. Among the varieties, the highest average yield was found in BRRI RS, Kushtia and the lowest in BRRI RS, Rangpur. In the ANOVA, it is clear that all the sources of variation (SV) showed significant differences. That means, locations had significant yield difference though the same management practice perform. Though same management practices were applied in case of all the varieties, the yield of the all varieties more or less significantly differed in all the locations. The reason is the genetic performance of the varieties. But the yield performances of the same variety at different locations were different. The causes of the yield difference were the soil factor variation and the climatic variation in the stations. Here, we analyse only the effect of the climatic factors on yield of BRRI varieties. From the effect analysis, we found that maximum temperature have positive effect on yield of all the BRRI varieties except BR4 and the other climatic factors (Minimum temperature, humidity, rainfall and sunshine) have negative effect on yield of most of the varieties.

**Table 3. BRRI regional station wise highest, average and lowest yielding variety in T. Aman 2015.**

| Season→ Region↓ | Highest yielding | | All variety average yield | Lowest yielding | |
|---|---|---|---|---|---|
| | Variety | Yield (t/ha) | | Variety name | Yield (t/ha) |
| Rangpur | BRRI dhan51 | 3.53 | 2.27 | BR23 | 1.08 |
| Rajshahi | BR11 | 6.51 | 4.90 | BR34 | 2.61 |
| Bhanga | BR33 | 6.49 | 4.72 | BR37 | 3.20 |
| Kushtia | BRRI dhan66 | 6.69 | 5.39 | BR37 | 3.88 |
| Satkhira | BR11 | 6.23 | 4.37 | BR38 | 2.48 |
| Sonagazi | BR23 | 4.98 | 3.69 | BRRI dhan57 | 2.37 |
| Comilla | BR32 | 6.09 | 4.44 | BRRI dhan57 | 1.70 |
| Gazipur | BR11 | 7.03 | 5.25 | BRRI dhan62 | 0.84 |

BR25, BRRI dhan57 and BRRI dhan62 shown the significant positive effect for maximum temperature but the minimum temperature has no significant effect. For humidity only the BRRI dhan62 showed the significant positive effect. Rainfall has the negative significant effect on BRRI dhan39, BRRI dhan57 and BRRI dhan62. Finally, BR4 has shown significant negative effect on the climatic parameter sunshine.

IDENTIFICATION OF DROUGHT PRONE AREAS THROUGH STANDARDIZED PRECIPITATION INDEX (SPI) AND MARKOV CHAIN MODEL

The main objective of this study is to assess the spatial and temporal pattern of meteorological drought over different regions of Bangladesh using the Standardized Precipitation Index. In the present study, monthly precipitation data of 35 meteorological stations were taken from Bangladesh Meteorological Department (BMD) for a maximum period of 36 years from 1980 to 2015. The total area of Bangladesh was divided into the four regions for better understanding of the meteorological drought i.e northern, southern, western region, central region and eastern regions. The calculation of SPI was followed in this study to assess anomalous and extreme precipitation. Standardized precipitation index (SPI) is more flexible and simpler than other indices. The most common first order two state Markov Chain Model was used to assess dry and wet periods for all the study stations. Geographic information system (GIS) has been used for mapping of spatial extent of meteorological drought.

**Meteorological droughts of northern region**

The assessment of meteorological drought of Pre-Kharif season, it was found that the highest number of extreme drought was two years in Dinajpur; three years severe drought in Bogra; five years moderate drought in Ishurdi and 14 years normal drought in Rajshshi and Ishurdi. The highest percentage of dry period was found in Ishurdi (55.56%) followed by Syedpur (52%), Rajshahi and Bogra (50%) in Pre-Kharif season. In Kharif season two extreme droughts in Rajshahi; three severe droughts in Dinajpur; 5 moderate droughts in Bogra and Ishurdi and 15 normal droughts in Bogra. The highest frequencies of dry period were 55.56% in Ishurdi, 52% in Syedpur and 50% in Bogra and Rajshahi. The highest numbers of severe and moderate droughts were five years in Ishurdi and six years in Dinajpur respectively in Rabi season.

**Meteorological droughts of southern and western region**

The highest number of severe drought was found in Satkhira and same result was found two years severe drought in Chuadanga, Khepupara, Khulna, Maijdi Court and Mongla stations. The large number of moderate drought was six years in Bhola and five years in Maijdi Court. highest normal drought was 18 years in Jessore and 17 years in Khulna and Patuakhali stations. The percentage of dry period was greater than 50% for all station in southern and western region during Pre-Kharif season.

**Meteorological droughts of central region**

In Pre-Kharif season, it is revealed that one year extreme drought in Comilla, Faridpur and Mymensingh station; 2 years severe droughts in Comilla, Dhaka, Faridpur and Tangail stations; six years moderate droughts in Madaripur station and maximum 16 years normal droughts in Dhaka and Comilla stations. The highest percentages of dry period were 55.56% in Comilla and Dhaka in Pre-Kharif season. Kharif season had the highest severe, moderate and normal drought years such as Faridpur- 3 years, Comilla- 5 years and Chandpur- 8 years respectively.

**Meteorological droughts of eastern region**

In pre-Kharif season, Sitakunda had the highest extreme drought years (two years), Sylhet and Teknaf had four years severe droughts, Kutubdia had highest moderate droughts (five years) and Sitakunda had 16 years normal droughts of total drought years. Among them the highest dry period frequency was found (55.56%) in Sitakunda. Feni and Teknaf station had the highest number of extreme drought years (two years) in Kharif season. In Rabi season three years extreme droughts occurred in Feni; four years severe droughts in Cox's Bazar, Rangamati, Sitakunda and Srimangal had occurred; none years moderate droughts in Sandwip and 17 years normal droughts in Sylhet during the study period. And the highest percentage of dry period was found (58.33%) in Sylhet station.

**Seasonal and spatial variation of droughts over different region of Bangladesh**

The changes and linear trends in drought areas (SPEI<-1) during 1980-2015 over three cropping season namely Pre-Kharif, Kharif and Rabi over different regions of Bangladesh. In case of Pre-Kharif season the most significant increasing trend of drought area was found in central region with a rate of 7.18%/10 years followed by southern and western region with a rate of 5.42%/10 years and northern region with a rate of 1.31%/10 years. Eastern region showed decreasing trend with a rate of 2.19%/10 years (Fig. 7). In Kharif season only northern region showed increasing trends with a rate of 2.63%/10 years and the other three regions namely central region, eastern region and southern and western regions had the decreasing trend 1.05, 3.02 and 3.02% per decade respectively (Fig. 8). Also in Rabi season the highest increasing rate of droughts areas were found in eastern region (11.11%) followed by northern region (8.22%), southern and western region (7.56%) and central region (6.79%) per 10 years. The most significant increasing trend of drought was found in Rabi season with a rate of 8.66%/10 years and Pre-Kharif season with a rate of 2.57%/10 years (Fig. 9).

Major findings of this study was Pre-Kharif and Rabi season the most vulnerable to meteorological drought that indicates high rainfall anomaly in most of the regions of Bangladesh. Most of the crops are cultivated in Kharif and Rabi seasons. Therefore, it is alarming to us to take proper crop management

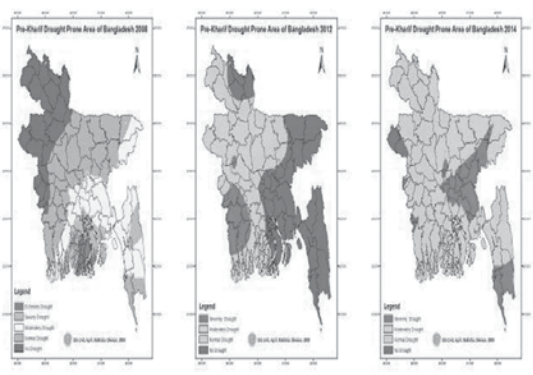


Fig. 7. Spatial distributions of meteorological drought in 2008, 2012 and 2014 of Pre-kharif season.

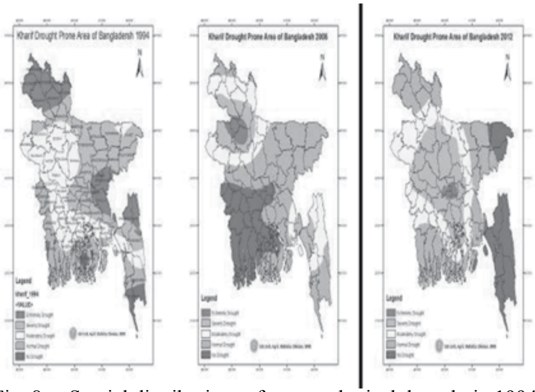


Fig. 8. Spatial distributions of meteorological drought in 1994, 2006 and 2012 of Kharif season.

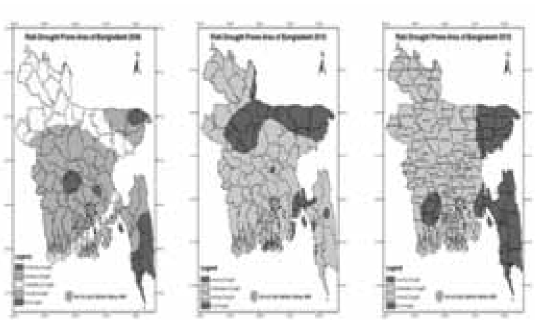


Fig. 9. Spatial distributions of meteorological drought in 2006, 2010 and 2012 of Rabi season.

against extreme conditions of meteorological droughts. It simultaneously affects the agricultural productivity, deficit of soil moisture, ground water level and socio economic problems in a drought hit region. So, agricultural planners and irrigation engineers can take necessary steps to mitigate drought vulnerability based on agro-climatic conditions of Bangladesh.

## RICE ZONING OF BRRI RICE VARIETIES

A major purpose of zoning is to put land to the use for which it is best suite. Some land is best left to be cultivated because of its unique soil characteristics. As every rice varieties has some unique characteristics, thus it has different suitable area for cultivation. So, variety wise rice zoning map is needed. BRRI dhan62 and BRRI hybrid dhan4 are very prospective varieties in T. Aman season. So, these two varieties zoning maps were done by using ArcGIS10 software and the whole process was mainly two steps. Step 1: suitability mapping, step 2: zonal mapping. Soil physical properties have been considered to determine suitable area (suitable, moderate/less suitable, not suitable) for growing particular rice varieties. soil physical have been weighted by the relative influence for suitability assessment. These weights have been the values of Percent Influence Field in the weighted overlay table of the Model Builder. Then finaly suitability map has been generated by using ArcGIS10 software. For step 2, upazila map has been superimposed on suitability map and suitable area (suitable, moderate/less suitable, not suitable) of each upazila has been calculated by map algebra tool, finally zonal map has been produced based on dominant suitability categories (suitable, moderate/less suitable, not suitable) covered by area of each upazila.

**Results and discussion**

Mainly top north-west and central north-west areas are suitable for BRRI dhan62 but central part of Bangladesh i.e. Gangeas flood plain, southern and eastern parts of Bangladesh are not suitable for BRRI dhan62. Here total 464 upazilas were considered, among them 128 upazilas were found under suitable zone, 164 upazilas were found under less suitable zone and 172 upazilas were found under not suitable zone. Figure 10 shows the zoning map of BRRI dhan62.

Few areas of north western side is suitable for BRRI hybrid dhan4. Middle part of Bangladesh is moderate suitable, eastern and southern sides are not suitable for BRRI hybrid dhan4. In this context 464 upazilas were considered, among them 52 upazilas were found under suitable zone, 221 upazilas were found under moderate suitable zone and 191 upazilas were found under not suitable zone. Figure 11 shows zoning map of BRRI hybrid dhan4. In a nut shell, it can be said that the northern side is suitable for cultivation of BRRI dhan62 and BRRI hybrid dhan4. But south and eastern sides are not suitable for both BRRI dhan62 and BRRI hybrid dhan4 cultivation.

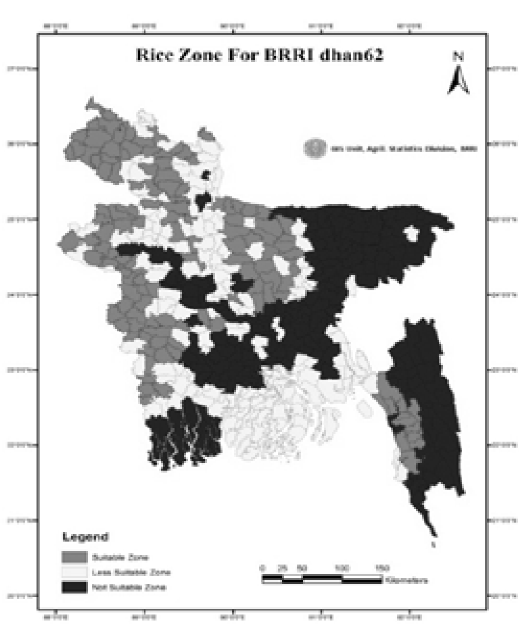



Fig. 10. Zoning map of BRRI dhan62.

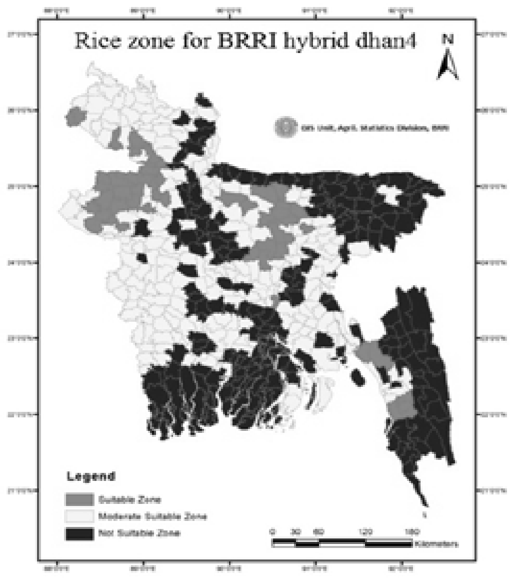



Fig. 11. Zoning map of BRRI hybrid dhan4.

IDENTIFYING SUITABLE AREA OF IRRIGATED RICE (BORO) BASED ON GROUNDWATER LEVEL CHANGE

Groundwater level condition varies spatially. So we need to find out spatial variation of groundwater level. As a result we could get suitable area of Boro cultivation i.e. irrigated rice. For this study, Natore district was selected which is under Rajshahi division, it falls into Barind tract and the northwestern part of Bangladesh.

The study was based on groundwater monitoring wells data of Bangladesh Water Development Board (BWDB). By GIS software contour map of groundwater depth (maximum, minimum and fluctuation) has been produced for the year 2015 to measure variability and flow direction of groundwater. Long-terms hydrographs has been produced by groundwater monitoring wells data to measure groundwater depth. Finally the suitable area has been identified.

### Groundwater depth contour map of minimum depth

With the start of the monsoonal rainfall the water table reaches to the highest elevation eventually minimum depth. The rising of water table refills the discharge. Generally, the minimum depth of water table occurs from July to September. The minimum depth water table contour map was prepared with 1 m interval (Fig. 12). Minimum depth varies from 1 to 9 m. Depth is very high in western and northern side of the study area and the high depth area covered by western side of Natore sadar, Bagatipara, Lalpur and northern side of Singra upazilas. On the other hand, depth is low central and eastern side of the study area and the low depth areas are covered by eastern side of Natore sadar, southern side of singra, Gurudaspur and Baraigram upazilas.

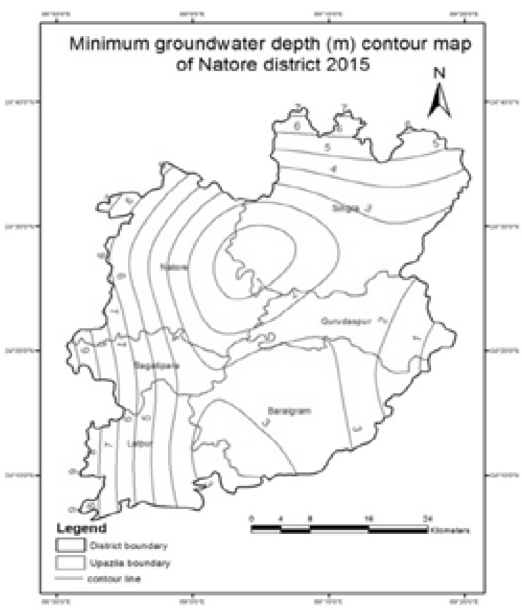



Fig. 12. Minimum groundwater depth contour map.

### Groundwater depth contour map of maximum depth

The maximum depth of the water table in the study area is measured at the driest period (January to March) of the year, where the maximum water is exploited by pumping through the tube wells. Groundwater depth contour map of maximum depth was prepared with 1 m interval (Fig. 13). Maximum depth varies from 5 to 15 m. Depth is very high in western side and moderate high in northern and eastern side of the study area. The high depth area are covered by western side of Natore sadar, Bagatipara, Lalpur upailas. Moderate high areas covered by northern side of Singra upazila and eastern side of Guruaspur and Bagatipara upazilas. On the other hand, depth is low central side of the study area and the low depth area are covered by eastern side of Natore sadar, southern side of Singra, Gurudaspur and Baraigram upazilas.

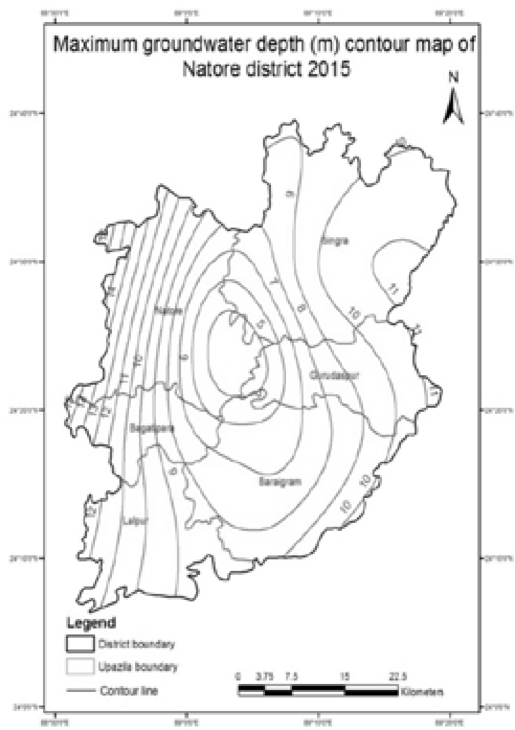



Fig. 13. Maximum ground depth contour map.

**Water table fluctuation depths contour map**

Within the study area, the fluctuation of groundwater level is ranged from 3 to 11m (Fig. 14) Fluctuation depth is very high in western and eastern side of the study area and the high fluctuation depth areas covered by western side of Natore sadar, Bagatipara upazilas and eastern side of Singra, Gurudaspur and Baraigram upazilas. On the other hand, fluctuation depth is low central, northern and southern side of the study area and the low fluctuation depth area are covered by eastern side of Natore sadar, Bagatiparta, weastern side of Gurudaspur and Baraigram upazilas and northern side of Lalpur upazila. It is noticeable that in western side of the study area minimum, maximum and fluctuation depths are high, eastern side fluctuation depth are high and maximum depths are moderate and low minimum depth. On the other hand in central part all minimum, maximum and fluctuation depths are low. Thus by the analysis of groundwater depth contour maps primarily we classified hole Natore district into three regions western, central and eastern side.

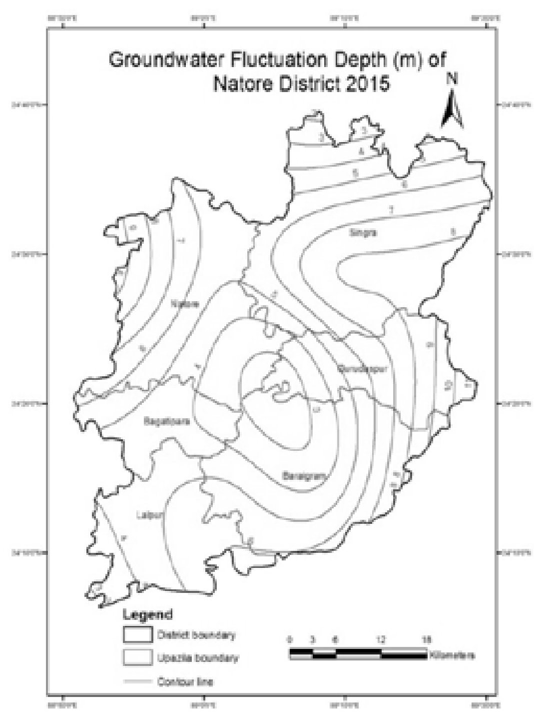



Fig. 14. Groundwater fluctuation depth contour map.

**Suitable area for Boro cultivation**

From the groundwater depth contour maps of minimum, maximum and fluctuation depths, it is found that groundwater condition in the western side was critical, eastern side and few areas of top most northern side were in moderate condition and central area was in good condition. Long term hydrographs of these three areas implies the same results as contour maps analysis. Thus we tried to the apparent condition for Boro suitability area of Natore district (Fig. 15).

ICT ACTIVITIES

**Online application system**

ICT Cell, Agricultural Statistics Division of BRRI will introduce online application system to decrease hassles of applicants for job application. It also reduces time of job applications processing for employer. Online application system developed by Teletalk Mobile Company Ltd. with the help of ICT Cell of Agricultural Statistics Division as well as Administration of BRRI.

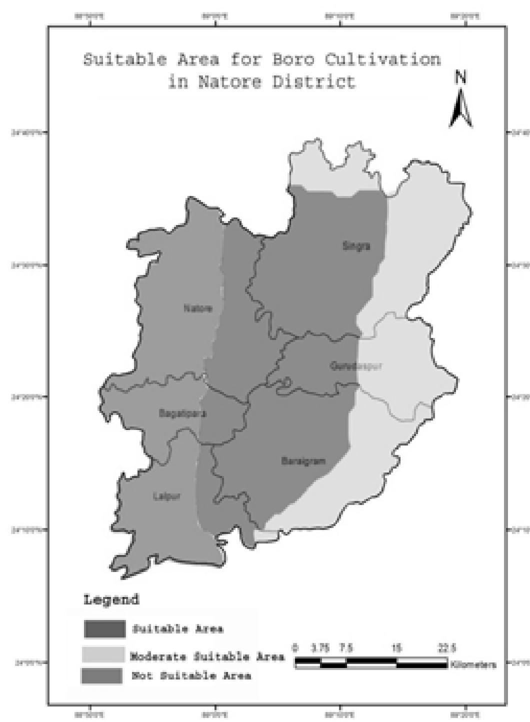



Fig.15. Suitable area for Boro.

**e-File (Nothi) management system**

BRRI has taken initiative to ensure a paper less office management system through e-Filing (Nothi) system. "e-File Management Software" is used by the administration and all the divisions of BRRI. e-File (Nothi) Management System is already introduced at BRRI with the help of A2i, Prime Minister's Office (PMO) on 24 September 2016.

**Mobile Apps of RKB (Rice Knowledge Bank)**

Mobile application of RKB has hosting at Google play store and also available at android-based smart phone. So anybody can download it from Google play store of any android mobile. It is regularly updating having varietal information regarding 85 varieties and associated technologies. It has included rice cultivation methods, soil and fertilizer management, insects and their management, diseases and their management, irrigation and water management.

**e-Tender system**

ICT cell of Agricultural Statistics Division has started an e-Tender related activities as the part of the Central Procurement Technical Unit (CPTU), IMED. The objectives are to develop 'e-Tender system' of BRRI as per requirement of the Ministry of Agriculture (MoA) introducing the online tendering system to facilitate the procurement process of BRRI. BRRI introduced e-Tender on 1st July of 2016. With this BRRI has become first organization among the NARS institutes and also a first organization under the Ministry of Agriculture (MoA). BRRI has already submitted 56 tenders into e-GP portal and the submission process is continuing under the provisions of the Public Procurement Act-2006 and the ICT Policy Act-2009.

**BRRI web portal management**

ICT Cell of Agricultural Statistics Division has developed the web portal of BRRI, using both English and Bangla. BRRI web portal (*www.brri.gov.bd*) has been registered with BTCL. At present, BRRI website is hosted into Bangladesh Computer Council (BCC) server. We have included rice database, climate database etc. at BRRI dynamic website and it is updated regularly. We developed individual web page including picture of headquarter and all BRRI regional stations for making it more updated and informative.

**Facebook group (BRRI networks)**

The main purpose of this work is to create a Facebook group for BRRI to promote all activities, where only official interactions, various problems and their solutions can be posted and creating a big forum for all kinds of scientists, officers and staffs of BRRI. BRRI introduced Facebook group as per instruction from Ministry of MoA. It is aimed to build a linkage among all scientists, officers and staffs, where BRRI Networks play an important role. BRRI Network group is regularly updated by skilled ICT employees.

**Management of local area network and internet connectivity**

The main purpose of this activity is to manage and maintain ICT network and internet connectivity of BRRI also managed and maintained BRRI local area network (LAN) and initiate e-Governance. We have increased our digital data network (DDN) bandwidth connectivity from 35 Mbps to 40 Mbps. Now our internet speed is faster than the previous one. We established LAN connectivity at five regional stations i.e. Rangpur, Barisal, Sonagazi, Comilla and Habiganj. It increased 2 Mbps full duplex, dedicated and 3.5G (3.5 Generation) internet bandwidth at four regional stations i.e. Rangpur, Sonagazi, Comilla and Habiganj. We also established WiFi connection at five regional stations i.e. Rangpur, Barisal, Sonagazi, Comilla and Habiganj.

**BRKB website management**

Rice Knowledge Bank (BRKB) has been developed in order to provide all necessary information about various technologies and techniques regarding modern rice cultivation methods. BRKB has been modernized over the years by adding the latest findings about modern rice production technologies. It updates regularly with latest information of Aus, Aman and Boro rice varieties included latest variety of BRRI dhan80 and BRRI hybrid dhan6 with the help of Training and concerned divisions. Agricultural extension personnel as well as the farmers, scientists, teachers, students and other stake holders can use it easily as a free online service (http://knowledgebank-brri.org) through a space.

**Personal data sheet (PDS)**

The objectives of this work are to develop PDS database for all scientists, officers and staffs of BRRI, we are maintaining PDS database using user name and password as well as getting BACKUP of PDS database regularly. We have increased 339 users into BRRI PDS software. It is a continuous process. PDS database is updated regularly with latest information.

**Web mail and group mail**

The objectives of this work are to develop Web mail for all scientists and officers of BRRI for research and administration works and to develop Group mail for all scientists and officials of BRRI for research and administrative works. We have created individual e-mail ID into BRRI domain for all scientists and all officers as per requirement of the Ministry of Agriculture (MoA). We have created group mail for all scientists as per requirement of BRRI scientists.

**Management information system (MIS)**

The objectives of this work is to manage and maintain BRRI MIS, get BACKUP of MIS (9 modules) every day. Data input process is continuing in every module. It is a continuous process. ICT cell of Agricultural Statistics division provide MIS software related support services such as create user, permission and access MIS modules, installation etc.

**Video conference system**

The main objective is to develop video conference system of BRRI to connect administration, all divisional and regional station heads of BRRI for research and administration works. We have created Skype account for all divisional and regional station heads. The communication between BRRI headquarters and other regional stations has been enhanced by video conference system in monthly coordination meeting.

**Heritage of BRRI**

The objectives of this work are to develop a heritage for all retired scientists, officers, staffs and labourers of BRRI. It is aimed at fulfilling awareness among the present employees of BRRI about retired scientists and officers' activities. So that they can follow their instructions and know about their works and importance of preserving their documents as a digital format in the BRRI web portal. It is updating regularly.

**Achievement**

BRRI was awarded National Information and Communication Technology (ICT) Award-2016 (Figs. 16 and 17) at Digital World Fair 2016 for ICT excellence through innovative service delivery specially for developing Rice Knowledge Bank (RKB) mobile app.

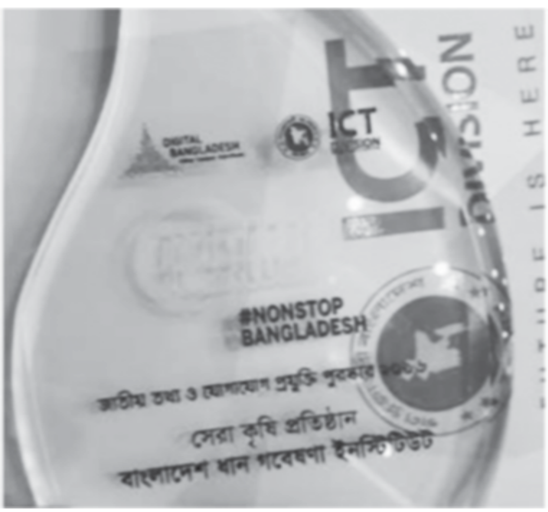



Fig. 16. National ICT Award-2016 of BRRI


Fig. 17. BRRI developed mobile apps Rice Knowledge Bank (RKB).

SUPPORT SERVICES

The scientists of this division are also engaged in helping scientists of other disciplines in planning experiments, statistical data analysis and interpretation of results. Fifty-five different types of analyses were performed during the reporting year. A number of maps were prepared using GIS and supplied to the scientists of other divisions whenever required. ICT cell of Agricultural Statistics Division has taken initiative in accordance with government perspectives but 'BRRI Network' group is first introduced among all National Agricultural Research System (NARS) and also first among all research institutes. The ICT cell of Agricultural Statistics Division provides e-Filing management system and and e-Tender related support services to other divisions, administration and procurement sections. Also, we provide hardware, network and internet related support services to other divisions.

# Farm Management Division

In seed quality experiment, sixteen August planting gave higher grain yield than that of 12 September. Among the varieties, BRRI dhan46 was the highest yielder than BRRI dhan40 and BRRI dhan41. Considering seed quality, 16 August planting performed better than that of 12 September. In case of varieties, BRRI dhan46 was the best in terms of GM%, HDG%, SDW and RDW. In seedling age experiment, 15-day-old seedling produced the highest number of tiller per hill from 15 to 120 DAT. The lowest number of tillers was recorded in 40-day-old seedling in all the sampling dates. The highest grain yield (5.23 t/ha) obtained from 15-day-old seedling followed by 20, 25, 30, 35 and the lowest (4.11 t/ha) in 40-day-old seedling. In BRRI, Gazipur farm, no need to four to five ploughing followed by laddering for land preparation. Land can be prepared as one ploughing followed by removal of grass by hand and then laddering or herbicide application followed by one ploughing and laddering. BRRI recommended fertilizer produced the tallest plant, highest number of tiller $m^{-2}$, panicle $m^{-2}$, grain $panicle^{-1}$ and grain yield than kitchen waste, poultry litter and bio-slurry. Evaluation of Shamolbangla bio-fertilizer on rice revealed that BRRI recommended fertilizer gave the highest grain yield 7.5 t/ha in Boro and 7.15 t/ha in T. Aman season. Average wage rate of labour per day throughout the year varies from Tk 440-485. During May, July-August and December- January, it was Tk 480-530, 480-500 and 450-500 respectively. In the reporting period Farm Management Division produced 24,308 kg rice of which 15,457, 565 and 8286 kg was seed, non-seed and mixed rice respectively. Moreover 6,299 kg breeder seed was produced. BRRI has 766 labourers of which 508 are regular and the rest 258 are irregular. BRRI HQ 474 labourers of which 330 are regular and 144 irregular. BRRI has 274 ha land of which 163 ha was cultivable. Total labour utilization in different divisions was 1,88,252 man days of which 52.02, 41.59 and 3.39% were utilized for research, support service and holidays, respectively. About 72.87 ha land was cultivated by different research divisions of which 6.95 ha in Aus, 32.54 ha in Aman and 33.38 ha in Boro season. Flower gardens have been maintained for the beautification of BRRI campus during winter and summer season.

## RESEARCH ACTIVITIES

**Seed quality of different T. Aman rice as affected by rainfed (drought) in ripening (seed formation) phase**

This experiment was conducted at the West Byde of BRRI farm, Gazipur during T. Aman 2016 to investigate the seed quality of rice that are affected by rain fed condition during reproductive and ripening phases. The treatments were two planting dates ($D_1$= 16 August and $D_2$= 12 September) and three rice varieties ($V_1$= BRRI dhan40, $V_2$= BRRI dhan41 and $V_3$= BRRI dhan46). The treatments were arranged in a Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 4 × 3 m. Yield and yield components data were taken. The germination percentage (GM%), seedling vigour index (SVI), high density grain (HDG%), shoot dry weight (SDW), and root dry weight (RDW) of seeds of harvested crop were also taken for observing the performance of seed quality. The collected data were analyzed using Crop Stat Software programme.

**Yield and yield components.** The interaction between planting dates and variety was insignificant in all the parameters of yield and yield components. Therefore, only the main effect has been described below:

**Effect of planting dates on yield and yield components.** The planting dates had significant effect on yield and yield components (Table 1). Sixteen August planting gave higher number of tillers $m^{-2}$, panicles $m^{-2}$, grain $panicle^{-1}$, 1000-grain weight (TGW), grain and straw yield. The grain yield significantly decreased in 12 September planting might be due to decrease in rainfall, temperature and solar radiation during reproductive and ripening phases (Table 1 and Figs. 1 and 2).

**Effect of variety on yield and yield components.** Panicles $m^{-2}$, grain $panicle^{-1}$ and TGW were significantly affected by planting dates but number of tillers m,$^{-2}$ grain and straw yield were not significantly affected by planting dates (Table 1). BRRI dhan46 gave the highest grain yield (4.12 t/ha) due to the highest number of panicles $m^{-2}$, grain $panicle^{-1}$ and TGW.

**Seed quality.** The interaction between planting dates and variety was not significant on seed quality such as germination percentage (GM%), seedling

**Table 1. Yield and yield components of rice as affected by the planting date and variety in T. Aman 2016.**

| Treatment | Tiller $m^{-2}$ (no.) | Panicle $m^{-2}$ (no.) | Grain $panicle^{-1}$ (no.) | 1000- grain wt. (g) | Grain yield ($t\ ha^{-1}$) | Straw yield ($t\ ha^{-1}$) |
|---|---|---|---|---|---|---|
| | | | *Planting date* | | | |
| 16 August | 229 | 199 | 96 | 24.16 | 4.49 | 6.00 |
| 12 Sept | 206 | 184 | 89 | 22.58 | 3.49 | 5.41 |
| LSD at 5% level | 12.95 | 2.27 | 2.51 | 1.06 | 0.49 | 0.58 |
| | | | *Varietiy* | | | |
| BRRI dhan40 | 219 | 190 | 92 | 22.30 | 3.94 | 5.70 |
| BRRI dhan41 | 214 | 189 | 91 | 23.68 | 3.91 | 5.57 |
| BRRI dhan46 | 221 | 194 | 96 | 24.13 | 4.12 | 5.86 |
| LSD at 5% level | ns | 2.78 | 3.07 | 1.30 | ns | ns |

In a column, different small letters indicate the differences among treatments, ns=Not significant.

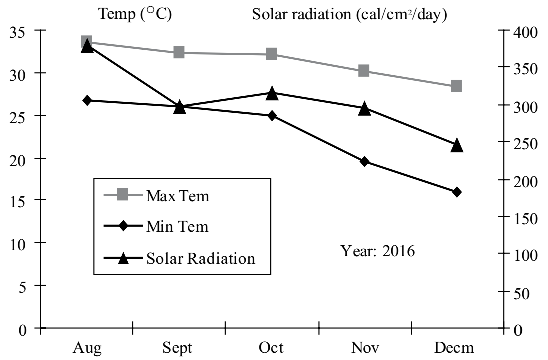



Fig. 1. Monthly number of rainy days and monthly total rainfall, T. Aman 2016.

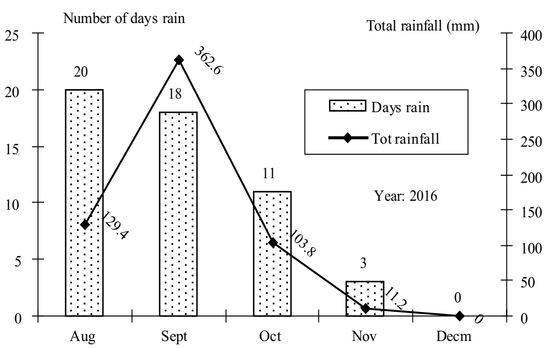



Fig. 2. Maximum and minimum temperature and solar radiation, T. Aman 2016.

vigour index (SVI), high density grain (HDG%), shoot dry weight (SDW) and root dry weight (RDW) (Table 2).

**Effect of planting dates on seed quality.** The SVI and HDG% were significantly affected by planting dates but GM%, SVI, SDW and RDW were not significantly affected by planting dates. All of these parameters performed better in 16 August planting than 12 September planting.

**Effect of variety on seed quality.** Variety had significant effect on GM% and HDG%. The highest GM% (94.66) was recorded in BRRI dhan46 followed by BRRI dhan41 and the lowest in BRRI dhan40 (90.66). The SVI was the highest in BRRI dhan41 and the lowest in BRRI dhan40. The HDG% also followed the same trend as GM%. The SDW was the highest in BRRI dhan46 (45.0 mg) followed by BRRI dhan41 and the lowest in BRRI dhan40 (30.0 mg). The variety had no significant effect on RDW but it was the highest in BRRI dhan46 (45.0 mg) and BRRI dhan40 (45.0 mg) and the lowest in BRRI dhan41 (36.66 mg).

Therefore it may be concluded that sixteen August planting gave higher grain yield than that of 12 September. Among the varieties, BRRI dhan46 was the highest yielder than BRRI dhan40 and BRRI dhan41. Considering seed quality, 16 August planting performed better than that of 12 September. In case of varieties, BRRI dhan46 was the best in terms of GM%, HDG%, SDW and RDW.

**Effect of seedling age on the growth, yield and yield components of rice**

This experiment was conducted at the West Byde of BRRI farm, Gazipur during T. Aman 2016 to determine the tillering pattern, growth, yield and yield components rice as affected by seedling age. The treatments were six different ages of seedling such as 15, 20, 25, 30, 35, and 40 days. The variety BRRI dhan46 was used in this experiment. The treatments were arranged in RCBD with three replications. The unit plot size was 4 × 4 m. One seedling per

**Table 2. Seed quality of rice as affected by the planting date and variety, T. Aman 2016.**

| Treatment | GM % | SVI | HDG % | SDW of 10 Seedling (mg) at 10 days old | RDW of 10 Seedling (mg) at 10 days old |
|---|---|---|---|---|---|
| | | | *Planting date* | | |
| 16 August | 93.11 | 1284.33 | 84.70 | 35.55 | 35.55 |
| 12 Sept | 92.11 | 1214.33 | 85.65 | 50.00 | 48.88 |
| LSD at 5% level | ns | 189.80 | 1.19 | 26.75 | 28.80 |
| | | | *Variety* | | |
| BRRI dhan40 | 90.66 | 1165.00 | 83.59 | 30.00 | 45.00 |
| BRRI dhan41 | 92.50 | 1309.67 | 85.06 | 40.00 | 36.66 |
| BRRI dhan46 | 94.66 | 1273.33 | 86.89 | 45.00 | 45.00 |
| LSD at 5% level | 2.42 | ns | 1.46 | ns | ns |

In a column, different small letters indicate the differences among treatments, ns=Not significant. (GM%=Germination percentage, SVI=Seedling vigour index, HDG%=High density grain).

hill at 20 × 20 cm spacing was transplanted. Tillers were counted from transplanting to maturity with 15 days intervals. Dry weight of leaf, stem and panicle were taken at 15 days interval from 15 days after transplanting (DAT) to maturity of crop. Yield and yield components data were also taken at maturity. The collected data were analyzed using Crop Stat Software programme.

**Tiller production.** The number of tillers produced at different DAT was significantly affected by seedling ages (Fig 3). Regardless of seedling ages, the tiller number gradually increased with the DAT and reached maximum at 45 DAT then gradually decreased and reached minimum at ripening and maturity stage i.e. 105 to 120 DAT. Fifteen-day-old seedling produced the highest number of tiller per hill from 15 to 120 DAT which was statistically identical with the tiller number produced from 20 and 25-day-old seedling. The lowest number of tillers was recorded in 40-day-old seedling in all the sampling dates, which was statistically similar to the tiller number produced from 35-day-old seedling.

**Dry matter production.** The dry matter weight of leaves stems and panicles were recorded at 15 days interval from transplanting to maturity of the crop as affected by seedling ages (Fig 4). Irrespective of seedling age, the stem dry weight of all seedling ages increased gradually and reached maximum at 75 to 90 DAT (flowering stage) then decreased and reached minimum at maturity stage. The leaf dry weight also followed the same trend as stem dry weight. The panicle dry weight in all the treatments sharply increased from flowering to maturity stage. The panicle dry weight of lower seedling ages at 105 DAT and maturity stage was

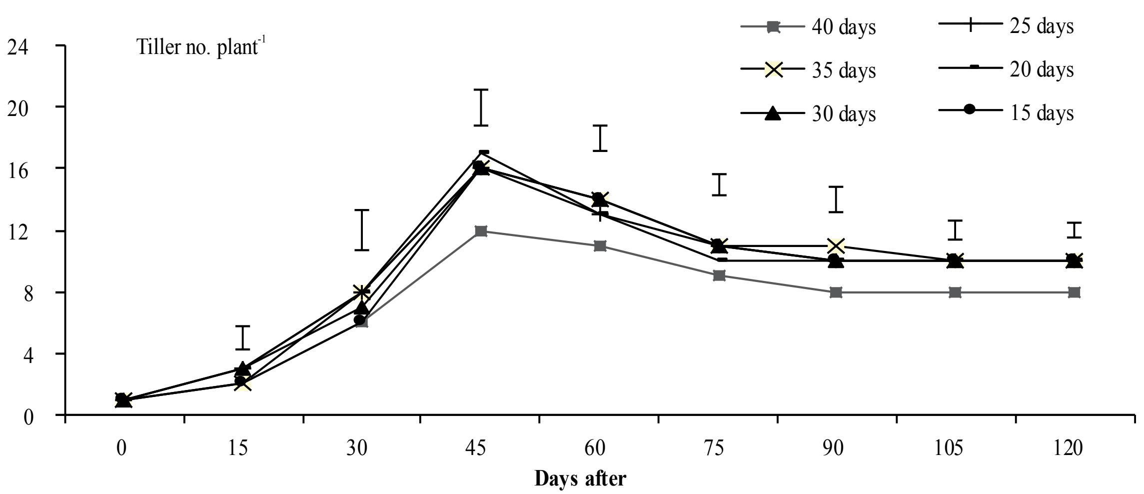



Fig. 3. Tiller number at different days after transplanting (DAT) as affected by seedling ages (Vertical bar represent the LSD (0.05) value indicates the differences between different seedling ages under same sampling date).

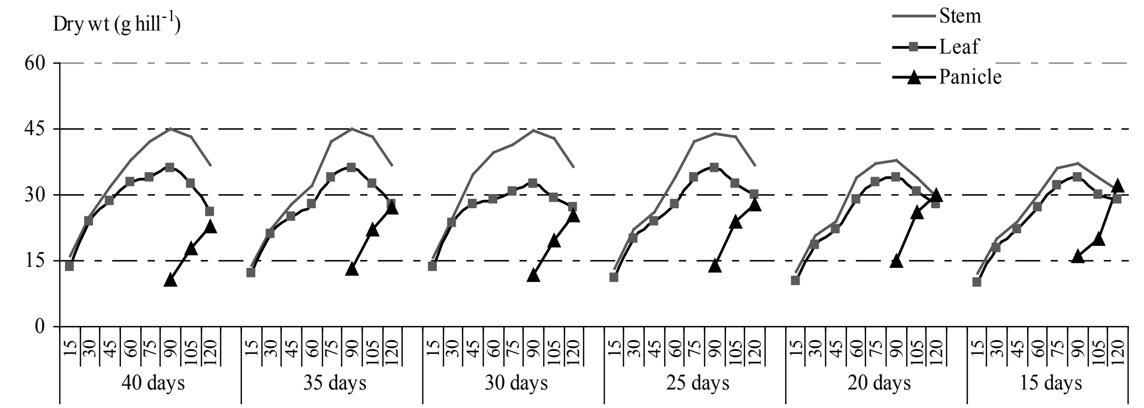



Fig. 4. Dry matter changes in leaves, stems and panicles of rice at different days after transplanting (DAT) as affected by different seedling ages.

comparatively higher than the older seedling ages. It has been observed that stem and leaf dry weight increased up to flowering stage after that decreased but panicle dry weight increased from flowering to maturity indicating that dry matter transferred from stem and leaf to the panicles.

**Yield and yield components.** The tiller number $m^{-2}$, panicle number $m^{-2}$, grain $panicle^{-1}$ and grain yield were significantly affected by seedling age but TGW and straw yield were not significantly affected by seedling age (Table 3).

**Tiller number.** The 15-day-old seedling produced the highest number of tiller. The tiller number $m^{-2}$ decreased gradually with increasing seedling age and the lowest number of tiller was recorded in 40-day-old seedling. Fifteen to 30-day-old seedling gave statistically similar number of tiller $m^{-2}$.

**Panicle number.** The panicle number $m^{-2}$ also increased with decreasing seedling age. It was the highest in 25-day-old seedling, which was statistically identical with the number of panicle produced from 15 to 35-day-old seedling. Forty-day-old seedling gave the lowest number of panicle.

**Grain number.** Fifteen to 35-day-old seedling produced higher number of grain $panicle^{-1}$ which was statistically identical. Forty-day-old seedling gave the lowest number of grain $panicle^{-1}$.

**Grain yield.** The highest grain yield (5.23 t/ha) was observed in 15-day-old seedling transplanted plot which was statistically identical with 20, 25, 30 and the lowest (4.11 t/ha) was in 40-day-old seedling.

It is concluded that yield and yield components was higher in younger seedling used plot that produced more tillers and panicles. The plants those are produced from younger seedlings translocated more carbohydrate from source to sink might be the reason of higher yield in younger seedling used plot.

**Effect of different tillage operations on the productivity and profitability of rice cultivation**

This experiment was conducted during T. Aman 2016 and Boro 2016-17 seasons in three fields of

**Table 3. Yield and yield components of rice as affected by different seedling ages.**

| Seedling ages | Tiller $m^{-2}$ (no.) | Panicle $m^{-2}$ (no.) | Grain $panicle^{-1}$ (no.) | 1000- grain wt. (g) | Grain yield ($t\ ha^{-1}$) | Straw yield ($t\ ha^{-1}$) |
|---|---|---|---|---|---|---|
| 40 days | 246 | 236 | 84 | 22.87 | 4.11 | 5.01 |
| 35 days | 254 | 243 | 94 | 23.27 | 4.67 | 4.97 |
| 30 days | 258 | 253 | 93 | 23.87 | 5.08 | 5.16 |
| 25 days | 260 | 259 | 94 | 23.60 | 5.11 | 5.30 |
| 20 days | 261 | 251 | 90 | 22.95 | 5.12 | 5.36 |
| 15 days | 262 | 253 | 92 | 22.88 | 5.23 | 5.38 |
| LSD at 5% level | 6.63 | 11.49 | 3.02 | ns | 0.63 | ns |

In a column, different small letters indicate the differences between treatments, ns=Not significant.

West Byde of BRRI farm, Gazipur to find out the suitable tillage operation for rice cultivation. The treatments were- $T_1$= Normal cultivation practices i.e. four ploughing followed by laddering, $T_2$ = Herbicide application followed by one ploughing and laddering and; $T_3$= One ploughing then removal of grass by hand followed by laddering. In each location the treatments were non-replicated i.e. full set of treatments were replicated in three locations called dispersed replication. The variety BRRI dhan49 and BRRI dhan29 were used in T. Aman and Boro season respectively. The unit plot size was 25 × 10 m irrespective of season. Labour requirements for different operations such as land preparation, seedling uprooting, transplanting, weeding, harvesting, threshing and winnowing were done through direct supervision. Data of three locations of each treatment was averaged and mean data were presented.

The labuor requirement from seed bed preparation to harvesting in $T_1$, $T_2$ and $T_3$ treatments was 266, 249 and 264 md $ha^{-1}$ respectively in T. Aman season. But in Boro season it was 282, 265 and 280 md $ha^{-1}$ in $T_1$, $T_2$ and $T_3$, respectively (Table 4). The cost for land preparation in T. Aman season was Tk 6500, 2600 and 5,800 in $T_1$, $T_2$ and $T_3$ treatments, respectively (Table 5). But in Boro season it was same for $T_1$ and $T_2$ but about 12% higher in $T_3$ due to higher number of labour involved for removal of grass. Generally, irrespective of treatment higher number of labour required in Boro season due to more number of labours required for shorter type of seedling uprooting and transplanting. In both the seasons $T_2$ required the lowest number of labour. Irrespective of season, the grain yield had no significant difference in different treatments. In both the seasons, total variable cost was the highest in normal cultivation practices followed by removal of straw/grass by hand and the lowest in herbicide applied plot. Total variable cost was higher in Boro season due to higher cost of irrigation, fertilizers and labourers. In both the seasons the highest gross margin was obtained from $T_2$ hence the cost of per kg rice was the lowest in $T_2$. It was Tk 26.60 and Tk 25.65 in Aman and Boro season respectively. Irrespective of treatment, the BCR was higher in Boro than Aman. In Aman, it was 1.08, 1.17 and 1.09 in $T_1$, $T_2$ and $T_3$ respectively. In Boro

**Table 4. Labour requirement (md $ha^{-1}$) of different tillage operations for rice cultivation in T. Aman 2016 and Boro 2016-17 seasons.**

| | Seed bed preparation, seedling uprooting etc | | Transplanting | | 1st weeding | | 2nd weeding | | Harvesting | | Carrying threshing cleaning drying | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aman | Boro | Aman | Boro | Aman | Boro | Aman | Boro | Aman | Boro | Aman | Boro | Aman | Boro |
| $T_1$ | 26 | 28 | 58 | 58 | 40 | 44 | 30 | 34 | 44 | 48 | 68 | 70 | 266 | 282 |
| $T_2$ | 26 | 28 | 58 | 58 | 30 | 34 | 25 | 29 | 44 | 48 | 66 | 68 | 249 | 265 |
| $T_3$ | 26 | 28 | 58 | 58 | 40 | 44 | 30 | 34 | 44 | 48 | 66 | 68 | 264 | 280 |

Labour wage Tk 450 per labour.

**Table 5. Cost (Tk $ha^{-1}$) of different tillage operation for rice cultivation in Aman 2016 and Boro 2016-17 season.**

| Cost item | Aman (BRRI dhan49) | | | Boro (BRRI dhan29) | | |
|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | T3 | $T_1$ | $T_2$ | $T_3$ |
| Land preparation: Diesel, driver, labour and herbicide | 6,500 | 2,600 | 5,800 | 6,500 | 2,600 | 5,800 |
| Labour for different operation | 1,19,700 | 1,12,050 | 1,18,800 | 1,26,900 | 1,19,250 | 1,26,000 |
| Seed | 700 | 700 | 700 | 700 | 700 | 700 |
| Fertilizer | 6,574 | 6,574 | 6,574 | 12,000 | 12,000 | 12,000 |
| Insecticide | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| Irrigation | 8,500 | 8,500 | 8,500 | 24,000 | 24,000 | 24,000 |
| Total variable cost (TVC) | 1,51,974 | 1,40,424 | 1,50,374 | ,180,100 | 1,68,550 | 1,78,500 |

Labour wage Tk 450 per labour. Price of rice and straw per kg: TK 27.5 and TK 3.0, respectively.

season, it was 1.17, 1.20 and 1.11 in $T_1$, $T_2$ and $T_3$ respectively. Gross margin showed that in Aman season, application of $T_2$ instead of $T_1$ and $T_3$ Tk 24,216-12,886 ha$^{-1}$ = Tk 11,330 ha$^{-1}$ and Tk 24,216-13,656 = Tk 10,560 ha$^{-1}$, respectively will be more profitable (Table 6). But in Boro season, application of $T_2$ treatment instead of $T_1$ and $T_3$ Tk 34,175-30,785 ha$^{-1}$ = Tk 3,390 ha$^{-1}$ and Tk 34,175-20,475 = Tk 13,700 ha$^{-1}$, respectively will be more profitable. The conclusion is that there is no need to four/five ploughing followed by laddering in land preparation of BRRI Gazipur farm. Land can be prepared as: Option 1: One ploughing followed by removal of grass by hand and laddering or Option 2: Herbicide application followed by one ploughing and laddering is sufficient.

**Effect of organic matter on soil properties and rice yield**

This experiment was initiated on a permanent layout at the BRRI farm, Gazipur since 2016 during T. Aman season. Five treatments in RCBD with three replications were imposed and each treatment was assigned in 4-m × 5-m sized plot. The treatments were different sources of soil nutrient such as i) BRRI recommended fertilizer dose, ii) Kitchen waste, iii) Cowdung bio-slurry; iv) Poultry litter and v) control (No nutrient supply). Kitchen waste, Cowdung bio-slurry and Poultry litter were applied as 3 tha$^{-1}$ (dry weight base) in Aman and 4 tha$^{-1}$ in Boro season. All manures, soil and plant samples analysis were done with the help of Soil Science Division of BRRI. Initial soil (0-15 cm depth) properties were: soil texture-clay loam; pH-7.0; organic matter-1.40%; Nitrogen-0.20%; Phosphorus-0.25% and Potassium-0.24%. Kitchen waste had 2.94% OC, 0.72% N, 0.62% P, and 0.74% K; in T. Aman and in Boro season 7.25% OC, 0.75% N, 0.69% P, and 0.70% K. In T. Aman Cowdung bio-slurry had 7.74% OC, 0.69% N, 0.59% P, 0.31% K and in Boro season 9.5% OC, 0.73% N, 0.76% P, 0.90 K. In T. Aman poultry litter had 6.5% OC, 0.94% N, 1.20% P, 0.21% K and 3.9% OC, 1.05% N, 1.20% P, 0.65% K in Boro season. Thirty-day-old seedling of BRRI dhan49 in T. Aman and 45-day-old seedling of BRRI dhan58 in Boro season were transplanted at 20 × 20-cm spacing. The irrigation water level at 5-7 cm was maintained and drained out the water 21 days before rice harvesting. Rice plants were collected before flowering and at harvesting stage for analysis of N, P, and K content and nutrient uptake based on BRRI standard methods. Collected data were statistically analyzed using a standard statistical procedure (R-software 1).

Grain yield, tiller number, panicle number, plant height and straw yield were significantly affected by the different effect of organic matter in both T. Aman and Boro seasons. BRRI recommended dose performed the best in all parameter except TGW. On the other hand control plot (No nutrient supply) gave the lowest result. Tables 7 and 8 present the related data.

**Evaluation of Shamolbangla bio-fertilizer on the yield and pest incidence**

This experiment was conducted to evaluate of Shamolbangla bio-fertilizer on the yield and yield components and pest incidence at the West Byde of BRRI farm, Gazipur during T. Aman 2016 and Boro 2016-17 following RCRD with three replications. Three treatments viz, $T_1$: 120 kg/acre mixed fertilizer (mixing of 96 kg Shamol Bangla and 24 kg urea) before final land preparation, $T_2$:

**Table 6. Yield, gross return, gross margin, cost of production of per kg rice and BCR for different tillage of rice cultivation in Aman 2016 and Boro 2016-17 seasons.**

| Item | Aman (BRRI dhan49) | | | Boro (BRRI dhan29) | | |
|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | T3 | $T_1$ | $T_2$ | $T_3$ |
| Grain yield (t ha$^{-1}$) | 5.3 | 5.28 | 5.26 | 6.87 | 6.57 | 6.45 |
| Straw yield (t ha$^{-1}$) | 6.35 | 6.48 | 6.46 | 7.32 | 7.35 | 7.2 |
| Gross return (Tk ha$^{-1}$) | 1,64,800 | 1,40,424 | 1,64,030 | 2,10,885 | 2,02,725 | 1,98,975 |
| Total variable cost (Tk ha$^{-1}$) | 1,51,914 | 1,40,424 | 1,50,374 | 1,80,100 | 1,68,550 | 1,78,500 |
| Gross margin (Tk ha$^{-1}$) | 12,886 | 24,216 | 13,656 | 30,785 | 34,175 | 20,475 |
| Cost of production (Tk kg$^{-1}$ rice) | 28.66 | 26.60 | 28.59 | 26.21 | 25.65 | 27.67 |
| BCR | 1.08 | 1.17 | 1.09 | 1.17 | 1.20 | 1.11 |

Price of rice and straw per kg : Tk 27.5 and Tk 3.0 respectively.

**Table 7. Yield and agronomic parameter of for different nutrient management practices during T. Aman 2016 and Boro 2016-17 in BRRI farm, Gazipur.**

| Treatment | Plant height (cm) | Tiller $m^{-2}$ (no.) | Panicle $m^{-2}$ (no.) | Grain $panicle^{-1}$ (no.) | 1000 grain wt (g) | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| *T. Aman 2016 (BRRI dhan49)* | | | | | | | |
| Control | 98.6 | 190 | 169 | 153 | 19.00 | 4.32 | 4.93 |
| BRRI dose | 108.8 | 215 | 200 | 174 | 20.10 | 5.56 | 6.36 |
| Kitchen waste (3 $tha^{-1}$) | 102.1 | 202 | 187 | 172 | 20.03 | 5.15 | 5.88 |
| Bio-slurry for cow-dung (3 $tha^{-1}$) | 100.3 | 198 | 179 | 156 | 20.85 | 4.73 | 6.12 |
| Poultry litter(3 $tha^{-1}$) | 100.5 | 199 | 177 | 168 | 20.57 | 5.09 | 5.41 |
| LSD at 5% level | 3.6 | 11.25 | 7.3 | 8.76 | ns | 0.40 | 0.45 |
| *Boro 2016-17 (BRRI dhan58)* | | | | | | | |
| Control | 76.5 | 225 | 184 | 107 | 21.44 | 2.05 | 2.42 |
| BRRI dose | 99.10 | 314 | 305 | 142 | 22.50 | 5.99 | 5.94 |
| Kitchen waste (4 $tha^{-1}$) | 80.70 | 288 | 248 | 120 | 22.26 | 3.15 | 3.56 |
| Bio-slurry for cow-dung (4 $tha^{-1}$) | 77.93 | 259 | 225 | 121 | 22.24 | 2.95 | 3.35 |
| Poultry litter (4 $tha^{-1}$) | 86 | 265 | 233 | 127 | 22.56 | 4.31 | 4.21 |
| LSD at 5% level | 2.76 | 12.11 | 12.99 | 7.14 | 0.78 | 0.48 | 0.53 |

**Table 8. Nutrient input, uptake and balance in T. Aman 2016 and Boro 2016-17.**

| Treatment | Nutrient input (kg/ha) | | | Nutrient uptake (kg/ha) | | | Balance (kg/ha) | | |
|---|---|---|---|---|---|---|---|---|---|
| | N* | P | K | N* | P | K | N* | P | K |
| *T. Aman, 2016* | | | | | | | | | |
| Control | 0.00 | 0.00 | 0.00 | 60.80 | 15.15 | 30.30 | -60.8 | -15.15 | -30.30 |
| BRRI dose | 92.00 | 13.00 | 42 | 91.40 | 18.00 | 57.70 | 0.60 | -5.0 | -15.70 |
| Kitchen waste | 21.46 | 18.60 | 22.20 | 76.60 | 20.90 | 40.30 | -55.14 | -2.30 | -18.10 |
| Bio-slurry | 20.67 | 17.60 | 9.20 | 70.26 | 18.70 | 57.50 | -49.59 | -1.10 | -48.30 |
| Poultry litter | 33.21 | 35.90 | 6.30 | 72.71 | 21.31 | 56.10 | -39.50 | 14.59 | -49.80 |
| LSD at 5% level | 1.97 | 6.15 | 1.1 | 12.75 | 4.67 | 6.34 | | | |
| *Boro, 2016-17* | | | | | | | | | |
| Control | 0.00 | 0.00 | 0.00 | 28.91 | 9.10 | 38.93 | -28.91 | -9.10 | -38.93 |
| BRRI dose | 136.00 | 18.00 | 62.00 | 99.52 | 19.78 | 88.90 | 37.48 | -1.78 | -26.90 |
| Kitchen waste | 29.94 | 27.60 | 27.87 | 52.91 | 16.47 | 56.07 | -22.97 | 11.13 | -28.2 |
| Bio-slurry | 29.22 | 30.56 | 36.00 | 50.35 | 16.27 | 35.04 | -21.13 | 14.29 | 0.96 |
| Poultry litter | 42.11 | 48.62 | 44.13 | 67.22 | 19.58 | 68.23 | -25.11 | 29.04 | -24.1 |
| LSD at 5% level | 5.18 | 11.45 | 7.75 | 4.29 | 3.10 | 8.28 | | | |

@ 120 kg/acre Mmixed fertilizer at 20 DAT and mulching and $T_3$: BRRI recommended fertilizer (Control) were tested in this experiment. BRRI dhan72 and an advanced line (CN6) were used in the experimental purpose. The plot size was 5 × 5 m. Twenty-five-day-old seedlings of BRRI dhan72 and 35-day-old seedlings of advanced line (CN6) were transplanted at the spacing of 20 × 20 cm during T. Aman and Boro seasons. BRRI recommended fertilizers were applied in the experimental plot as urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate at the rate of 300-123-148-83 and 11 kg $ha^{-1}$ in Boro season and 200-77-100-69-10 $kgha^{-1}$ applied in T. Aman season. Whole amount of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied prior to final land preparation. Urea was top dressed in three equal splits at 15, 35 and 55 days after transplanting (DAT) in $T_3$ treated plots. Irrigation application, weed control measures and all other intercultural operations were done as and when necessary. Yield and yield components data with plant height (cm), panicle $m^{-2}$, grain $panicle^{-1}$, TGW (g) and grain spot incidence were collected. Grain and straw yield calculated from an area of 10 $m^2$ at maturity stage of the crop. Collected data were statistically analyzed using a standard statistical procedure (R-software 1) and only mean differences among treatments were adjudged.

Grain yield and most of the yield parameters of BRRI dhan72 and advanced line (CN6) showed almost similar trends in both the seasons (Table 9). The tallest plant height (85.23 cm), higher number of panicles per unit area and grains panicle$^{-1}$ were recorded from BRRI recommended fertilizers applied plot, which contributed for obtaining higher grain yield (7.50 tha$^{-1}$) in Boro season 2016-17. But there was no significant effect among the treatment on spotted grains panicle$^{-1}$ and TGW (g) of advanced line (CN6).

In T. Aman season, there was no significant effect among the treatments on plant height, unfilled grains panicle$^{-1}$ and TGW (Table 9). The highest panicles per unit area were observed in bio-fertilizer treated plots ($T_1$ and $T_2$) but more grains panicle$^{-1}$(160) was found in BRRI recommended fertilizer ($T_3$) which leaded to obtain higher grain yield (7.15 tha$^{-1}$).

It may be concluded that among the treatments BRRI recommended fertilizer ($T_3$) gave the higher grain yield in both the seasons followed by two other treatments.

**Monitoring labour wage rate at different locations**

A survey was conducted to find out the labourers' wage rate at different locations around BRRI HQ such as Joydebpur, Chowrasta, Salna, Board Bazar and Konabari, etc (Table 10). It was observed that the average wage rate per day was Tk 440-485. The highest wage rate of labourers' was in May (Tk 480-530 per day) due to harvesting and post-harvest operations of Boro rice and transplanting of Aus rice. Another higher rate was during July-August (Tk 480-500 per day) due to harvesting and post-harvest operations of Aus rice and transplanting of Aman rice. The third higher wage rate was observed during December-January (Tk 450-500 per day) due to the peak period for harvesting and post-harvest operation of Aman rice and transplanting of Boro rice.

In another survey, it was observed that the wage rate varied from place to place and ranged between Tk 390-415, 370-430, 420-480, 385-445, 425-455, 420-480, 380-420 and 430-475 at Habiganj, Rangpur, Rajshahi, Barisal, Sonagazi, Comilla, Satkhira and Khulna respectively.

**Rice seed production**

In different seasons, this division produced 24,308 kg rice of which 15,457 kg seed, 565 non seed and 8,286 kg mixed rice. All rice has been stored in the BRRI general store.

As a part of the breeder seed production, this division also produced 6,299 kg breeder seed and 760 kg TLS. This seeds has been deposited to GRS Division of BRRI.

**Support services**

**Land and labour management.** Including Regional Stations, BRRI has 766 labourers of which 508 regular and 258 irregular. BRRI HQ has 474 labourers of which 330 regular and 144

**Table 9. Effect of Shamolbangla bio-fertilizer on the yield and yield components and pest incidence.**

| Treatment | Plant height (cm) | Panicle no.m$^{-2}$ (no.) | Grains panicle$^{-1}$ | Unfilled grains panicle$^{-1}$ | Spotted grains panicle$^{-1}$ | 1000- grain wt (g) | Grain yield (tha$^{-1}$) | Straw yield (tha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| | | | | *Boro 2016-17* | | | | |
| $T_1$ | 82.00b | 330b | 147.40b | 68.08b | 4.06a | 16.60a | 6.90b | 11.4b |
| $T_2$ | 82.07b | 352a | 146.53b | 63.86b | 3.50a | 15.72a | 7.20a | 12.3a |
| $T_3$ | 85.93a | 362a | 160.20a | 76.13a | 5.33a | 15.75a | 7.50a | 11.3b |
| LSD | 2.46 | 26.10 | 14.05 | 4.94 | 3.10 | 2.49 | 0.53 | 1.07 |
| CV (%) | 1.83 | 5.58 | 8.13 | 3.15 | 31.83 | 6.84 | 3.83% | 7.63 |
| | | | | *T. Aman 2016* | | | | |
| $T_1$ | 115.46a | 247.33a | 96.63b | 43.06a | 5.40b | 29.59a | 6.84a | 11.66ab |
| $T_2$ | 117.93a | 244.0ab | 103.67a | 41.46a | 11.87a | 31.10a | 6.63b | 10.60b |
| $T_3$ | 117.43a | 226.67b | 126.26a | 38.47a | 12.33a | 30.43a | 7.15a | 13.20a |
| LSD | 3.46 | 19.71 | 27.95 | 6.17 | 1.85 | 3.78 | 0.51 | 1.82 |
| CV (%) | 1.30 | 3.63 | 15.86 | 6.64 | 8.27 | 5.48 | 3.32 | 6.82 |

**Table 10. Labourer's wage rate without stuff at different places around BRRI Gazipur during 2016-17.**

| Month | Wage rate (Tk)* | Remark |
|---|---|---|
| April | 400-460 | Normal period |
| May | 480-530 | Peak period. Harvesting and post-harvest operation of boro rice and transplanting of aus rice. |
| June | 400-460 | Normal period |
| July | 480-500 | Peak period. Harvesting and post-harvest operation of Aus rice and transplanting of T. Aman rice. |
| August | 480-500 | |
| September | 440-480 | |
| October | 420-470 | Normal period |
| November | 450-480 | |
| December | 450-500 | Peak period. Harvesting and post-harvest operation of T. Aman rice and transplanting of Boro rice. |
| January | 450-500 | |
| February | 430-480 | |
| March | 410-460 | Normal period |
| Average | 440-485 | |

* Wage rate of each month is the average rate of different places such as Joydebpur, Chowrasta, salna, Board Bazar, Konabari etc.

irregular. BRRI has 274 ha of land of which 163 ha is cultivable (Table 11).

**Labour utilization.** Total labour utilization in different research divisions research related works, support service and leaves was 1,88,252 man days of which 52.02, 41.59 and 3.39% were utilized for research, support service purpose and holiday, respectively.

**Labour wages.** It was observed that total labour wages was Tk 10,93,05,524 of which Tk 6,79,54824 and Tk 3,81,59,200 and Tk 31,91,500 were paid to the labourers for research work, support service works, leaves and holidays respectively.

**Land utilization.** A total of 72.87 ha of land were utilized by different research divisions in different seasons of which 6.95 ha in Aus, 32.54 ha in T. Aman and 33.38 ha in Boro season.

**Garden management.** This division always manages a visible flower garden to maintain an aesthetic view of the office area, some parts of the campus during summer and winter season.

**Table 11. Land and labour strength of BRRI, 2016-17.**

| Location | Total land (ha) | Cultivable land | | Labour (no.) | | |
|---|---|---|---|---|---|---|
| | | Area (ha) | % of total land | Muster Roll | | Total |
| | | | | Regular | Irregular | |
| HQ at Gazipur | 76.83 | 44.45 | 57.9 | 330 | 144 | 474 |
| Comilla | 24.68 | 16.03 | 65.0 | 25 | 25 | 50 |
| Hobiganj | 35.03 | 25.90 | 73.9 | 29 | 10 | 39 |
| Sonagazi | 45.77 | 35.90 | 78.4 | 26 | 17 | 43 |
| Barisal | 41.10 | 10.74 | 26.1 | 21 | 13 | 34 |
| Rajshahi | 13.24 | 8.92 | 67.4 | 22 | 10 | 32 |
| Bhanga | 11.46 | 9.55 | 83.3 | 13 | 7 | 20 |
| Rangpur | 6.07 | 4.05 | 66.7 | 26 | 10 | 36 |
| Kushtia | 0 | 0 | 0 | 10 | 3 | 13 |
| Satkhira | 20.00 | 8.10 | 40.5 | 6 | 19 | 25 |
| Total | 274.18 | 163.64 | 59.7 | 508 | 258 | 766 |

# Farm Machinery and Postharvest Technology Division

SUMMARY

The plastic mold of BRRI manual rice transplanter was developed at Alam Engineering Works, Wari, Dhaka. Locally available materials were used to fabricate the machine. The capacity of the machine was about 0.05 ha/h. The number of seedling per hill varies from 3 to 6 depends on seedling density. Comparing with traditional hand transplanting, the machine can save about 60% labour and 45% transplanting cost. One-person can operate this machine up to one hours and two persons need to operate the machine alternately for increasing machine efficiency and reducing human drudgery. This machine is suitable for marginal farmer who's purchasing and land holding capacity small and it is an intermediate technology up to fully introducing of power operated mechanical rice transplanter.

A second prototype of mini combine harvester was fabricated using locally available materials in Janata Engineering workshop, Chuadanga under Private Public Partnership (PPP). BRRI provides design, drawing, technical and financial support to develop and fabricate the machine. The faults of first prototype were taken in consideration to fabricate the second prototype. The study was aimed at design, fabrication and testing the performance of the prototype. The preliminary performance of the 1stversion was tested in wheat and Aus 2016 season to find out the capacity, efficiency, operation fault etc. The field test revealed functional problem in gear system and cleaning mechanism. The harvesting capacity and fuel consumption were found 0.15~0.20ha/h, 2.75~3.00 l/h respectively. The success of this machine may create a new era in Bangladesh agriculture for harvesting and also mitigate the labour shortage.

A push-pull type manually operated double row rotary weeder was designed and fabricated in the FMPHT divisional research workshop. It consists of four rotors. The weight of the double row weeder is 7.5 kg. An observation trial was done and the fabricated weeder was primarily tested in the BRRI research field, Gazipur. The weeding efficiency was found 80-82%. The field capacity was observed 0.036-0.04 ha/h. The weeder can uproot and bury the weeds in two single rows at a time with push pull operation. The performance of the double row weeder was found satisfactory and suitableto control weeds in the line transplanted field in terms of laboratory based field test. Some modification of the double row weeder is under process and it will be tested thoroughly in the next season.

Adaptive field trial of BRRI prilled urea applicator (BPUA) was conducted in the farmer's field at Rajpat, Kashiyani of Gopalganj district during the Boro season of 2017 to calibrate and evaluate the applicator for the establishment of long duration rice variety (cv BRRI dhan29). The treatments were- $T_1$ = Urea deep placement by BPUA (70% urea fertilizer of recommended dose), $T_2$ = Urea deep placement by BPUA (80% urea fertilizer of recommended dose), $T_3$ = Hand broadcasting (Recommended dose of urea @ 270 kg $ha^{-1}$) and $T_4$ = Control (-N). The treatments were arranged as randomized complete design with three replications. Field performance of the BPUA was found suitable under both 70 and 80% of urea deep placement in operation though field capacity was found more for 70% rate of fertilizer application. Grain and straw yield did not vary with the two different rate of deep placement of urea fertilizer while benefit-cost ratio (BCR) was found more for 80% of urea fertilizer application in non-oxidize zone. Farmer can apply 80% of urea by BPUA for long duration rice variety.

A de-husking machine was developed to improve the milling performance of rice processing. The capacity of the developed de-husker was 647 kg/h. The husking efficiency was found more than 90% for BRRI dhan70 and milling recovery was 63% polished in friction type polisher. The average head rice recovery based on input paddy was 54.6%, which is promising for processing of premiere quality rice. Old steel engelberg huller can be replaced with the combination of de-husker and polisher. Besides, this combination gives similar milling recovery of the semi and automatic rice mill. In addition separately collected husk and bran can be used for making briquette and extracting edible oil respectively.

Adaptive trial and field demonstration of farm machinery and technology was conducted in Rajpat, Kasiyani of Gopalganj district during Boro 2017 season. The technologies were seedling raising technique, mechanical rice transplanter, BRRI prilled urea applicator, BRRI weeder and reaper. BRRI dhan58, BRRI dhan50, BRRI dhan29 and BRRI dhan28 were cultivated in all the trial plots. Total 101 field trials were conducted during this Boro 2017 season. Four trainings, four field

days and one motivational tour programme were conducted during this season. Forty plot covering 20 bighas of land in 12 different farmer's paddy fields were harvested by reaper as promotional activity. Prilled urea application by BRRI prilled urea applicator gave the highest grain yield than hand broadcasting of urea due to uniform placement of urea in subsurface of soil.

MACHINERY DEVELOPMENT AND TESTING

**Design and development of manual rice transplanter**

The plastic mold of BRRI manual operated rice transplanter was developed at Alam Engineering works, Wari, Dhaka. The transplanter was fabricated with locally available materials such as fibre board, plastic strips, jet bar, nuts and bolts, rivets, rods, springs, chain and sprocket etc. The row-to-row spacing is 20 cm whereas plant-to-plant spacing depends on operator foot-step. The machine is functioning in backward pull-push action and it can transplant four rows in a single pass. Floating system facilitate the transplanter to slide over the puddled soil surface. Fixed opening type pickers were used with the transplanting arm of the machine. Figures 1-5 show the different views of BRRI manual rice transplanter.

The performance of plastic version BRRI manual rice transplanter was evaluated in BRRI research field and farmers field as well. A total of 10 domstrations cum informal training were organized at Dhirashorm in Gazipur district, Mithapukur and Sadar upazila in Rangpur district and Sorojganj in Chuadanga district. About 400 participants (both male and female) attended in these demonstrations cum training programmes. The performance of the machine for transplant paddy was found satisfactory. One-person can operate it but two person can alternatively operate the machine for the whole day. The capacity of the machine is 0.05-ha/h. The number of seedling per hill varies from 3 to 6 depending on seedling density. Compared to traditional hand transplanting the machine transplanting can save about 60% labour and 45% transplanting cost.

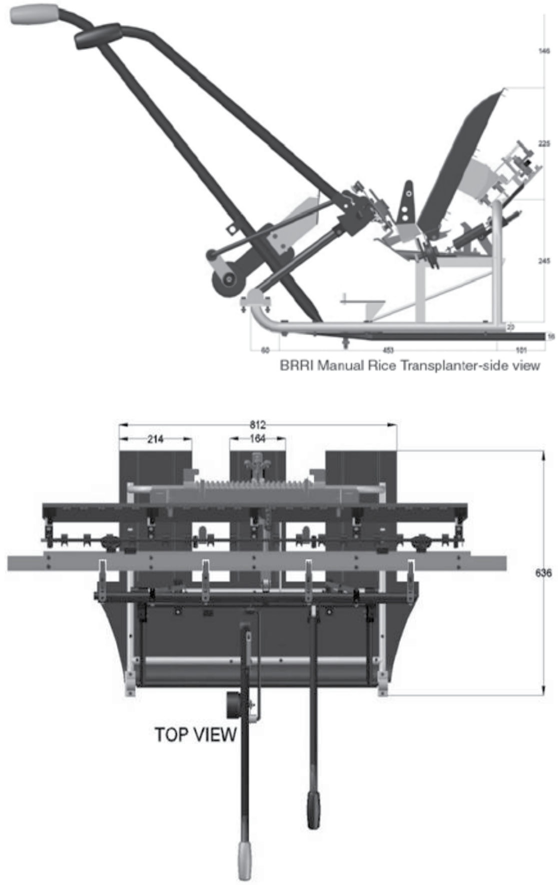



Fig. 1. BRRI manual rice transplanter. All dimensions are in mm.

**Design and development of a mini combine harvester**

Considering fragmented land, inaccessibility of farm road, high machine price, purchasing capacity of farmer, scarceness of quality machine supply to end-users etc research on mini combine harvester has been undertaken. A second prototype of mini combine harvester was fabricated using locally available materials in the Janata Engineering workshop, Chuadanga under private public partnership (PPP) programme. BRRI provides design, drawing, technical and financial support to develop and fabricate the machine. The faults of first prototype were taken in consideration to fabricate the second prototype. The gear system, engine position and cleaning arrangement have changed to improve the machine performance. The important functional elements are cutter bar, reel, grain screw conveyer, feeding conveyer, threshing drum, blower

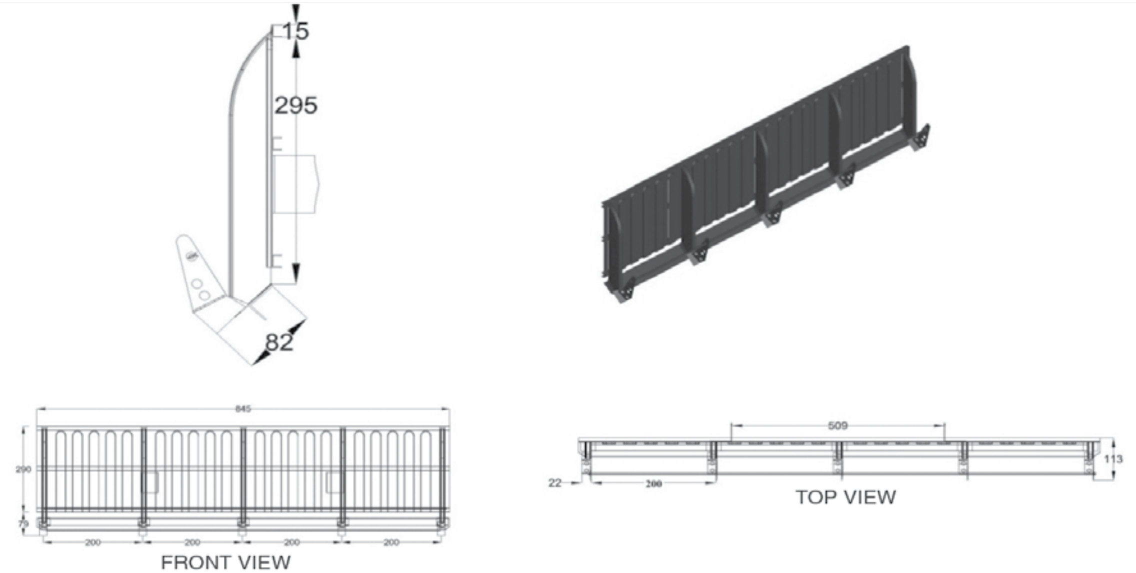


Fig. 2. View of seedling tray of BRRI manual rice transplanter.

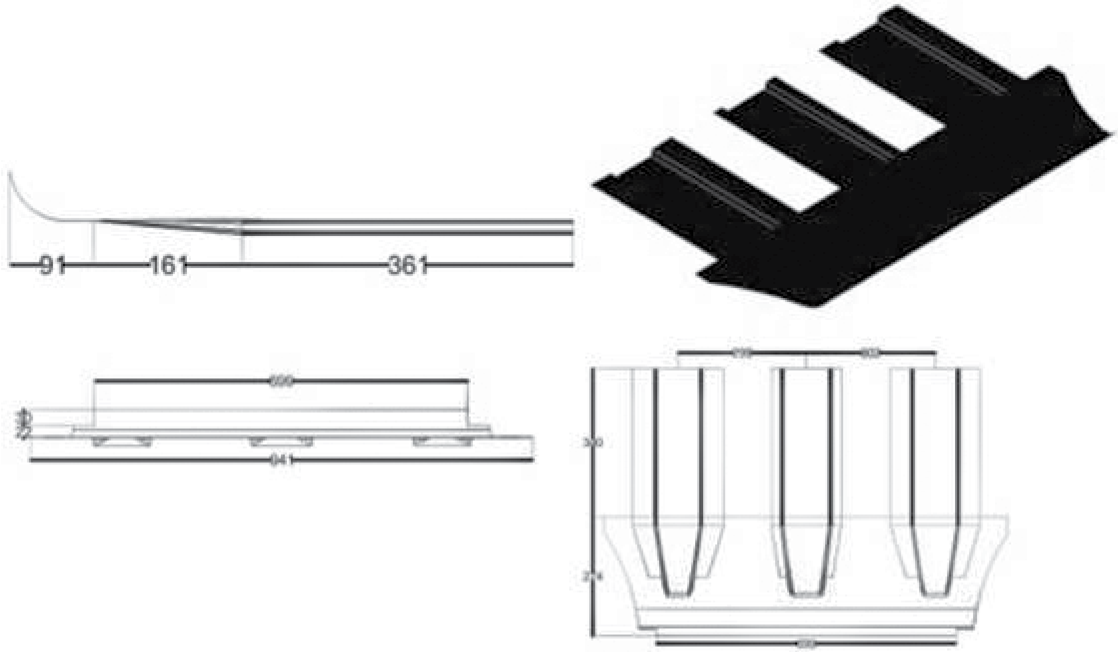


Fig. 3. Skid of BRRI manual rice transplanter. All dimensions are in mm.

fan, paddy screw conveyer and driving power of the combine. A cyclone separator and horizontal gear mechanism was introduced in the second prototype instead of blower fan and vertical gear. The design parameters were:

- The rotational speed of the screw conveyer was higher than the forward speed of the combine to avoid grain loss
- The capacity of conveying feeder was designed to match with the reel speed

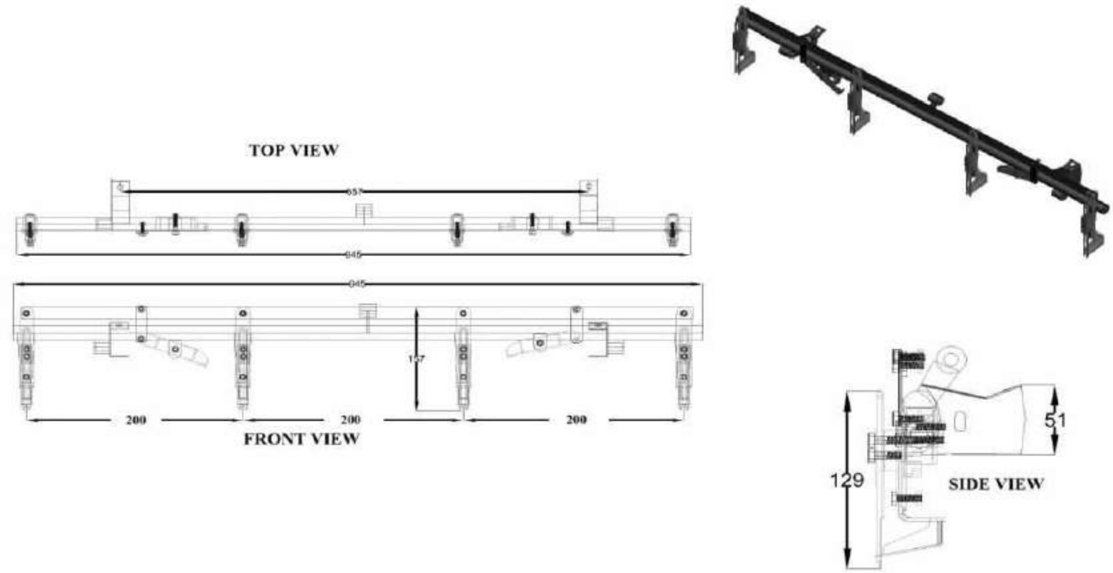



Fig. 4. Side and isometric view of the picker.

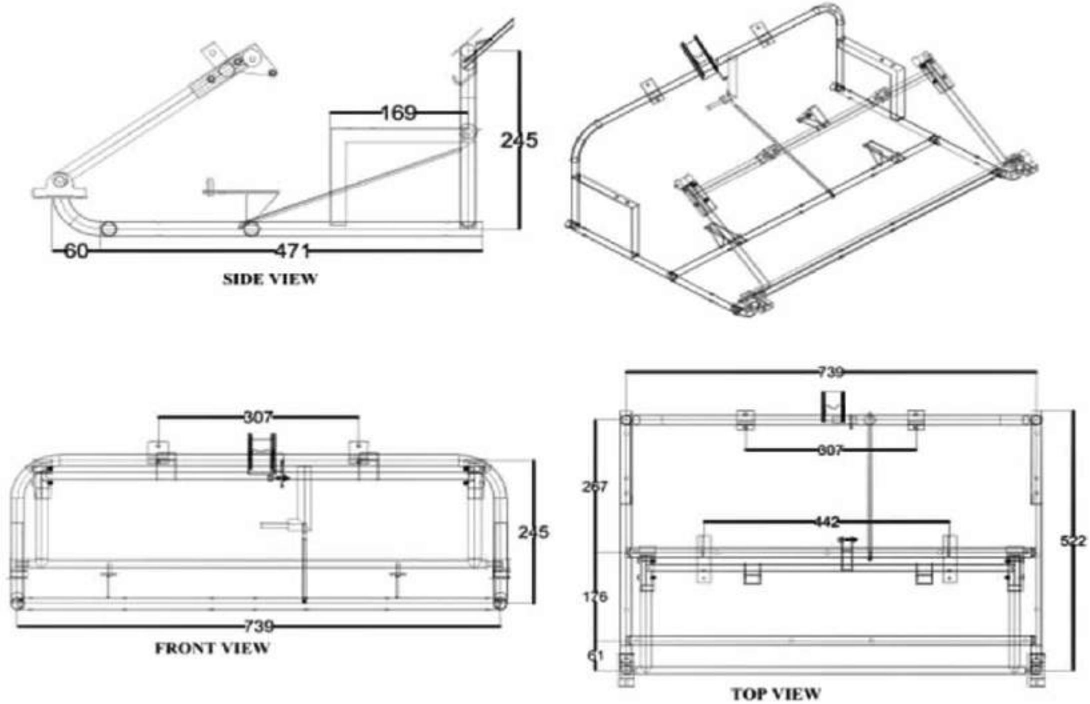



Fig. 5. View of the main frame of BRRI manual rice transplanter. All dimensions are in mm.

- The cutting height of the plant can be adjusted from 10-80 cm with the cutting speed 400-450 rpm, and reel peripheral speed 25-50% greater than the machine forward speed
- The threshing drum speed considered 550-600 rpm, which is same as close drum thresher
- The inclination of grain conveyer is greater than 30°

## Consecutive development

1st prototype

The main drawback was the winnowing problem

2ndprotptype

Introduce the cyclone separator for cleaning purpose

## Preliminary results and features

| Particular | | | | Model-2 |
|---|---|---|---|---|
| Dimension (Length*Width*Height) cm | | | | 262*103*134 |
| Feeding type | | | | Whole |
| Feeding capacity, kg/s | | | | 2.0 |
| Cutting height, cm | | | | 15-66 |
| Suitability | | | | Dry and wetland |
| Working efficiency/ Area coverage (Bigha/h) 1.2-1.75 | | | (ha/h) | 0.16-0.23 |
| | | | | |
| Effective cutting width (cm) | | | | 80 |
| Number of reaped (row to row distance: 20 cm) | | | | 4 |
| Type of reaping | | | | Cutting blade and two blades sliding cutting |
| Operators needed/manpower | | | | 3 |
| Threshing type | Whole feeding | | | Single threshing drum |
| | Threshing drum type | | | Axial flow, spike tooth |
| | Threshing drum (Diameter and length ) | | | 46 cm and 80 cm |
| Cleaning mechanism | | | | Cyclone separator |
| Engine | | Type | | Water cooling, four stroke, single cylinder, diesel engine |
| | Output/rpm, kw/rpm | | 11.94/2200 | |
| | Starting system | | Manual | |
| | Fuel tank capacity, L | | 6 | |
| Traveling system | | Crawler specification (width*pitch*No. of tooth) | | 40 cm*9 cm*46 |
| | Ground clearance, cm | | 26 | |
| | Transmission | | Hydrostatic transmission | |
| Fuel consumption, l/h | | | | 1.75.-2.5 |
| Working speed, km/h | | | | 1.9-2.2 |
| Screw conveyer type | | | | Extendible transverse conveyer |
| Grain tank capacity (kg) | | | | - |
| Wet field passing (Depth) | | | | 11cm |
| Grain unloading method | | | | Manually |

The field performance of the 1st prototype was tested in wheat and Aus 2016 season to find out the capacity, efficiency, operation fault etc. The field test revealed functional problem in gear system and cleaning mechanism. The harvesting capacity and fuel consumption were found 0.15-0.20 ha/h and 2.75-3.00 l/h respectively.

**Design and development of a double row conical weeder**

A manually operated double row weeder was designed considering 28-32 cm width of operation for uprooting weeds and mulching of soil. An engineering design was done with the help of AutoCAD programming and prototype was fabricated using locally available materials GI pipe, GI sheet, MS sheet, MS flat bar and MS shaft at the FMPHT divisional research workshop (Fig. 6). This is an adjustable weeder. This double row weeder has two options. This double row weeder can be used as two single row weeders. On the other hand, if someone wants to increase the capacity of the weeder, then adjusted two single row weeders with each other by the main body frame and then it would be a double row weeder. Skid and main frame is the basement of the double row weeder. The main frame holds the four rotary type rotors with 'Y' shape blade which helps to rotate the rotors and can uproot the weeds from the soil surface. All force (push and pull) exerted on the rotary type rotors by the main frame. Float angle of the skid was considered as 25°, which helps to make slippage of the body. Two floats of 36 cm in length and 12 cm in width had been designed in front portion that prevents the penetration into soil. Each float was designed 2 mm thickness with 2 cm MS flat bar attached with thin metal sheet. Handle attached upon the main frame for exerted push and pull type of force to operate the weeder. The BRRI double row weeder has four rotary type drum shape rotors mounted in tandem with opposite orientation. 'Y' shape blades are arranged with helically upon the drum to uproot and burry weeds when the rotors create a back and forth movement in the top 3 cm of soil.

During design, the following criteria were considered:

- Easy weeding and simple operation and maintenance
- Row to row distance
- It should be minimum force required to operate in the field
- It should have simple and easy adjustment
- It should be adjustable so that it can operate as two single row weeder if need be
- Locally available materials should be used to minimize the fabrication cost
- Light weight for easy handling
- It should be easy to repair and maintain
- It should be suitable for operation by a single person

An observation trial was conducted in the FMPHT divisional research field, Gazipur (plate 1). The weeding efficiency was found 80-82%. The field capacity was observed 0.036-0.04 ha/h. The performance of the weeder was found satisfactory in terms of laboratory basis field test. This hand operated manual machine helps to make weeding an easy process. It can be weeded two single rows at a time with push pull operation. Thoroughly test and performance evaluation of the final version of double row weeder is going under process.

Fig. 6. AutoCAD drawing of BRRI double row weeder.


Plate 1. Observation trial in BRRI research field.

**Mechanical deep-placement of urea fertilizer with a prilled urea applicator for long duration rice variety of BRRI dhan29**

The prilled urea fertilizer formed a smaller and softer substance than other materials commonly used in fertilizer blends. As a result, major portion of urea fertilizer lost in different ways after top application to the field. Farmers in Bangladesh apply urea fertilizer in the rice field by hand broadcasting method. Its application efficiency is only 35 to 40%. Deep placement of urea fertilizer into the anaerobic soil zone is an effective method to reduce volatilization loss and increase the application efficiency up to 60%. It has been proven that deep placement of urea (either granule or prilled form) in transplanted rice is an agronomically efficient and environmentally safe as compared with the traditional application method of prilled urea. Based on this concept, the scientists of the FMPHT Division of BRRI developed a prilled urea applicator namely 'BRRI Prilled Urea Applicator' to deep placement of prilled urea in between two rows of plants. It was found suitable during field trials in different soil conditions and seasons though one additional top dress is required for long duration rice variety before panicle initiation stage. Therefore, BPUA should be recalibrated to apply urea fertilizer in different saving rate for long duration rice variety for identifying the suitable rate of fertilizer deep placement. Furthermore, fertilizer use efficiency also needs to observe under different rate of fertilizer deep placement. Hence, the study was conducted in the farmer's field at Rajpat, Kashiyani, Gopalganj, Bangladesh during the Boro season of 2017 to calibrate and evaluate the applicator for the establishment of long duration rice variety (cv BRRI dhan29). The treatments were- $T_1$ = Urea deep placement by BPUA (70% urea fertilizer of recommended dose), $T_2$ = Urea deep placement by BPUA (80% urea fertilizer of recommended dose), $T_3$ = Hand broadcasting (Recommended dose of urea @ 270 kg $ha^{-1}$) and $T_4$ = Control (-N). The treatments were arranged as randomized complete design with three replications.

Twenty-five-day-old seedling of BRRI dhan29 was transplanted manually maintaining line to line and plant to plant spacing of 20 cm. BPUA was operated after two days of transplanting. Before operation of the applicator, it was calibrated to maintain the pre-designed fertilizer dose. BRRI recommended urea fertilizer dose was considered 270 kg $ha^{-1}$. At 70 and 80% of the recommended dose, the rate of urea fertilizer is 189 and 216 kg $ha^{-1}$. To maintain the desired fertilizer rate, fertilizer dispensing rate per rotation of the driving wheels of the applicator was calculated using the following formula.

$$FDR = \frac{\pi D \times 2L \times RoF}{10^5}$$

Where,

FDR = Fertilizer dispensing rate per rotation of the driving wheel (g/rotation)

D = Wheel diameter of the applicator, cm

L = Line to line spacing of the transplanted rice, cm

RoF = Desired rate of fertilizer application, kg $ha^{-1}$

This formula was developed for easy calibration of the applicator.

Applicator operation times included time required during turning of the applicator, fertilizer refill time, operator's personal time, adjustment time etc. These were summed to calculate the actual field capacity of BPUA, which is fertilizing area covered (ha) divided by the operation time (h) (Plate-2 and plate-3). Field efficiency was measured based on the actual field capacity and calculated theoretical field capacity. Actual percentage of saving was calculated dividing the actual dispensing fertilizer rate by the recommended fertilizer rate of the respected area of operation. Applicator operational cost, yield and yield contributing character, harvest index (HI), agronomic efficiency for N (AE), partial factor productivity (PFP) and benefit-cost ratio (BCR) was calculated using the standard formula and method.

**Field performance of the applicator**

Both actual and theoretical field capacity was found less for operation of the machine at 20% saving of fertilizer due to frequent inputs of fertilizer in the hopper of the applicator. Field efficiency of the applicator was 59 and 53% for operation at 30 and 20% saving, respectively (Table 1). Actual saving percentage of urea fertilizer was noted 34 and 24% in the field against the calibration of 30 and 20% of saving (Table 2).

**Crop performance.** Plant height was not varied up to 30 days after transplanting (Fig. 7). Significant variation of plant height was observed from 45 days after transplanting to the harvest. From 45 to 105 days after transplanting, significantly lower height of the plant was observed in control plot whereas plant height for urea deep placement either 70% or 80% of the recommended dose and hand broadcasting was found similar. In 120 days after transplanting, urea deep placement (both 80 and 70%) showed significantly higher plant height compared to hand broadcasting method of urea application. Number of tillers per hill was not varied up to 30 days after transplanting whereas variation of tiller number per hill was observed at 45 DAT

Plate 2. Field operation of the BPUA.

Plate 3. Record keeping during field operation of the BPUA.

**Table 1. Field performance of BPUA.**

| Condition of BPUA operation | Forward speed of operation (km $hr^{-1}$) | Actual field capacity (ha $hr^{-1}$) | Theoretical field capacity (ha $hr^{-1}$) | Field efficiency (%) |
|---|---|---|---|---|
| Machine application (30% saving) | 2.46 | 0.12 | 0.20 | 59 |
| Machine application (20% saving) | 2.61 | 0.11 | 0.21 | 53 |

Note: Average value of three replications, area covered per pass of the applicator is 0.8 m.

**Table 2. Percent of fertilizer saving as affected by two saving moods of operation.**

| Condition of BPUA operation | Area ($m^2$) | Urea dispensed (kg) | Urea dispensed rate (kg/ha) | Theoretical rate of dispensed (kg/ha) | Recommended dose (kg/ha) | % of saving | % of deviation (±) |
|---|---|---|---|---|---|---|---|
| Machine application (30% saving) | 243.8 | 4.33 | 177.60 | 196.00 | 270.00 | 34.22 | +4.22 |
| Machine application (20% saving) | 260.5 | 5.37 | 206.01 | 216.00 | 270.00 | 23.70 | +3.70 |

Note: Average value of three replications, area covered per pass of the applicator is 0.8 m.

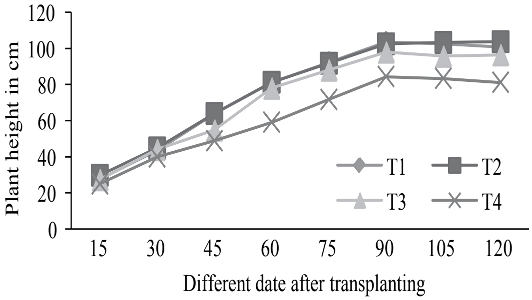



Fig. 7. Plant height in respect to days after transplanting as affected by rate and application methods of urea fertilizer.

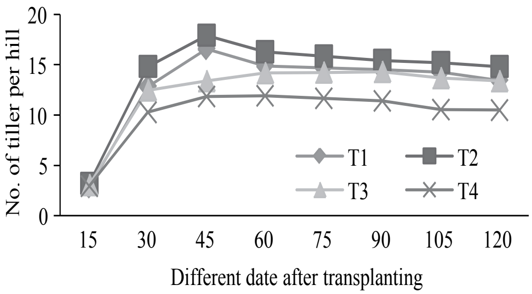



Fig. 8. Plant population in respect date after transplanting as affected by rate and application methods of urea fertilizer.

(Fig. 8). Significant variation of tiller number was observed from 75 days after transplanting to the harvest. From 75 to 105 days after transplanting, significantly lower tiller number of the plant was observed in control plot whereas tiller number per hill for urea deep placement either 70% or 80% of the recommended dose and hand broadcasting was found similar. There was no significan difference of plant height and number of tillers per hill between 80 and 70% of recommended dose of urea fertilizer application in non-oxidize zone by the BPUA.

**Yield performance.** Deep placement of the urea fertilizer (70 and 80% of recommended dose) gave significantly higher yield (6.7-6.8 t/ha) compared to hand broadcasting of urea (6.1 t/ha). Straw yield did not vary with the mode and rate of fertilizer. Harvest index was also found similar irrespective of treatments (Table 3).

**Yield parameters.** Panicles per hill and filled grains per panicle did not vary with the mode and rate of urea application while it was significantly higher than that of control (Table 4). The agronomic efficiency and partial factor productivity for N observed higher in urea fertilizer deep placement field compared to broadcasting whereas both the

**Table 3. Yield performance as affected by mode and rate of urea fertilizer application.**

| Treatment | Grain yield at 14% m.c | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | % of HI |
|---|---|---|---|---|
| $T_1$ | 6.7 | 5.2 | 11.9 | 56.5 |
| $T_2$ | 6.8 | 6.0 | 12.8 | 53.3 |
| $T_3$ | 6.1 | 6.3 | 12.3 | 49.8 |
| $T_4$ | 3.3 | 3.1 | 6.5 | 51.3 |
| CV, % | 3.4 | 12.3 | 6.3 | 4.9 |
| LSD | 0.4 | 1.3 | 1.4 | NS |

Note: $T_1$ = Urea deep placement by BPUA (70% Urea), $T_2$ = Urea deep placement by BPUA (80% Urea), $T_3$ = Hand broadcasting (Urea @ 270 kg ha$^{-1}$) and $T_4$ = Control (-N).

**Table 4. Yield contributing parameters as affected by mode and rate of urea fertilizer application.**

| Treatment | Hills m$^{-2}$ | Panicles hill$^{-1}$ | Filled grain panicle$^{-1}$ | TGW at 14% (g) |
|---|---|---|---|---|
| $T_1$ | 27.8 | 12.2 | 91.3 | 22.2 |
| $T_2$ | 26.3 | 13.6 | 90.7 | 21.4 |
| $T_3$ | 27.0 | 12.3 | 88.2 | 20.8 |
| $T_4$ | 26.9 | 9.4 | 64.2 | 20.8 |
| CV, % | 6.6 | 6.5 | 6.2 | 3.4 |
| $LSD_{0.05}$ | NS | 1.5 | 10.38 | NS |

Note: $T_1$ = Urea deep placement by BPUA (70% Urea), $T_2$ = Urea deep placement by BPUA (80% Urea), $T_3$ = Hand broadcasting (Urea @ 270 kg ha$^{-1}$) and $T_4$ = Control (-N). TGW = Thousand grain weight.

parameters did not varied for 30 and 20% saving rate (Table 5).

**Benefit-cost ratio.** Table 6 presents economic analysis including production cost and return. BPUA accounted the highest BCR (1.72 and 1.67) for 80 and 70% of the recommended urea fertilizer application in non-oxidize zone hand broadcasting of urea fertilizer (1.56) due to less input cost and more yield.

Field performance of the BPUA was found suitable under both 70 and 80% of urea deep placement in operation though field capacity was found more for 70% rates of fertilizer application. Grain and straw yield did not vary with the two different rate of deep placement of urea fertilizer while benefit-cost ratio (BCR) was found more for 80% of urea fertilizer application in non-oxidize zone. Farmer can apply 80% of urea by BPUA for long duration rice variety (cv. BRRI dhan29).

## MILLING AND PROCESSING TECHNOLOGY

### Test, evaluation and modification of rubber roll de-husker

Modified rubber roll de-husker (rubber roll diameter 230 mm and length 154 mm) driven by 4 kW (3-phase 4 wire 1,440 rpm) electric motor and it rotated within 1048 rpm. The adjustable rubber roll diameter and length are also same as fixed rubber rollbut it is running at 788 rpm. The blower runs at 1,028 rpm. Bottom end ofthede-husker connected with a husk aspirator through a pipe (dia. 200 mm). Aspirator fan (dia. 330 mm) operates by 1.5 kW (2840 rpm) motor. A cyclone separator attached in the de-husker for collecting husk. Previously, husk was directly collected from aspirator discharge outlet with gunny bag thus created huge amount of dust in the working area. Rubber roll de-husker does not damage the aleuronic layer of paddy, so the husker discharge does not contain any bran; only a few amount of broken embryo was present. An airstream is blown over the grains and immature grains drop into the separate hopper for discharge. The paddy and husk are discharged separately. BRRI dhan70 (un-parboiled) was used in this experiment and the moisture content was 11.3% (wb.) and each sample size was 20 kg. De-husked paddy was processed in MNMP-15 model friction type polisher to evaluate the milling parameter.

**Table 5. Effect of N application methods and rate on crop parameters.**

| Treatment | AUE (Kg grain kg $N^{-1}$) | PFP (Kg grain kg $N^{-1}$) |
|---|---|---|
| $T_1$ | 37.3 | 74.3 |
| $T_2$ | 34.6 | 68.1 |
| $T_3$ | 22.0 | 48.8 |
| $T_4$ | - | |
| CV, % | 4.82 | 2.37 |
| $LSD_{0.05}$ | 4.82 | 2.27 |

Note: $T_1$ = Urea deep placement by BPUA (70% Urea), $T_2$ = Urea deep placement by BPUA (80% Urea), $T_3$ = Hand broadcasting (Urea @ 270 kg $ha^{-1}$) and $T_4$ = Control (-N).

The average capacity of the husker was 647 kg/h and husking efficiency was 91% (Table 7). Husking efficiency can be increased by closing the gap between tworollerbut broken rice (brown) was observed. The average brown rice was found 76% and the rest was husk and embryo. Average fixed and adjustable rubber roll rpm was found 1048 and 788 respectively.

Adjustable rubber roll rotate 24.81% less rpm than the fixed rubber roll. The difference in peripheral speed subjects the paddy grain falling between the rolls to a shearing action that strips off the husk. The clearance between the rolls is adjustable and it kept at less than the thickness of the grain.

**Table 6. Benefit-cost ratio as affected by mode and rate of urea fertilizer application.**

| Treatment | Input cost (Tk $ha^{-1}$) | Gross return (Tk $ha^{-1}$) | Gross margin (Tk $ha^{-1}$) | BCR |
|---|---|---|---|---|
| $T_1$ | 84315 | 141800 | 57485 | 1.68 |
| $T_2$ | 84813 | 145000 | 60187 | 1.71 |
| $T_3$ | 85169 | 131450 | 46281 | 1.54 |
| $T_4$ | 78864 | 70650 | -8214 | 0.90 |

Note: $T_1$ = Urea deep placement by BPUA (70% Urea), $T_2$ = Urea deep placement by BPUA (80% Urea), $T_3$ = Hand broadcasting (Urea @ 270 kg $ha^{-1}$) and $T_4$ = Control (-N).

**Table 7. Capacity, husking efficiency of husker and brown rice percentage of BRRI dhan70.**

| Capacity (one pass) Kg/h | Husking Efficiency (one pass) % | Brown Rice, % (based on input paddy) | Adjustable roll speed (rpm) | Fixed roll speed (rpm) | % of less speed in Adjustable roll |
|---|---|---|---|---|---|
| 655 | 91 | 75.5 | 785 | 1045 | 24.88 |
| 648 | 90 | 77.0 | 790 | 1050 | 24.76 |
| 640 | 93 | 76.0 | 787 | 1049 | 24.97 |
| 647 | 91 | 76.0 | 788 | 1048 | 24.81 |

Brown rice of BRRI dhan70 from rubber roll de-husker was polished in friction type polisher. The average capacity of the polisher was 674 kg/h and the average milling recovery was 63% (Table 8). The average head rice recovery (based on input paddy) was 54.6% and head rice recovery (based on total milled rice) was 86.67%. The broken rice percentage was 8.4% (based on input paddy) and 13.3% (based on total milled rice).

EXTENSION OF AGRICULTURAL MACHINERY

**Enhancement of crop productivity and reduction of production cost using farm machinery**

Field demonstrations and trials of farm machinery and technologies were conducted in different locations of Rajpat, Kasiyani, Gopalganj district. Adaptive trial of farm machinery was conducted during Boro 2017 season. BRRI developed high yielding varieties namely BRRI dhan28, BRRI dhan29, BRRI dhan50, BRRI dhan58 and Hybrid Hira were cultivated in the farmers' field. In mechanical rice transplanting, the treatments were- MT = Transplanting by mechanical transplanter and HT = Manual transplanting. In urea fertilizer application, the treatments were- PUA = urea application by prilled urea applicator and HB = Hand broadcasting. In weed management practices, the treatments were- BW = Weeding by BRRI weeder and HW = Hand weeding. The plant height was measured from the base of the hill to the tip of the longest panicle. Length of the panicle was taken from the basal node of the rachis to the apex of each panicle. Three hills from each of the plots were collected randomly. The panicles that had at least one grain were considered as effective tillers. The panicles that had no grain were considered as non-effective tillers. The number of effective and non-effective tillers of each hill was noted and the total number of tillers was counted for each hill. Grain yield were recorded from pre-selected 10 $m^2$ land area and adjusted moisture content of 14% moisture level. Statistical analysis was done by using MS-excel software. Average and standard error were used to compare the treatment mean.

**Field trial**

Field trials on seedling raising, mechanical rice transplanter, BRRI prilled urea applicator, and BRRI weeder were conducted in 101 farmer's plots.

**Yield Performance of mechanically transplanted rice.** Grain yield of mechanically transplanted rice of BRRI dhan58 was 7.70±0.17 t $ha^{-1}$ and BRRI dhan29 was 5.54±0.33 t $ha^{-1}$. Mechanically transplanted rice produced the highest yield than hand transplanting of rice due to use of tender aged seedling.

**Yield performance of rice in different urea fertilizer management.** Figure 9 shows the yield performance of rice under different urea

**Table 8. Milling parameter of BRRI dhan70 processed in friction type polisher.**

| Sl. no. | Capacity of polisher kg/h | Milling yield % | Head rice % (Based on input paddy) | Head rice % (Based on total milled rice) | Broken rice % (Based on input paddy) | Broken rice % (Based on total milled rice) |
|---|---|---|---|---|---|---|
| 1. | 662.0 | 63 | 55.4 | 88.0 | 7.56 | 12.0 |
| 2. | 670.0 | 62 | 54.8 | 87.0 | 8.19 | 13.0 |
| 3. | 690.0 | 64 | 53.6 | 85.0 | 9.45 | 15.0 |
| Av. | 674.0 | 63 | 54.6 | 86.67 | 8.4 | 13.3 |

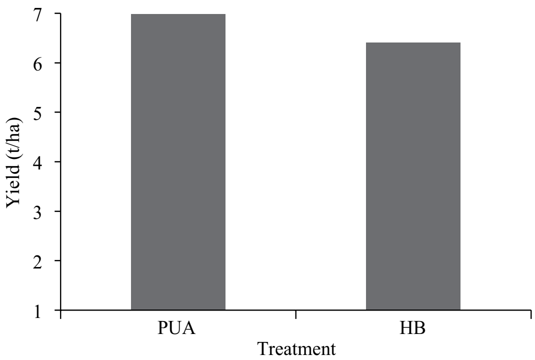



Fig. 9. Grain yield of different urea fertilizer methods.

management practices. Grain yield of fertilizer application by prilled urea applicator was 6.98±0.05 t $ha^{-1}$and hand broadcasting of urea is 6.13±0.19 t $ha^{-1}$. The grain yield of BRRI dhan50 was the highest in prilled urea application by BRRI prilled urea applicator followed by hand broadcasting of urea due to uniform placement of urea in subsurface. Efficacy of deep placement of prilled urea was always higher than that of hand broadcasting of urea.

**Yield performance of rice in weed management options.** Grain yield of weed management by hand (5.98±0.12 t $ha^{-1}$) and BRRI weeder (6.13±0.17 t $ha^{-1}$) is higher than that of hand weeding (Fig. 10). BRRI weeder reduced the human drudgery and ensured faster in field operation.

**Promotional activities**

About 40 plot covering 20 bighas of land in 12 different farmer's paddy were harvested by reaper as promotional activity.

**Mechanized village**

A 'mechanized village' was formed at Rajpat, Kasiyani, Gopalganj district during this Boro 2017 season with the active co-operation of the farmers and DAE personnel of this upazilla. Different machinery technologies such as seedling raising technique, mechanical rice transplanter, BRRI prilled urea applicator, BRRI weeder and reaper were done in this area. An experiment was also set up at the mechanized village. In total 101 different machinery field trials covered by 50-60 bighas of land were conducted during this Boro 2017 season.

**Training**

A total of 145 participants participated in the training programme. Among the participants, 90 were males and 55 were females. Participants were divided into two groups to complete the training events easily. Introductory session was arranged to brief them the about seedling raising technique in tray. After practical demonstration, the participants are able to prepare the tray successfully. Finally each farmer prepared a tray by himself.

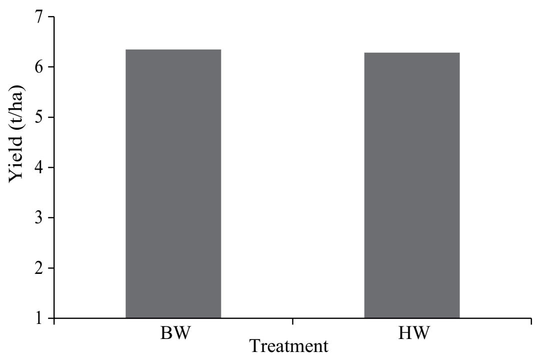



Fig. 10. Grain yield of different weed management methods.

# Workshop Machinery and Maintenance Division

SUMMARY

The effects of tillage depths on the productivity of paddy were determined. Field experiments were conducted in Aman 2016 and Boro 2017 seasons at research farm of BRRI RS, Rajshahi in different tillage depths. There were three tillage depths i.e. 4-5, 5-6 and 6-7 inches. Tillage depths affected both the yield of BR11 in Aman 2016 and BRRI dhan28 in Boro 2017 season. The highest grain yields were found 4.34 t/ha and 4.01 t/ha in the tillage depth of 6-7 inches and the lowest yields were found 3.81 t/ha and 3.29 t/ha in the tillage depth of 4-5 inches of BR11 in Aman 2016 and BRRI dhan28 in Boro 2017 season respectively. The highest grain yields of all the seasons were found under the higher tillage depths of 6-7 inches and the lowest yields were obtained in the lower tillage depth of 4-5 inches, which is practiced by the farmers of Bangladesh. Fuel consumptions were calculated in different plots at different tillage depths during ploughing in Aman 2016 and Boro 2017. Fuel consumptions were varied little bit in different plots at different tillage depths in Aman season but these were more or less same in different plots at different tillage depths in Boro season.

Different kinds of farm machinery have been used in the farmers' field. Some of them were imported and the rest were made by the local workshops. Agricultural machinery workshops were surveyed at different places in Bangladesh. The facilities of machinery of the workshops were foundry, lathe, shaper, drill, milling, grinding, welding, metal cutting and colour compressor. They produced different kinds of agricultural machinery using locally available materials in their workshops. Close drum thresher, open drum thresher and maize sheller were the common machinery produced by the local manufacturers, and someone also produced chopper, bed planter, winnower and weeder.

There are different kinds of transport/vehicles and farm machinery at BRRI. Repair and maintenance works of these were done by WMM Division. Repair works and changed of spare parts of these vehicles and farm machinery were also done under major and moderate/minor repair and maintenance work. The total cost of major and moderate/minor repair and maintenance was Tk 31,78,153 from July 2015 to June 2016. Among them major repair and maintenance cost was Tk 23,07,350 and, moderate/minor repair and maintenance cost was Tk 8,70,803. The major repair and maintenance work was done by direct cash purchase, direct contracting through work order, RFQ (Request for quotation) and OTM (Open tender method). On the other hand, the moderate/minor repair and maintenance work was done only by using the revolving fund.

## DEVELOPMENT OF AGRICULTURAL MACHINERY

**Determination of tilling efficiency of power tiller at selected areas of Bangladesh**

Tillage improves soil conditions by altering the mechanical impedance to root penetration, aggregate size distribution, hydraulic conductivity and water holding capacity, which in turn, affects plant growth and crop productivity. Tillage helps to mix the soil and level the soil surface that reduces the amount of water wasted by uneven pockets of too-deep water or exposed soil. Effective land leveling allows the seedlings to become established more easily. Tillage allows the seeds to be planted at the right depth, and also helps weed control. Interaction of tillage depths affect the soil physical properties such as bulk density, particle density, porosity, field capacity and permanent wilting point significantly. If had significant effect on grain yield. This might be due to exposure of roots to absorb more moisture and nutrients in deep tillage practices, because soil stores more moisture in deep tillage. As a result, grain filling stage does not suffer from water shortage. Crop production could be increased by adopting appropriate tillage operation with different depths which needs intensive field research.

Experiments were conducted at BRRI RS, Rajshahi in Aman 2016 and Boro 2017 seasons to determine paddy yield as influenced by different tillage depths. There were three different tillage depths such as: 4-5, 5-6 and 6-7 inches. Land preparation and the tillage depths were maintained by a power tiller. All sorts of weeds were removed from the field before planting of seedling. Time and fuel were recorded in every ploughing to measure fuel consumption. Seedlings were transplanted at 20 cm apart from rows maintaining 20 cm hill to hill distance and three seedlings per hill. Necessary gap filling was done eight days after transplanting. Applying irrigation, weeding and other intercultural operations were done as and when necessary. Paddy was harvested at full maturity. Harvesting, threshing, cleaning and drying of grain were done plot-wise separately. The weights of paddy were also recorded plot-wise.

Grain yield of BR11 in Aman 2016 and BRRI dhan28 in Boro 2017 seasons were varied from different tillage depths. The highest grain yield of BR11 in Aman 2016 season was found 4.34 t/ha in the tillage depth up to 6-7 inches and the lowest yield was found 3.81 t/ha in the tillage depth up to 4-5 inches (Table 1). Table 1 also shows the highest grain yield of BRRI dhan28, which was 4.01 t/ha in the tillage depth up to 6-7 inches and the lowest yield was obtained 3.29 t/ha in the tillage depth up to 4-5 inches in Boro 2017 season. The highest yields of all the seasons were found under the higher tillage depths up to 6-7 inches and the lowest yields were obtained in the tillage depth up to 4-5 inches, which was practiced by the farmers.

Deep tillage improved the soil physical environment. It made the soil softer, which was indicated by reduced bulk density, penetration resistance and encouraged root growth and increased the moisture retention capacity of the soil. This might have favoured the roots to proliferate down into the deeper layers of the soil profile to extract more nutrients and moisture that has led to higher growth and yield of the crops. Higher tillage depth favorably influenced the soil-water-plant ecosystem, thereby improved crop yields and quality. Higher tillage depth also reduced weed infestation.

Fuel requirements were measured and recorded at different tillage depths during ploughing in Aman 2016 and Boro 2017. Table 2 and Table 3 show the values of fuel requirements at different tillage depths in different plots in Aman 2016 and Boro 2017 respectively. Fuel requirements in first and second ploughing in different plots were same in Aman and Boro seasons, because total land (2,460 $m^2$) was ploughed combinedly up to second ploughing. After second ploughing, total land was divided into three plots and the area of each plot was 820 $m^2$. From third ploughing, fuel and time were also measured and recorded at different depths in Aman season. Fuel requirements were varied little bit in third and forth/final ploughing in each and different plots at different tillage depths where each of the plots (820 $m^2$) was ploughed separately (Table 2). On the other hand, in Boro season fuel requirements were measured and it varied little bit in third/final ploughing in each and different plots at different tillage depths where each of the plots ploughed separately (Table 3). Fuel requirements decreased chronologically in each and different plots at different tillage depths from first ploughing to

**Table 1. Yield of paddy with different tillage depths.**

| Year | Season | Paddy | Tilling depth (inch) | Paddy yield (t/ha) |
|---|---|---|---|---|
| | | | 4-5 | 3.81 |
| 2016 | Aman | BR 11 | 5-6 | 4.04 |
| | | | 6-7 | 4.34 |
| | | | 4-5 | 3.29 |
| 2017 | Boro | BRRI dhan28 | 5-6 | 3.58 |
| | | | 6-7 | 4.01 |

**Table 2. Fuel consumption and ploughing time of different plots at different tillage depths in Aman 2016.**

| | 1st plot (6-7" depth) | | 2nd plot (5-6" depth) | | 3rd plot (4-5" depth) | |
|---|---|---|---|---|---|---|
| | Fuel (ml) | Time (min) | Fuel (ml) | Time (min) | Fuel (ml) | Time (min) |
| 1st ploughing | 1465 | 30 | 1465 | 30 | 1465 | 30 |
| 2nd ploughing | 992 | 20.5 | 992 | 20.5 | 992 | 20.5 |
| 3rd ploughing | 800 | 17 | 700 | 16 | 650 | 16 |
| Final ploughing | 750 | 16 | 700 | 15 | 650 | 14 |
| Total | 4007 | 83.5 | 3857 | 81.5 | 3757 | 80.5 |
| Fuel consumption (l/hr) | 2.88 | | 2.77 | | 2.74 | |

final ploughing (Tables 2 and 3). Fuel consumptions were calculated in different plots at different tillage depths during ploughing in Aman 2016 and Boro 2017. Fuel consumptions varied little bit in different plots at different tillage depths in Aman season but these were more or less same in different plots at different tillage depths in Boro season.

Required time was recorded at different tillage depths in different plots during ploughing in Aman 2016 and Boro 2017 seasons (Tables 2 and 3). Time requirements in first and second ploughing in different plots were same in Aman and Boro seasons because total land (2,460 $m^2$) was ploughed combinedly up to second ploughing. From third ploughing, time consumed in each ploughing in different plots at different tillage depths were recorded and these were more or less same but it decreased chronologically in each plot from first ploughing to final ploughing where the area of each plot was same and it was 820 $m^2$.

**Potentiality of engineering workshop for enhancing farm mechanization in selected areas**

Different kinds of farm machinery are used from land preparation to threshing/ winnowing/cleaning crops in the farmers' field. These are open drum thresher, close drum thresher, pedal thresher, weeder, sprayer, seeder, maize sheller, power tiller, pump, combined harvester, rice transplanter, bed-planter, potato grader, potato planter, chopper, mango heat treatment etc for enhancing farm mechanization in our country. As a result cropping intensity has been increasing day by day. Most of the machinery were imported and costly, which were used in our agricultural sector but now-a-days, lot of engineering workshops have been developed at different places in our country for manufacturing those agricultural machinery using the locally available materials. So, the farmers are getting these machinery in their locality with low cost. It is necessary to investigate the capacity, limitations and prospects of the engineering workshops at farm level, and quality, production and use level of machinery at different farm operations.

Agricultural machinery workshops were surveyed at different places in Bangladesh. The facilities of machinery of the workshops are foundry, lathe machine, shaper machine, drill machine, milling machine, grinding machine, welding machine, metal cutting and colour compressor (Table 4). They produce different kinds of agricultural machinery using locally available materials by using these machinery facilities. Table 5 shows the result of the produced machinery by the manufacturers. Close drum thresher, open drum thresher and maize

**Table 3. Fuel consumption and ploughing time of different plots at different tillage depths in Boro 2017.**

| | 1st plot (6-7" depth) | | 2nd plot (5-6" depth) | | 3rd plot (4-5" depth) | |
|---|---|---|---|---|---|---|
| | Fuel (ml) | Time (min) | Fuel (ml) | Time (min) | Fuel (ml) | Time (min) |
| 1st ploughing | 1000 | 22 | 1000 | 22 | 1000 | 22 |
| 2nd ploughing | 850 | 18 | 850 | 18 | 850 | 18 |
| Final ploughing | 700 | 16 | 600 | 14 | 550 | 13 |
| Total | 2550 | 56 | 2450 | 54 | 2400 | 53 |
| Fuel consumption (l/hr) | 2.74 | | 2.72 | | 2.71 | |

**Table 4. Machinery facilities of different engineering workshops.**

| Workshop / Facility | Foundry (no.) | Lathe machine (no.) | Shaper machine (no.) | Drill machine (no.) | Milling machine (no.) | Grinding machine (no.) | Welding machine (no.) | Metal cutting (no.) | Colour compressor (no.) |
|---|---|---|---|---|---|---|---|---|---|
| Bipul Machinery | | 1 | | 1 | | 1 | 3 | 1 | |
| Mamun Krisi Parts | | 1 | | | | | 1 | | |
| Abu Bakar Engineering Workshop | | 1 | | 2 | | | 2 | 1 | |
| Rahman Eng. Workshop | | 1 | 1 | 1 | 1 | 1 | 2 | 1 | |

**Table 5. List of machinery produced by manufacturers.**

| Machinery / Workshop | Open drum thresher | Close drum thresher | Maize sheller | Chopper | Bed planter | Winnower | Weeder |
|---|---|---|---|---|---|---|---|
| Bipul Machinery | √ | √ | √ | | | | |
| Mamun Krisi Parts | √ | √ | | | | | |
| Abu Bakar Engineering Workshop | √ | √ | | | | | |
| Rahman Eng. Workshop | √ | √ | | | | | |

sheller are the common machinery produced by the manufacturers, and someone also produced sprayer, chopper, bed planter, winnower and weeder. They have no facility of foundry works but they can do any kind of foundry related works from other workshops in their locality if it is necessary.

Various kinds of materials are used to make different parts of the agriculture machinery. Metal sheet, angle bar, rod/sheet, wood and glass are the common materials to make these machinery which are available in the market (Table 6). Manufacturers face some problems to fabrication/manufacturing and marketing of agricultural machine (Table 7).

There is no way to develop the agriculture sector without mechanization. High rate of imported machinery is a great problem to spread the mechanization. Local workshops/manufacturers can play an important role to reach the agriculture machinery at farm level if they use the locally available material to manufacture the machinery. As a result, the manufacturing cost of the machinery will be low. Then the farmers can buy the machinery from the manufacturers at a cheaper rate. Lack of fund is the main problem to the manufacturer to produce machinery. They need subsidy and proper support from the government, which will help them to produce the machinery by improving their workshop.

## MAINTENANCE WORK OF WMM DIVISION

### Repair and maintenance works of transports/vehicles and farm machinery

Different kinds of transport/vehicles and farm machinery are at BRRI. WMM Division of BRRI does the repair and maintenance works of different kinds of transport/vehicles and farm machinery. There were 39 vehicles (4-wheeler), 110 motor cycles, 4 tractors with accessories (one scrapper, three harrows, five rotaries, three discs and three scissors), 21 power tillers, 13 hydro-tillers, one reaper, 4 BRRI field mower, 22 pumps, 13 threshers, two engines, and other farm machinery were repaired and changed of spare parts under major and moderate/minor repair and maintenance work. The repair and maintenance works have been divided into two groups such as:

- Moderate/minor repair and maintenance work
- Major repair and maintenance work

### Moderate/minor repair and maintenance work

Moderate/minor repair and maintenance works have been classified into three groups:

- Moderate/minor spare parts change and repair
- Minor CNG related trouble shooting and electrical works of vehicles
- Transport/vehicles/machinery cleaning and servicing

**Table 6. Availability of used materials in workshop.**

| Workshop / Material | Metal sheet | Angle bar | Rod/ Shaft | Wood | Glass | Rubber |
|---|---|---|---|---|---|---|
| Bipul Machinery | √ | √ | √ | √ | √ | √ |
| Mamun Krisi Parts | √ | √ | √ | √ | √ | |
| Abu Bakar Engineering Workshop | √ | √ | √ | √ | √ | |
| Rahman Eng. Workshop | √ | √ | √ | √ | √ | |

**Table 7. Problem of fabrication/manufacturing and marketing of agriculture machine.**

| Identity | Bipul Machinery | Mamun Krisi Parts | Abu Bakar Engg. Workshop | Rahamna Engg. Workshop |
|---|---|---|---|---|
| Lack of capital and credit facility | √ | | √ | √ |
| Complexity and delay in getting loan | √ | √ | √ | √ |
| Lack of technological know-how | √ | | √ | √ |
| High cost of raw materials | √ | √ | √ | √ |
| High custom duty on finished product | √ | | √ | |
| Excise duty on raw materials | √ | √ | | |
| Scarcity of skilled labour | √ | | √ | |
| Load shedding | √ | √ | √ | √ |
| Uncertain and low demand | √ | | √ | |
| Seasonality of demand | √ | √ | | |
| Small or dispersed market | √ | | √ | √ |
| Marketing and distribution problem | √ | | √ | |
| People/custom do not have adequate idea about agril machine | | | √ | |

Moderate/minor spare parts change and repair works of all the vehicles and different farm machinery were done day to day in BRRI except CNG related trouble shootings of these vehicles, because there was no trained manpower in BRRI regarding CNG related trouble shootings. As a result, major/moderate/minor/or any kind of CNG related trouble shootings of these vehicles was totally done outside BRRI. A total of 39 vehicles (4-wheeler) in 855 times, 99 motor cycles and other farm machinery in 90 times were repaired and changed of spare parts under moderate/minor repair and maintenance work (Table 8). The total cost of moderate/minor repair and maintenance was Tk 8,70,803 from July 2016 to June 2017 (Table 8).

**Major repair and maintenance work**

There are seven types of major repair and maintenance works:

- Major spare parts change and repaire
- Overhauling
- CNG conversion
- Denting-painting
- Tyre-tube
- Battery
- Major CNG related trouble shooting

Major repair and maintenance works have been done in BRRI workshop and outside BRRI. Some of the major spare parts change, overhauling and repair works have been done in BRRI workshop but major works were done outside BRRI due to fund limitation and some of the major works have been done by direct contracting through BRTC (a Government Workshop), Tejgaon, Dhaka; NAVANA Toyota 3S center, Tejgaon, Dhaka and also in local workshops. On the other hand, most of the CNG related works (CNG conversion, any kinds of CNG related trouble shooting) have been done by direct contracting through Rupantorito Prakritic Gas Co. Ltd., Joar Sahara, Dhaka, a government workshop but denting-painting works have totally been done outside BRRI. At present electrical works have been done in BRRI workshop. Purchasing the battery and tyre-tube or taking the tyre-tube from BRRI store (if available) through requisition were attached to the vehicles/transports in BRRI workshop. The major repair and maintenance cost and times of work of individual vehicles (4-wheeler), motor cycles, tractor/ power tiller/hydro-tiller from July 2016 to June 2017 were recorded (Table 8). A total of 39 vehicles (4-wheeler) in 105 times, tractor in 4 time, power tiller in 4 times, hydro tiller in 3 times and others were repaired and changed of spare parts in BRRI workshop and outside BRRI under major repair and maintenance work. The total cost of major repair and maintenance work was Tk 23,07,350 from July 2016 to June 2017 (Table 8).

Total cost of major and moderate/minor repair and maintenance was Tk 31,78,153 from July 2016 to June 2017 (Table 8). Major repair and maintenance cost was Tk 23,07,350 and moderate/minor repair and maintenance cost was Tk 8,70,803 (Fig. 1). The moderate/minor repair and maintenance work

**Table 8. Cost and times of repair and maintenance work of different vehicles/transports and farm machinery of BRRI from July 2016 to June 2017.**

| Type of vehicle | Vehicle/ Machine (no.) | Time of major works | Time of moderate/ minor works | Total number of works | Cost of major works | Cost of moderate/ minor works | Total cost (Tk) |
|---|---|---|---|---|---|---|---|
| Bus | 0004 | 7 | 63 | 70 | 140870 | 62820 | 203690 |
| -do- | 3831 | 4 | 116 | 62 | 75080 | 37520 | 112600 |
| Mini-bus | 8430 | 1 | 102 | 103 | 13186 | 2150 | 15336 |
| Micro-bus | 0034 | 0 | 80 | 80 | 0 | 9043 | 9043 |
| -do- | 0076 | 0 | 53 | 53 | 0 | 16220 | 16220 |
| -do- | 3870 | 0 | 34 | 34 | 0 | 15650 | 15650 |
| -do- | 0052 | 0 | 31 | 31 | 0 | 21500 | 21500 |
| -do- | 0053 | 1 | 24 | 25 | 8000 | 22660 | 30660 |
| -do- | 005 | 3 | 38 | 41 | 233875 | 38700 | 272575 |
| -do- | 0009 | 3 | 22 | 25 | 67390 | 7210 | 74600 |
| -do- | 0010 | 4 | 24 | 28 | 52116 | 11067 | 63183 |
| Jeep | 0170 | 7 | 15 | 22 | 267120 | 53979 | 321099 |
| -do- | 0188 | 2 | 31 | 33 | 40500 | 10520 | 51020 |
| -do- | 0189 | 3 | 31 | 34 | 63355 | 20345 | 83700 |
| -do- | 0190 | 1 | 26 | 27 | 52000 | 34634 | 86634 |
| -do- | 0086 | 1 | 6 | 7 | 133900 | 4300 | 138200 |
| -do- | 0103 | 3 | 26 | 29 | 51300 | 42572 | 93872 |
| -do- | 0024 | 1 | 10 | 11 | 126212 | 5282 | 131494 |
| -do- | 0025 | 1 | 5 | 6 | 83635 | 5645 | 89280 |
| -do- | 0026 | 1 | 19 | 20 | 8510 | 14830 | 23340 |
| Pickup | 0091 | 1 | 15 | 16 | 12500 | 11150 | 23650 |
| -do- | 0017 | 0 | 33 | 33 | 0 | 7030 | 7030 |
| -do- | 0056 | 2 | 30 | 32 | 14500 | 48224 | 62724 |
| -do- | 0057 | 7 | 25 | 32 | 79521 | 29340 | 108861 |
| -do- | 0058 | 3 | 38 | 41 | 40853 | 43840 | 84693 |
| -do- | 0089 | 1 | 6 | 7 | 24740 | 5880 | 30620 |
| -do- | 0090 | 2 | 13 | 15 | 83310 | 5300 | 88610 |
| -do- | 0109 | 1 | 21 | 22 | 24800 | 22717 | 47517 |
| -do- | 0002 | 2 | 21 | 23 | 31565 | 23585 | 55150 |
| -do- | 0018 | 0 | 0 | 0 | 0 | 0 | 0 |
| -do- | 0011 | 2 | 35 | 37 | 43737 | 6445 | 50182 |
| -do- | 0025 | 1 | 6 | 7 | 83635 | 5645 | 89280 |
| -do- | 1641 | 1 | 5 | 6 | 22500 | 0 | 22500 |
| -do- | 004 | 1 | 5 | 6 | 12500 | 6490 | 18990 |
| -do- | 015 | 1 | 0 | 1 | 90000 | 0 | 90000 |
| Truck | 0020 | 1 | 23 | 24 | 24900 | 2920 | 27820 |
| -do- | 0101 | 1 | 16 | 17 | 6350 | 11188 | 17538 |
| -do- | 0001 |  | 30 | 30 | 0 | 8935 | 8935 |
| -do- | 0011 | 2 | 0 | 2 | 22500 | 0 | 22500 |
| Subtotal | 72 | 72 | 1078 | 1060 | 2034960 | 675336 | 2710296 |

**Table 8. Continued.**

| Type of vehicle | Vehicle/ Machine (no.) | Time of major works | Time of moderate/ minor works | Total number of works | Cost of major works | Cost of moderate/ minor works | Total cost (Tk) |
|---|---|---|---|---|---|---|---|
| Motor cycle (110 nos.) | 0 | 470 | 470 | 0 | 43247 | 43247 | |
| Tractor (4 nos.) | 2 | 23 | 25 | 9640 | 1880 | 11520 | |
| Power tiller (21 nos) | 5 | 170 | 175 | 86750 | 17980 | 104730 | |
| Hydro tiller (13 nos) | 3 | 23 | 26 | 64500 | 12830 | 77330 | |
| Pump+mower (26 nos.) | 2 | 20 | 22 | 37000 | 5500 | 42500 | |
| Tyres & tubes | 0 | 0 | 0 | 0 | 0 | 0 | |
| Others/Threshers (13 nos.) | 5 | 46 | 51 | 74500 | 114030 | 188530 | |
| Sub total | | 17 | 752 | 769 | 272390 | 195467 | 467857 |
| Grand total | | 89 | 1830 | 1829 | 2307350 | 870803 | 3178153 |

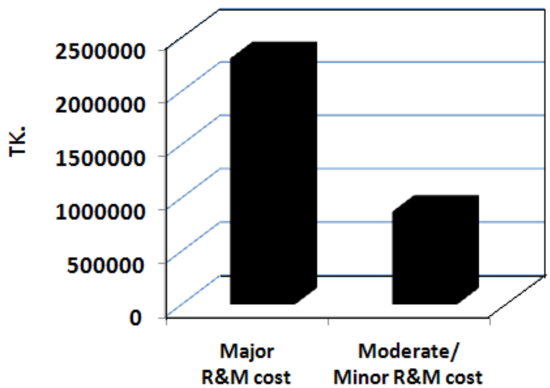



Fig. 1. Major and moderate/minor repair and maintenance cost of different vehicles and farm machinery of BRRI from July 2016 to June 2017.

was done only by using the revolving fund. On the other hand, the major repair and maintenance work was done by direct cash purchase, direct contracting through work order, RFQ (Request for quotation) and OTM (Open tender method).

# Adaptive Research Division

SUMMARY

In the reporting period, 41 advanced breeding lines for different seasons were evaluated by conducting 14 advanced line adaptive research trials (ALART) at farmers' field in different agroecological regions of the country. Considering specialty on some important characteristics and farmers' opinion, eight advanced lines for different characteristics in different seasons were recommended for proposed variety trial (PVT). In Aus 2016, two advanced lines for transplanting condition and one for broadcast method were recommended for PVT. For rainfed low land rice, two advanced lines from Plant Breeding and one from Biotechnology Division were found suitable for PVT during T. Aman 2006. In Boro 2017, one line for favourable condition and one for long duration developed by Biotechnology Division were recommended for PVT.

In Aus 2016, Aman 2016 and Boro 2017, seed production and dissemination programmes (SPDP) were conducted by using different BRRI varieties and other technologies under different projects. A total of 420 demonstrations were conducted in 135 upazilas of 35 districts, from which about 257 tons of paddy grains were produced and 37 tons were retained as seeds by the farmers for next year cultivation. Thirty-two thousand farmers gained awareness and knowledge about BRRI varieties through demonstrations, knowledge sharing, field days, field visit and other interactions. Among them about eight thousand farmers were motivated to adopt BRRI varieties.

In Aman 2016 and Boro 2017, seed support programme to farmers and different stakeholders were conducted in different locations of the country under TRB project to enhance rapid dissemination of newly released BRRI varieties. In T. Aman 2016, 1710 kg seeds of 12 varieties (BRRI dhan34, 49, 52, 54, 56, 57, 62, 66, 70, 71, 72 and 73) were distributed to 266 farmers/stakeholders in 60 upazilas of 17 districts. In Boro 2017, 2100 kg seeds of 11 varieties (BRRI dhan29, 50, 55, 58, 59, 60, 63, 64, 67, 69 and 74) were distributed to 300 farmers/stakeholders in 74 upazilas of 30 districts. Adaptive Research Division (ARD) conducted 48 farmers' training at different locations in which 1,735 trainees (1,480 farmers and 255 SAAOs of DAE) participated. The Division also conducted 43 field days at different locations. About 6,450 persons participated in those occasions. A total of 5.20 tons good quality seeds of different BRRI varieties were produced by ARD at BRRI farm those were used for follow up adaptive research trials. Two seed centers for farmers were established at Singherbangla, sadar, Netrakona and Kushodanga, Koyra, Khulna. We provided eight plastic drums at each center. Around 75 kg seeds can be preserved in each drum.

TECHNOLOGY VALIDATION

**Advanced line adaptive research trial (ALART)**

**T. Aus 2016.** Two advanced lines BR7718-55-1-3 and WKI along with BRRI dhan48 as a check were tested at farmers' field in 7 locations of Comilla region. On an average, two evaluated lines out yielded (4.58-4.72 t/ha) the average yield of check variety BRRI dhan48 (4.54 t/ha) (Table 1). Mean growth duration of BR7718-55-1-3 and WKI was 108 and 110 days respectively, which was similar to the check variety BRRI dhan48 (108) days. In terms of grain yield, growth duration, grain and plant types, most of the farmers preferred both the advanced lines BR7718-55-1-3 and WKI. Considering grain yield, growth duration, disease infections, farmers' opinion and other necessary aspects, the two advanced lines BR7718-55-1-3 and WKI were recommended for proposed variety trial (PVT).

**B. Aus 2016.** Four advanced lines BI dhan5, BRH11-9-14-6-7B, IR92240-40-2-2-1 and BR7178-2B-19 along with check variety BRRI dhan42 were tested at farmers' field in 10 locations. On average, all the evaluated lines gave higher yield (3.36-3.60 t/ha) than the check variety BRRI dhan42 (3.24 t/ha). Among the five tested lines, BI dhan5 gave the highest average yield (3.60 t/ha) ranged from 2.40 to 4.37 t/ha followed by IR92240-40-2-2-1 (3.50 t/ha), BRH11-9-14-6-7B (3.41 t/ha) and BR7178-2B-19 (3.36 t/ha) (Table 2). The lowest yield was found in the check variety BRRI dhan42 (3.24 t/ha). Mean growth duration of BI dhan5 (98 days) was almost similar to the check variety BRRI dhan42 (99 days). In terms of grain yield, growth duration and grain type, most of the farmers

**Table 1. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of some advanced lines under ALART grown in different locations of Comilla region, during T. Aus 2016.**

| Genotype | Location | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | | | | | | | | | | |
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | Mean | Mean | Mean | Mean |
| BR7718-55-1-3 | 4.63 | 4.55 | 5.04 | 4.85 | 4.49 | 4.67 | 4.82 | 4.72 | 108 | 22.31 | 110 |
| WKI | 4.38 | 4.41 | 4.52 | 4.73 | 4.59 | 4.87 | 4.58 | 4.58 | 110 | 23.47 | 108 |
| BRRI dhan48 (ck) | 4.24 | 4.75 | 4.69 | 4.37 | 4.53 | 4.57 | 4.61 | 4.54 | 108 | 23.76 | 107 |
| $LSD_{0.05}$ | | | | 0.39 | | | | 0.15 | 0.33 | 0.19 | 1.5 |

L1- Noakhali (Sadar), L2- Comilla (Chandina), L3- B. Baria (Sadar), L4- Chittagong (Mirsori), L5- Feni (Sadar), L6- Comilla RS, L7- BRRI HQ (East byde).

**Table 2. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART grown in different locations of Bangladesh during B. Aus 2016.**

| Genotype | Location | | | | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | | | | | | | | | | | | | |
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | L10 | Mean | Mean | Mean | Mean |
| BI dhan5 | 3.86 | 2.40 | 4.35 | 2.98 | 4.13 | 4.37 | 3.63 | 3.71 | 3.15 | 3.49 | 3.60 | 98 | 23.21 | 97 |
| BRH11-9-14-6-7B | 3.07 | 2.48 | 3.11 | 3.56 | 3.85 | 4.10 | 3.36 | 3.82 | 3.00 | 3.71 | 3.41 | 116 | 23.82 | 103 |
| IR92240-40-2-2-1 | 3.41 | 2.71 | 4.50 | 3.42 | 3.89 | 4.07 | 3.52 | 3.86 | 2.60 | 3.10 | 3.50 | 111 | 24.71 | 110 |
| BR7178-2B-19 | 4.09 | 2.85 | 4.73 | 3.20 | 3.84 | 3.90 | 3.01 | 3.12 | 2.17 | 2.72 | 3.36 | 98 | 23.75 | 111 |
| BRRI dhan42 (ck) | 3.04 | 2.80 | 3.74 | 3.04 | 4.16 | 4.26 | 3.26 | 3.29 | 2.20 | 2.58 | 3.24 | 99 | 23.79 | 110 |
| LSD $(_{0.05})$ | | | | | 0.42 | | | | | | 0.13 | 0.3 | 0.27 | 1.40 |

L1-Sylhet, L2-Kushtia, L3-Habiganj, L4-Faridpur, L5-Naogaon, L6-Rajshahi (Godagari), L7-Gazipur (BRRI), L8-Chuadanga, L9-Rajshahi (Poba), L10-Natore.

preferred BI dhan5. Considering grain yield, growth duration, disease infections, farmers' opinion and other necessary aspects, the advanced line BI dhan5 was recommended for PVT.

**T. Aman 2016, rainfed lowland rice-1 (RLR-1).** Three advanced lines IR70213-10-CPA 4-2-2-2, BR8214-19-3-4-1 and BR8214-23-1-3-1 along with BRRI dhan39 as check were tested at farmers' field in 10 locations. Except entry no. 1, the tested advanced lines were not found to be over yielder than the check variety (Table 3). The entry no.1 gave slightly higher yield than the check. But the growth duration of the check variety was about 4-6 days earlier than the tested advanced lines. Considering all necessary aspects, farmers did not show so much interest about the entries compared to check variety BRRI dhan39. Considering grain yield, grain size, growth duration, lodging tendency, phenotypic acceptance and farmers' opinion, none of the advanced lines was found suitable for PVT.

**T. Aman 2016, rainfed lowland rice-2 (RLR-2).** One swarna type advanced line BR8210-10-3-1-2 along with checks, BRRI dhan49, Lal Swarna and Local Swarna checks (Sumon swarna, Swarna-59, Guti Swarna, Swarna pari, Swarna-5) were tested at farmers' field in eight locations. The yield performance of the advanced line BR8210-10-3-1-2 (4.52 t/ha) was not better than the check varieties (4.66-4.83 t/ha) (Table 4). The mean growth duration of the line (133 days) was similar to BRRI dhan49 (132 days) but it was about 3-4 days earlier than Lal swarna (138 days) and local swarna (136 days). In respect to grain yield, grain size, growth duration and disease incidence, farmers did not show interest about the tested advanced line BR8210-10-3-1-2 over the check varieties. However, considering some positive sides of the line, it was decided that re-ALART of the advanced line would be done in next season.

**T. Aman 2016, Rainfed lowland rice-3 (RLR-3).** Five breeding materials BR-SS(Raj)-PL5-B, BR-RS(Raj)-PL4-B, BR-NS(Rang)-PL2-B, BR-SF(Rang)-PL1-B and BR-GS(Raj)-PL3-B along with BR11 and BRRI dhan49 as checks were tested at farmers' field in eight locations. On average of eight locations, all the tested entries gave yield ranging from 4.60-4.95 t/ha. Having the highest yield in three locations, only entry no. 2 gave higher

**Table 3. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (RLR-1) grown in different locations during T. Aman 2016.**

| Genotype | Location | | | | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | | | | | | | | | | | | | |
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | L10 | Mean | Mean | Mean | Mean |
| IR70213-10-CPA 4-2-2-2 | 3.99 | 4.37 | 4.73 | 4.08 | 4.59 | 3.85 | 4.40 | 4.43 | 4.26 | 5.05 | 4.37 | 126 | 28.36 | 120 |
| BR8214-19-3-4-1 | 4.93 | 4.21 | 4.11 | 4.32 | 4.93 | 3.74 | 3.95 | 3.15 | 4.00 | 5.27 | 4.26 | 128 | 26.34 | 129 |
| BR8214-23-1-3-1 | 5.03 | 4.17 | 3.34 | 4.49 | 4.74 | 3.61 | 3.37 | 3.89 | 3.91 | 4.98 | 4.15 | 128 | 26.06 | 126 |
| BRRI dhan 39 (ck) | 3.93 | 4.03 | 4.08 | 3.71 | 4.75 | 4.13 | 4.12 | 3.47 | 4.36 | 5.01 | 4.16 | 122 | 24.28 | 114 |
| LSD ($_{0.05}$) | | | | | 0.43 | | | | | | 0.13 | 0.30 | 0.26 | 1.09 |

L1-Barisal, L2-Chittagong, L3-Sherpur, L4-Rangpur, L5-Sylhet, L6- Gazipur (BRRI), L7-Natore, L8-Feni, L9-Khulna, L10-Jessore.

**Table 4. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (RLR-2) grown in different locations during T. Aman 2016.**

| Genotype | Location | | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | | | | | | | | | | | |
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | Mean | Mean | Mean | Mean |
| BR8210-10-3-1-2 | 4.50 | 4.25 | 3.53 | 5.80 | 4.72 | 5.10 | 3.83 | 4.42 | 4.52 | 133 | 23.41 | 117 |
| BRRI dhan49 (ck) | 4.95 | 4.63 | 3.79 | 5.60 | 5.36 | 4.81 | 4.25 | 5.00 | 4.80 | 132 | 21.12 | 103 |
| Lal Swarna (ck) | 4.46 | 4.54 | 4.75 | 5.01 | 4.32 | 5.30 | 4.41 | 4.47 | 4.66 | 138 | 20.84 | 97 |
| Local ck | 4.26<br>Sumon Swarna | 4.20<br>Swarna-59 | 5.17<br>Sumon Swarna | 5.79<br>Guti Swarna | 4.53<br>Swarna Pari | 5.40<br>Guti Swarna | 4.70<br>Swarna-5 | 4.60<br>Sumon Swarna | 4.83 | 136 | 21.68 | 115 |
| LSD (0.05) | | | | 0.45 | | | | | 0.14 | 0.31 | 0.26 | 1.23 |

L1- Rajshahi, L2- Naogaon, L3- Chapainawabganj, L4- Nilphamari, L5- Ponchogor, L6- Thakurgaon, L7- Rangpur, L8-BRRI HQ (East byde).

yield (4.95 t/ha) than the check varieties BR11 (4.62 t/ha) and BRRI dhan49 (4.70 t/ha). Mean grain yield of entry no.4 was 4.80 t/ha, which was apparently slightly higher but statistically similar to that of BR11 and BRRI dhan49 (Table 5). Farmers showed interest about the tested entries, especially for entry no. 2 and 4 for their better yield, attractive grain size and phenotypic acceptance. Considering grain yield, grain size, growth duration, phenotypic acceptance and farmers' opinion, BR-RS(Raj)-PL4-B (entry no. 2) and BR-SF(Rang)-PL1-B (entry no. 4) were recommended for PVT.

**T. Aman 2016, zinc enriched rice (ZER).** Five zinc enriched advanced lines BR7528-2R-HR16-12-3-P1, BR7528-2R-HR16-12-23-P1, IR84750-213-2-2-3-1, BR7895-4-3-3-2-3 and BR8445-54-6-6 along with BRRI dhan39, BRRI dhan49 and BRRI dhan72 as checks were tested at farmers' field in 10 locations. But the trial at Barisal was damaged due to high tidal pressure along with heavy rainfall. In respect to grain yield, grain size and growth duration, none of the advanced lines performed better compared to check varieties, especially BRRI dhan49 and BRRI dhan72 (Table 6). Compared to check varieties, farmers did not show interest for any line. So, considering grain yield, grain size, growth duration, disease reaction, lodging tendency, phenotypic acceptance and farmers‘opinion, none of the advanced lines was recommended for PVT.

**T. Aman 2016, RLR-Biotechnology.** Two advanced breeding lines developed by Biotechnoly Division: BR(Bio)9786-BC2-119-1-1 and BR(Bio)9786-BC2-132-1-3 along with BRRI dhan49 as check were tested at farmers' field in 10 locations. But the trial at Barisal was damaged due to high tidal pressure along with heavy rainfall. Results showed that among the tested advanced lines, BR(Bio)9786-BC2-132-1-3 (entry no. 2) gave similar yield to that of BRRI dhan49 but the entry

**Table 5. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (RLR-3) grown in different locations during T. Aman 2016.**

| Genotype | Location | | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | | | | | | | | | | | |
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | Mean | Mean | Mean | Mean |
| BR-SS(Raj)-PL5-B | 5.12 | 4.33 | 5.36 | 5.03 | 5.08 | 4.33 | 4.26 | 4.02 | 4.69 | 139 | 21.23 | 118 |
| BR-RS(Raj)-PL4-B | 4.92 | 5.07 | 5.43 | 5.04 | 5.48 | 4.83 | 4.52 | 4.31 | 4.95 | 138 | 21.33 | 117 |
| BR-NS(Rang)-PL2-B | 4.88 | 4.36 | 5.57 | 5.00 | 5.22 | 3.99 | 4.35 | 4.01 | 4.67 | 139 | 22.76 | 116 |
| BR-SF (Rang)-PL1-B | 4.40 | 4.99 | 5.97 | 4.74 | 5.04 | 4.03 | 4.71 | 4.56 | 4.80 | 137 | 21.01 | 117 |
| BR-GS(Raj)-PL3-B | 4.05 | 5.15 | 5.58 | 4.31 | 5.17 | 4.53 | 4.11 | 3.95 | 4.60 | 138 | 20.94 | 117 |
| BR11 (ck) | 4.25 | 4.41 | 5.68 | 4.06 | 5.29 | 4.70 | 4.23 | 4.38 | 4.62 | 138 | 24.35 | 112 |
| BRRI dhan49 (ck) | 4.87 | 3.60 | 5.51 | 4.88 | 4.97 | 4.43 | 4.65 | 4.70 | 4.70 | 133 | 21.06 | 103 |
| LSD (0.05) | | | | 0.57 | | | | | 0.20 | 0.25 | 0.24 | 1.69 |

L1- Rajshahi, L2- Chapainawabganj, L3- Nilphamari, L4- Ponchogor, L5- Thakurgaon, L6- Rangpur, L7-Naogaon, L8-BRRI H/Q (East byde).

**Table 6. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (ZER) grown in different locations during T. Aman 2016.**

| Genotype | Location | | | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | | | | | | | | | | | | |
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | Mean | Mean | Mean | Mean |
| BR7528-2R-HR16-12-3-P1 | 4.30 | 3.17 | 4.60 | 4.26 | 4.62 | 4.78 | 4.20 | 4.40 | 4.56 | 4.32 | 134 | 23.25 | 123 |
| BR7528-2R-HR16-12-23-P1 | 5.05 | 4.32 | 4.04 | 5.36 | 5.78 | 4.51 | 4.34 | 4.43 | 4.50 | 4.70 | 134 | 2340 | 136 |
| IR84750-213-2-2-3-1 | 3.92 | 4.10 | 3.81 | 4.10 | 4.00 | 4.47 | 4.93 | 3.81 | 4.09 | 4.13 | 130 | 28.11 | 135 |
| BR7895-4-3-3-2-3 | 4.68 | 3.95 | 4.50 | 5.41 | 5.86 | 5.00 | 5.60 | 4.77 | 4.22 | 4.90 | 128 | 28.04 | 124 |
| BR8445-54-6-6 | 4.08 | 4.10 | 4.06 | 4.38 | 4.60 | 4.70 | 4.43 | 3.31 | 3.90 | 4.17 | 112 | 24.33 | 123 |
| BRRI dhan39 (ck) | 4.04 | 4.06 | 4.12 | 4.15 | 4.06 | 4.96 | 4.45 | 3.64 | 3.83 | 4.14 | 122 | 24.00 | 111 |
| BRRI dhan49 (ck) | 4.93 | 3.80 | 4.83 | 4.88 | 5.37 | 5.10 | 5.20 | 4.63 | 4.70 | 4.82 | 134 | 20.61 | 108 |
| BRRI dhan72 (ck) | 5.07 | 3.63 | 4.52 | 4.45 | 4.85 | 5.04 | 5.33 | 4.40 | 4.60 | 4.65 | 130 | 28.14 | 122 |
| Lsd $_{(0.05)}$ | | | | | 0.52 | | | | | 0.18 | 0.28 | 0.20 | 1.16 |

L1-Natore, L2-Feni, L3-Khulna, L4-Sherpur, L5-Chittagong, L6- Jessore, L7-Sylhet, L8-Rangpur, L9-BRRI (WB).

was about seven days earlier than BRRI dhan49 (Table 7). Grain size of the entry was more long slender than the check variety. The entries were found free from false smut disease, whereas BRRI dhan49 showed susceptibility in some locations. Among the two tested entries, farmers' interest were concentrated for BRRI dhan49, alongside the entry no. 2 for its better yield, grain size, shorter growth duration and less incidence of diseases. Considering grain yield, grain size, growth duration, phenotypic acceptance, disease tolerance and farmers' opinion, BR(Bio)9786-BC2-132-1-3 (entry no. 2) was recommended for PVT.

**B. Aman 2016, deep water rice (DWR).** Three advanced lines bred for semi deep water rice: BR9390-6-2-2B, BR10260-2-19-2B and BR7730-5-1-2B along with Lal Mohon and Habiganj Aman-1 as checks including local check (Fulkuri, Dhaldigi, Sarsaria, Manik digha, Lal Digha) were tested at farmers' field in nine locations. But the advanced lines were damaged in most of the locations because of higher water depth and hence statistical analysis was not possible. Only mean data were calculated. Trials at Sylhet and Shunamganj were totally damaged. Trials at Habiganj, Natore and Faridpur were not affected due to low water depth. Most

**Table 7. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (RLR-Bio) grown in different locations during T. Aman 2016.**

| Genotype | Location | | | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | | | | | | | | | | | | |
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | Mean | Mean | Mean | Mean |
| BR(Bio)9786-BC2-119-1-1 | 5.10 | 4.50 | 4.61 | 4.45 | 5.01 | 4.60 | 3.69 | 5.00 | 4.30 | 4.60 | 127 | 23.85 | 130 |
| BR(Bio)9786-BC2-132-1-3 | 5.36 | 4.65 | 4.75 | 4.76 | 5.52 | 5.20 | 4.33 | 5.36 | 4.42 | 4.92 | 126 | 23.78 | 131 |
| BRRI dhan49 (ck) | 5.33 | 4.78 | 4.91 | 4.72 | 5.36 | 5.10 | 4.41 | 5.30 | 4.60 | 4.95 | 133 | 20.60 | 110 |
| LSD (0.05) | | | | | 0.45 | | | | | 0.15 | 0.40 | 0.16 | 1.0 |

L1-Sherpur, L2-Natore, L3-Khulna, L4-Rangpur, L5-Jessore, L6- Sylhet, L7-Feni, L8-Chittagong, L9-BRRI (WB).

farmers were not so much interested to cultivate DW rice due to its poor yield with long duration and complex environment. As the advanced lines were damaged in most of the locations, the results were not conclusive. Farmers did not prefer the advanced lines due to its lower yield and longer duration (Table 8). On the other hand, they preferred their respective local varieties. So, none of the advanced lines was recommended for PVT.

**Boro 2017, favourable Boro rice (FBR).** Three advanced lines for favourable condition: BR8338-34-3-4, BR8340-16-2-1 and BRRI dhan29-SC3-8-HR1 (Com) along with BRRI dhan58 and BRRI dhan29 as checks were evaluated in 10 locations. Average yield performance of BRRI dhan29-SC3-8-HR1 (Com) (entry no. 3) was found to be slightly higher (6.55 t/ha) than the other tested lines (6.03-6.25 t/ha) and check variety BRRI dhan58 (6.30 t/ha) and it was similar to that of check variety BRRI dhan29 (6.70 t/ha) (Table 9). Growth duration and grain size of entry no. 3 was very similar to that of BRRI dhan29. Flowering was also uniform as like as BRRI dhan29. So, considering grain yield, growth duration, grain size, lodging tolerance, phenotypic acceptance, disease tolerance and farmers' opinion, BRRI dhan29-SC3-8-HR1 (Com) (entry no. 3) was recommended for PVT.

**Boro 2017, premium quality rice (PQR).** Two advanced lines for premium quality rice: BR8076-1-2-2-3 and BR7372-18-2-1-HR1-HR6 (Com) along with BRRI dhan50 and BRRI dhan63 as checks were evaluated in 10 locations. On average of 10 locations, both the advanced lines gave lower yield, ranged from 5.36-5.53 t/ha, than the check varieties BRRI dhan50 (5.76 t/ha) and BRRI dhan63 (6.06 t/ha). BRRI dhan63 was found to be the highest yielder and it matured in the shortest period of time (145 days) among the entries. Average growth

**Table 8. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (DWR) grown in different locations during B. Aman 2016.**

| Genotype | Location | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | | | | | | | | | | |
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | Mean | Mean | Mean | Mean |
| BR9390-6-2-2B | 3.32 | Damaged | Damaged | 3.09 | Damaged | 2.23 | Damaged | 2.88 | 187 | 24.63 | 180 |
| BR10260-2-19-2B | 3.40 | Damaged | Damaged | 3.11 | 2.98 | 2.29 | 1.51 | 2.66 | 184 | 23.37 | 188 |
| BR7730-5-1-2B | 2.75 | Damaged | 2.65 | 2.61 | Damaged | 2.17 | Damaged | 2.55 | 176 | 24.49 | 216 |
| Lal mohon (ck) | 2.75 | Damaged | 2.65 | 2.61 | 2.41 | 2.17 | 1.42 | 2.33 | 177 | 28.54 | 266 |
| Habigonj Aman-1 (ck) | 2.80 | 2.27 | 2.40 | 2.93 | 2.08 | 1.92 | Damaged | 2.40 | 170 | 26.25 | 326 |
| Local (ck) | 2.63 | 2.26 | 2.32 | 2.00 | 2.13 | 2.40 | 2.35 | 2.30 | 174 | 27.43 | 250 |
| | Fulkuri | Dhaldigi | Sarsaria | Dhaldigi | Manik Digha | Lal Digha | - | | | | |

L1- Habigonj, L2- Pabna, L3- Sirajganj, L4- Natore, L5- Tangail, L6- Faridpur, L7- Gopalganj.

**Table 9. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (FBR) grown in different locations during Boro 2017.**

| Genotype | Location Grain yield (t/ha) | | | | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | L10 | Mean | Mean | Mean | Mean |
| BR8338-34-3-4 | 6.50 | 6.94 | 6.60 | 6.37 | 4.59 | 6.18 | 5.95 | 5.00 | 5.75 | 6.38 | 6.03 | 156 | 24.47 | 97 |
| BR8340-16-2-1 | 6.65 | 7.50 | 6.15 | 6.85 | 4.66 | 7.30 | 7.27 | 5.14 | 5.08 | 5.94 | 6.25 | 154 | 22.40 | 106 |
| BRRI dhan29-SC3-8-HR1(Com) | 7.25 | 7.60 | 6.75 | 6.24 | 6.80 | 7.45 | 6.71 | 5.50 | 5.64 | 5.59 | 6.55 | 157 | 21.86 | 99 |
| BRRI dhan 58 (ck) | 7.36 | 6.76 | 6.62 | 6.82 | 5.55 | 7.36 | 6.37 | 5.15 | 5.40 | 5.58 | 6.30 | 151 | 23.24 | 97 |
| BRRI dhan 29 (ck) | 7.52 | 7.26 | 7.15 | 6.94 | 5.64 | 7.67 | 6.84 | 5.50 | 5.69 | 6.74 | 6.70 | 159 | 22.40 | 100 |
| LSD ($_{0.05}$) | | | | | 0.53 | | | | | | 0.17 | 0.36 | 0.30 | 1.28 |

L1-BRRI HQ, Gazipur, L2-Rangpur, L3-Barisal, L4-Chittagong, L5-Habiganj, L6- Khulna, L7-Jessore, L8-Feni, L9-Cox's bazar, L10-Mymensingh.

duration of the tested entries ranged from 146-148 days and it was 148 days for BRRI dhan50 (Table 10). Flowering and maturity of the advanced lines were highly irregular. Disease susceptibility of the advanced lines was also higher than the checks. So, considering all the required characteristics, none of the lines was found suitable for PVT.

**Boro 2017, cold tolerant rice (CTR).** Cold tolerant advanced line BR7812-19-1-6-1-P2 along with BRRI dhan28 and BRRI dhan36 as checks were evaluated at farmers' field in eight locations. Averaged grain yield of the only advanced line was lower (5.43 t/ha) than the check variety BRRI dhan28 (5.88 t/ha) and BRRI dhan36 (5.68 t/ha) (Table 11). On the other hand, mean growth duration of the line (151 days) was about 10 days higher than the check varieties (140-142 days). Flowering and maturity of the line was highly irregular. Moreover, it has a record of lodging tendency and neck blast susceptibility. So, the line was not recommended for PVT.

**Boro 2017, short duration-Biotechnology (SD-Bio).** Developed by Biotechnology Division, three advanced lines: BR(Bio)9787-BC2-63-2-2, BR(Bio)9787-BC2-63-2-4 and BR(Bio)9787-BC2-173-1-3 along with BRRI dhan28 as check were evaluated in 10 locations. Averaged yield performance of the tested advanced lines was not better than the check variety (Table 12). Growth duration of the lines was slightly higher (about 2-3 days) than the check and the lines were found to be lodging tolerant. But the plant height was shorter than the check, which may be harmful in early flush flood. Reddish coloured grain of the lines was medium bold and short type and it was shorter in length than BRRI dhan28. But the lines were found to be very much susceptible to sheath blight and also have higher shattering tendency at maturity.

**Table 10. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (PQR) grown in different locations during Boro 2017.**

| Genotype | Location Grain yield (t/ha) | | | | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | L10 | Mean | Mean | Mean | Mean |
| BR8076-1-2-2-3 | 5.36 | 4.28 | 5.86 | 6.05 | 5.91 | 5.39 | 5.12 | 5.16 | 4.92 | 5.50 | 5.36 | 148 | 22.46 | 101 |
| BR7372-18-2-1-HR1-HR6 (Com) | 5.58 | 4.50 | 6.00 | 5.50 | 6.14 | 5.78 | 5.16 | 5.40 | 5.13 | 6.11 | 5.53 | 146 | 25.58 | 100 |
| BRRI dhan50 (ck) | 5.76 | 5.01 | 6.06 | 6.81 | 5.17 | 4.66 | 6.37 | 6.01 | 5.53 | 6.24 | 5.76 | 148 | 19.59 | 84 |
| BRRI dhan63 (ck) | 5.22 | 4.73 | 6.84 | 6.80 | 6.04 | 5.38 | 6.94 | 6.41 | 6.15 | 6.10 | 6.06 | 145 | 21.84 | 87 |
| LSD ($_{0.05}$) | | | | | 0.45 | | | | | | 0.14 | 0.35 | 0.44 | 1.02 |

L1-Rangpur, L2-Feni, L3-Jessore, L4-Chittagong, L5-Cox's bazar, L6- Mymensingh, L7-Barisal, L8-Khulna, L9-BRRI Gazipur, L10-Habiganj.

**Table 11. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (CTR) grown in different locations during Boro 2017.**

| Genotype | Location | | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | | | | | | | | | | | |
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | Mean | Mean | Mean | Mean |
| BR7812-19-1-6-1-P2 | 6.38 | 5.81 | 6.62 | 5.90 | 4.14 | 4.54 | 4.14 | 5.90 | 5.43 | 151 | 23.10 | 106 |
| BRRI dhan28 (ck) | 6.92 | 6.40 | 6.80 | 5.63 | 6.47 | 4.44 | 4.15 | 6.25 | 5.88 | 140 | 22.46 | 101 |
| BRRI dhan36 (ck) | 6.02 | 6.21 | 6.57 | 5.42 | 6.08 | 4.77 | 4.24 | 6.12 | 5.68 | 142 | 24.63 | 85 |
| LSD (0.05) | | | | 0.49 | | | | | 0.18 | 0.29 | 0.20 | 1.54 |

L1- Naogaon, L2- Rajshahi, L3- Ponchogor, L4- Rangpur, L5- Kushtia, L6- Dinajpur, L7-Habiganj, L8-BRRI HQ, Gazipur.

**Table 12. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (SD-Bio) grown in different locations during Boro 2017.**

| Genotype | Location | | | | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | | | | | | | | | | | | | |
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | L10 | Mean | Mean | Mean | Mean |
| BR(Bio)9787-BC2-63-2-2 | 6.22 | 5.38 | 5.14 | 6.52 | 5.67 | 5.06 | 5.12 | 6.03 | 5.12 | 4.92 | 5.52 | 145 | 19.10 | 88 |
| BR(Bio)9787-BC2-63-2-4 | 6.26 | 5.45 | 5.09 | 6.12 | 4.93 | 4.40 | 5.75 | 6.27 | 5.75 | 4.52 | 5.45 | 146 | 19.61 | 90 |
| BR(Bio)9787-BC2-173-1-3 | 6.14 | 5.71 | 6.54 | 6.19 | 5.60 | 5.72 | 5.45 | 5.30 | 5.10 | 5.27 | 5.70 | 146 | 20.33 | 89 |
| BRRI dhan28 (ck) | 5.60 | 4.81 | 6.58 | 6.60 | 5.58 | 5.38 | 6.29 | 6.54 | 6.32 | 5.96 | 5.97 | 143 | 22.33 | 97 |
| LSD ($_{0.05}$) | | | | | 0.50 | | | | | | 0.16 | 0.22 | 0.35 | 1.58 |

L1-Rangpur, L2-Feni, L3-Jessore, L4-Chittagong, L5-Cox'sbazar, L6- Mymensingh, L7-Barisal, L8-Khulna, L9-BRRI HQ, Gazipur, L10-Habiganj.

Considering above situation and farmers' opinion, none was found suitable for PVT.

**Boro 2017, long duration-Biotechnology (LD-Bio).** Four long duration advanced lines: BR(Bio)9786-BC2-122-1-3, BR(Bio)9786-BC2-49-1-2, BR(Bio)9786-BC2-59-1-2 and BR(Bio)9786-BC2-124-1-1 developed by Biotechnology Division along with BRRI dhan29 as check were evaluated in 10 locations. The tested genotype BR(Bio)9786-BC2-59-1-2 (entry no.3) gave similar mean yield (6.65 t/ha) to that of the check variety BRRI dhan29 (6.69 t/ha) (Table 13). Growth duration of the above entry (158 days) was also similar to that of BRRI dhan29 (159 days). On the other hand, plant height of the above entry was found to be longer (108 cm) than the check (100 cm), which might be helpful in flush flood condition in haor areas. Despite to be taller than BRRI dhan29, the entry was found lodging tolerant in all locations. Grain size of the entry was bolder and longer than BRRI dhan29. Phenotypic character of the advanced line was also good and it was appreciated by the farmers. Moreover, disease incidence of the advanced lines, especially the above entry was comparatively lower than BRRI dhan29. So, considering the above results and farmers' opinion, BR(Bio)9786-BC2-59-1-2 (entry no. 3) was recommended for PVT.

**Boro 2017, long duration-Comilla (LD-Comilla).** Three advanced lines: BR8261-19-1-13, HHZ15-SAL13-Y1 and BR7781-10-3-2-2 along with BRRI dhan58 as check were evaluated in eight locations of Comilla region. Results revealed that none of the advanced lines over yielded the check variety BRRI dhan58 (Table 14). Among the lines, entry no. 3 gave 5.92 t/ha mean yield, which was only about foru t/ha lower than the check (6.31 t/ha). But the above entry was four days earlier than the check. Flowering and maturity of entry no. 1 and 2 was highly irregular. Although, it was uniform for entry no. 3 but it had higher shattering tendency. All the tested lines including

**Table 13. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (LD-Bio) grown in different locations during Boro 2017.**

| Genotype | Location | | | | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | | | | | | | | | | | | | |
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | L10 | Mean | Mean | Mean | Mean |
| BR(Bio)9786-BC2-122-1-3 | 6.90 | 6.91 | 6.55 | 7.64 | 5.19 | 7.71 | 5.29 | 4.64 | 6.50 | 7.01 | 6.43 | 159 | 25.74 | 110 |
| BR(Bio)9786-BC2-49-1-2 | 6.39 | 7.07 | 6.86 | 7.02 | 4.51 | 7.43 | 4.72 | 5.15 | 7.16 | 7.24 | 6.36 | 157 | 24.81 | 107 |
| BR(Bio)9786-BC2-59-1-2 | 6.55 | 7.35 | 7.25 | 7.58 | 4.86 | 7.89 | 5.16 | 5.29 | 7.03 | 7.51 | 6.65 | 158 | 24.32 | 108 |
| BR(Bio)9786-BC2-124-1-1 | 6.18 | 7.14 | 6.22 | 7.24 | 4.49 | 7.91 | 4.65 | 4.73 | 7.35 | 7.40 | 6.33 | 158 | 25.40 | 109 |
| BRRI dhan29 (ck) | 6.74 | 7.67 | 6.84 | 7.15 | 5.50 | 6.94 | 5.69 | 5.64 | 7.25 | 7.51 | 6.69 | 159 | 22.40 | 100 |
| LSD $_{(0.05)}$ | | | | | 0.59 | | | | | | 0.19 | 0.30 | 0.29 | 1.49 |

L1-Mymersingh, L2-Khulna, L3-Jessore, L4-Barisal, L5-Feni, L6- Chittagong, L7-Cox's bazar, L8-Habigonj, L9-Rangpur, L10- BRRI, Gazipur.

**Table 14. Grain yield, growth duration, TGW and plant height of some advanced lines under ALART (LD-Comilla) grown in different locations during Boro 2017.**

| Genotype | Location | | | | | | | | | Growth duration (day) | TGW (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (t/ha) | | | | | | | | | | | |
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | Mean | Mean | Mean | Mean |
| BR8261-19-1-13 | 5.12 | 4.82 | 4.70 | 6.47 | 4.93 | 6.25 | 5.09 | 3.41 | 5.10 | 149 | 22.0 | 108 |
| HHZ15-SAL13-Y1 | 6.67 | 5.49 | 5.96 | 6.00 | 5.20 | 6.57 | 5.33 | 6.10 | 5.92 | 146 | 22.6 | 100 |
| BR7781-10-3-2-2 | 5.46 | 4.78 | 6.25 | 5.92 | 4.67 | 6.11 | 5.00 | 4.52 | 5.34 | 148 | 17.9 | 107 |
| BRRI dhan58 (ck) | 6.63 | 6.85 | 7.00 | 6.85 | 5.94 | 7.20 | 6.11 | 3.91 | 6.31 | 150 | 23.0 | 99 |
| LSD (0.05) | | | | 0.50 | | | | | 0.18 | 0.60 | | 1.2 |

L1- B.Baria (Sadar), L2- Chandpur (Haziganj), L3- Comilla (Burichong), L4- Comilla (Daudkandi), L5- Feni (Dagonbhuya), L6- BRRI Gazipur, L7-Laxmipur (Sadar), L8-Noakhali (Sonaimuri).

the entry no. 3 was found to be sheath blight and blast (leaf and neck) susceptible. Moreover, phenotypic acceptance of entry no. 3 was not so much acceptable and it had a record of lodging tendency in some locations. Considering the above condition and farmers' opinion, none of the lines was recommended for PVT.

## TECHNOLOGY DISSEMINATION

### Seed production and dissemination programme

For rapid dissemination and increase availability of newly released BRRI varieties among the farmers, Adaptive Research Division (ARD) conducted seed production and dissemination programme (SPDP) in every season of the year. This is an effective programme for the adoption of BRRI varieties through quality seed production. In the reported period, the SPDPs were conducted in different locations of the country in Aus, Aman and Boro seasons under different funding sources. In this programme, mainly BRRI varieties were demonstrated in farmers' fields.

### GOB funded SPDP

**SPDP in B. Aus 2016.** SPDPs were conducted in six upazilas of three districts (Magura, Rajbari and Sylhet) in B. Aus 2016. BRRI dhan43 and BRRI dhan65 were disseminated in this programme. Total rice production through demonstrations of BRRI dhan43 and BRRI dhan65 were about 4.5 tons and farmers retained 940 kg seeds from those varieties for next year cultivation. About 900 farmers gained awareness about the varieties through field visits, discussion and knowledge sharing. About 365 farmers were motivated to cultivate those varieties in next year.

**SPDP in Jhum 2016.** Demonstration of BRRI dhan43 and BRRI dhan65 were conducted in eight upazilas of three hilly districts (Khagrachari, Rangamati and Bandarban) under SPDP. About 5.2 tons of paddy grains were produced under this programme. And farmers retained 557 kg seeds from those varieties for the next year cultivation. About 1,155 farmers gained awareness about the varieties through field visits, discussion and knowledge sharing. And about 213 farmers were motivated to cultivate those varieties in next year.

**SPDP in valley (T. Aus), 2016.** SPDPs were conducted in eight upazilas of three hilly districts of Bangladesh (Bandarban, Rangamati, Khagrachari) in T. Aus 2016. BRRI developed Aus rice variety BRRI dhan55 were used in the demonstration. Total production of BRRI dhan55 was about 4.48 tons and farmers retained 495 kg seeds from BRRI dhan55 for the next year cultivation. About 710 farmers gained awareness about the variety through field visits, discussion and knowledge sharing. Furthermore, 167 farmers were motivated to cultivate the variety next year.

**SPDP with USG, T. Aman 2016.** SPDPs with USG were conducted in 32 upazilas of 16 districts (Sherpur, Netrakona, Gazipur, Rajbari, Khulna, Jessore, Naogoan, C. Nawabganj, Gaibandha, Thakurgoan, Panchagarh, Jhalokathi, Pirojpur, Chittagong, Cox's Bazar and Sylhet) in T. Aman 2016. BRRI dhan34, 41, 49, 54, 56, 57, 62, 66, 71, 72 and 73 were used in the demonstration according to the suitability of the varieties in the respective locations. Total production of those varieties was about 27 tons from which about 2.8 tons quality seeds were retained by the farmers for the next year use. About 4,924 farmers gained awareness and knowledge about those varieties and the beneficial effect of USG. More than 1,375 farmers were motivated to cultivate those varieties and adopt USG.

**SPDP with USG, Boro 2017.** SPDPs with USG were conducted in 33 upazilas of 17 districts (Sherpur, Netrakana, Mymensingh, Khulna, Jessore, Chuadanga, Noagoan, Gaibandha, Dinajpur, Pirojpur, Bhola, Sunamganj, Feni, Chittagong, Cox's Bazar, Khagrachari and Bandarban) in Boro 2017. Ten modern rice varieties (BRRI dhan47, 50, 55, 58, 60, 63, 64, 67, 69 and 74) were used in those demonstrations in different locations. As a whole, total production by the above demonstrations was 70 tons and farmers retained 11 tons seeds of those varieties for the next year use. A total of 9,834 farmers gained awareness and knowledge through field visits, discussion and knowledge sharing and 2,112 farmers were motivated to adopt those varieties and USG.

**SPIRA (Strengthening Physical Infrastructure and Research Activities of BRRI) funded SPDP**

**SPDP in Boro 2017.** SPDPs were conducted in seven upazilas of seven districts (Panchagarh, Thakhurgoan, Nilphamari, Bagerhat, Narsindhi, Sylhet and Moulivibazar) in Boro 2017. Three modern rice varieties (BRRI dhan58, 60 and 63) were used in those demonstrations in different locations. As a whole, total production by the above demonstrations was 35 tons and farmers retained 5.6 tons seeds of those varieties for the next year use. A total of 3,485 farmers gained awareness and knowledge through field visits, discussion and knowledge sharing and 1,179 farmers were motivated to adopt those varieties.

**TRB (Transforming Rice Breeding Project) funded SPDP**

**SPDP in T. Aus 2016.** SPDPs were conducted in two upazilas of two districts of Bangladesh (Chuadanga and Rajshahi) in T. Aus 2016. BRRI developed T. Aus rice variety BRRI dhan48 was used in the demonstration. Total production of BRRI dhan48 was about 6.1 tons and farmers retained 2,050 kg seeds of BRRI dhan48 for the next year cultivation. About 290 farmers gained awareness about the variety through field visits, discussion and knowledge sharing. Furthermore, 70 farmers were motivated to cultivate the variety next year.

**SPDP in T. Aman 2016.** SPDPs were conducted in 16 upazilas of 14 districts (Netrakona, Mymensingh, Khulna, Satkhira, Rajbari, Rajshahi, Chapai-Nawabganj, Naogaon, Dinajpur, Comilla, Chittagong, Cox's Bazar, Sylhet and Moulovibazar) of Bangladesh. Eleven BRRI developed varieties (BRRI dhan49, 52, 54, 56, 57, 62, 66, 70, 71, 72 and 73) were used in those demonstrations in the different locations. Total production of those varieties was about 42.3 tons and farmers retained 2.7 tons seeds from those varieties for the next year cultivation. About 4,360 farmers gained awareness about the variety through field visits, discussion and knowledge sharing. Furthermore, 503 farmers were motivated to cultivate those varieties next year.

**SPDP in Boro 2017.** SPDPs were conducted in 11 upazilas of nine districts (Netrakona, Mymensingh, Khulna, Rajshahi, Noagoan, Dinajpur, Comilla, Chittagong, Cox's Bazar and Sylhet) of Bangladesh. Five BRRI developed varieties (BRRI dhan58, 60, 63, 69 and 74) were used in those demonstrations in the different locations. Total production of those varieties was about 40.3 tons and farmers retained about 8.5 tons seeds from those varieties for cultivation next year. About 4,106 farmers gained awareness about the variety through field visits, discussion and knowledge sharing. Furthermore, 1,560 farmers were motivated to cultivate these varieties next year.

**Mujibnagar Integrated Agricultural Development Project (MIADP) funded SPDP**

**SPDP in T. Aman 2016.** SPDPs were conducted in 12 upazilas of four districts of Bangladesh (Kushtia, Meherpur, Chuadanga and Jhinaidah) in T. Aman 2016. BRRI developed BRRI dhan49, 52 and 57 were used in those demonstrations in the different locations. Total production of these varieties was about 22 tons and farmers retained 2.3 tons seeds from those varieties for cultivation next year. About 2,307 farmers gained awareness about the variety through field visits, discussion and knowledge sharing. Furthermore, 888 farmers were motivated to cultivate the variety next year.

**Seed support to stakeholders under TRB project**

In Aman 2016 and Boro 2017 seed support programmes to farmers and different stakeholders were conducted in different locations of Bangladesh under TRB project to enhance rapid dissemination of newly released BRRI varieties. In T. Aman 2016, 1,710 kg seeds of 12 varieties (BRRI dhan34, 49, 52, 54, 56, 57, 62, 66, 70, 71, 72 and 73) were distributed to 266 farmers/stakeholders in 60 upazilas of 17 districts. In Boro 2017, 2,100 kg seeds of 11 varieties (BRRI dhan29, 50, 55, 58, 59, 60, 63, 64, 67, 69 and 74) were distributed to 300 farmers/stakeholders in 74 upazilas of 30 districts. A total of 3,810 kg seeds of 23 BRRI developed varieties were distributed among 566 farmers of 134 upazilas under 37 districts for cultivation of 742 bighas (98 hectares) of land during T. Aman 2016 and Boro 2017 seasons.

**Farmers training and promotional activities**

**Farmers' training.** During the reporting period, ARD conducted 48 farmers' training at different locations of the country in which 1,735 trainees (1,440 farmers and 295 SAAOs of DAE) participated on modern rice production technologies.

**Field day/farmers' rally.** ARD conducted 43 field days at different locations of the country under GOB and different projects (SPIRA, TRB and MIADP). Around 6,450 participants including farmers, local leaders and DAE personnel participated in the field days. These programmes also generated much enthusiasm about modern rice production technologies and BRRI varieties, which help rapid dissemination of technologies.

**Seed production at BRRI farm**

Seeds of recent and promising rice varieties were produced in T. Aus, T. Aman and Boro seasons during the reporting period under the close supervision of ARD. A total of 5.2 tons quality seeds of different BRRI varieties were produced.

**Establishment of farmers' seed center under TRB**

Two seed centers for farmers were established at Singherbangla, Sadar, Netrakona and Kushodanga, Koyra, Khulna. We provided eight plastic drums at each center. Around 75 kg seeds can be preserved in each drum. Farmers will preserve good quality seeds of promising rice varieties for rapid dissemination through seed exchange or selling among the farmers.

**Farmer's feedback about BRRI rice varieties**

Table 15 presents farmers' feedback about the varieties demonstrated in Aus and Aman 2016 and Boro 2017 collected from farmers and DAE personnel.

**Table 15. Farmers' feedback about the varieties demonstrated in Aus 2016, Aman 2016 and Boro 2017.**

| Variety | Advantage | Disadvantage |
|---|---|---|
| | *Season: Aus* | |
| BRRI dhan43 | Good yield | |
| BRRI dhan48 | Higher yield, more grains in panicle, better crop stand. | - |
| BRRI dhan55 | Higher yield, long slender grain and stickiness | Uneven flowering |
| BRRI dhan65 | Long slender grain | Low yield |
| | *Season: Aman* | |
| BRRI dhan49 | Higher yield, better crop stand and Nizersail type grain, higher market price. Rabi crop easily can be grown after harvesting, lodging tolerant | False smut susceptible |
| BRRI dhan52 | Higher yield, bold grain, lodging tolerant and submergence tolerant | Higher pest infestation especially stem borer and bacterial blight |
| BRRI dhan54 | Comparatively shorter growth duration, suitable for coastal region | Low yield |
| BRRI dhan56 | Short duration, drought tolerant along with better yield, lodging tolerant, fine grain, higher market price for attractive grains Rabi crops can easily be grown after its harvest | Lower yield compared to BRRI dhan49 and Swarna |
| BRRI dhan57 | Short duration which can escape drought along with better yield. Lodging tolerant and fine grain<br>Higher market price for attractive grains. Rabi crops easily can be grown after its harvest | Lower yield compared to BRRI dhan49 and Swarna<br>Farmers are disappointed in some areas for shattering tendency in maximum ripening condition |
| BRRI dhan62 | Shorter duration with Zn enrichment<br>Rabi crops can easily be grown after its harvest<br>Farmers' awareness is increasing about its zinc content | Lower yield compared to BRRI dhan49 and Swarna<br>Farmers are disappointed in some areas for spikelet germination at the ripening stage<br>Cooked rice sticky |
| BRRI dhan66 | Drought tolerant | Lower number of panicle per unit area and low yield |
| BRRI dhan70 | Long slender grain | Higher sterility and low yield |
| BRRI dhan71 | Drought tolerant, higher yield | - |
| BRRI dhan72 | Higher yield | Bold grain |
| BRRI dhan73 | Salt tolerant, higher yield | Have lodging tendency |
| | *Season: Boro* | |
| BRRI dhan58 | Higher yield, more grains in panicle,<br>better crop stand, no lodging | Some spikelets in panicle tip remained sterile due to cold injury |
| BRRI dhan60 | Slender grain | Low yield, uneven flowering<br>Some grains remained green in matured panicle |
| BRRI dhan63 | Long slender grain, good yield, good taste of cooked rice, higher market price | Susceptible to blast disease |
| BRRI dhan67 | Tolerant to salinity, higher yield, less pest incidence, good taste | - |
| BRRI dhan68 | | Bold grain |
| BRRI dhan69 | - | Bold grain, cooked rice sticky |
| BRRI dhan74 | Zn enriched | Bold grain |

# Training Division

SUMMARY

Training Division has conducted 58 training programmes in the reporting year with course duration from one day to one week. Need based course curriculum was developed for these courses. Total number of participants were 1,401. The participants were- different level of agriculture extension officers of Department of Agriculture Extension (DAE) and Non Government Organizations (NGOs), scientists of BRRI, Imam of mosques and farmers. The highest number of participants was from the DAE. The average improvement of knowledge for extension personnel in 1-week Rice Production Training (RPT) varied widely and ranged from 188 to 303%. The results indicate the significance of rice production training for extension personnel. Effectiveness of imparted trainings was determined on the basis of feedback remarks on different aspects. Most of the trainees expressed positive views about the course content and training method. However, participants of all courses, specially the 1-week course, suggested for increasing duration of the course from 1-week to at least 2-3 weeks. Most of the BRRI's speakers' performance was very good to excellent.

TRAINING NEED ASSESSMENT

A need assessment session was conducted at the beginning of each batch of training to know the expectation of the trainees. A total of 1,315 responses on different issues were received from the trainees of one week modern rice production training. Of which 610 from GOB funded training course, 487 from Strengthening Physical Infrastructure and Research Activities project (SPIRA), 74 from Pirojpur-Gopalganj-Bagerhat Integrated Agricultural Development Project (PGB) and 144 from NGO personnel (Table 1). Though the participants were different categories and from different regions and environments of the country, their expectations were very much similar. SAAOs showed high expectation about disease and insect management followed by variety related issues. Participants from NGOs also showed similar expectations like SAAO. High expectation of participants, in case of 3-days RPT course for DAE and NGO officers was on disease, insects and variety related issue followed by seeds (Table 2).

CAPACITY BUILDING AND TECHNOLOGY TRANSFER

**One-week rice production training**

The main objective of the course was to train the field level extension workers of DAE and NGOs. The course curriculum was designed based on the priority of field problems related to rice production and rice based technologies. Lecture and discussion,

**Table 1. Expectations of the trainees on different subjects in 2016-17.**

| Subject/issue | Expectation (%) | | | | | Subject/issue | Expectation (%) | |
|---|---|---|---|---|---|---|---|---|
| | SAAO | | | | | | NGO | Rank |
| | GOB | SPIRA | PGB | Av. | Rank | | | |
| Disease | 22 | 28 | 19 | 23 | 1 | Disease | 24 | 1 |
| Insect | 21 | 27 | 15 | 21 | 2 | Insect | 18 | 2 |
| Variety | 18 | 12 | 16 | 15 | 3 | Variety | 13 | 3 |
| Seed | 9 | 5 | 10 | 8 | 4 | Seed | 12 | 4 |
| IWM | 8 | 6 | 9 | 8 | 4 | Agronomy | 10 | 5 |
| Soil and fertilizer | 6 | 5 | 9 | 7 | 5 | Physiology | 6 | 6 |
| Physiology | 6 | 4 | 4 | 5 | 6 | Soil and fertilizer | 5 | 7 |
| Agronomy | 6 | 5 | 6 | 5 | 6 | Irrigation | 5 | 7 |
| Farm machinery | 3 | 1 | 5 | 3 | 7 | F. machinery | 2 | 8 |
| Others | 2 | 4 | 4 | 3 | | Others | 2 | 8 |
| Total | 100 | 100 | 100 | 100 | | | 100 | |
| Response no. | 610 | 487 | 74 | | | | 144 | |

**Table 2. Expectations of the trainees on different subjects in 2016-17.**

| Subject/issue | Expectation (%) | | | |
|---|---|---|---|---|
| | DAE officer | NGO officer | Average | Rank |
| Disease | 26 | 39 | 33 | 1 |
| Insect | 20 | 20 | 20 | 2 |
| Variety | 15 | 11 | 13 | 3 |
| Crop management | 9 | 11 | 10 | 4 |
| Physiology | 6 | 9 | 8 | 5 |
| Fertilize management | 7 | 2 | 5 | 6 |
| Seed | 5 | 2 | 4 | 7 |
| IWM | 5 | - | 3 | 8 |
| Farm machinery | 2 | 4 | 3 | 8 |
| Others | 4 | 2 | 3 | |
| Total | 100 | 100 | | |
| Response no. | 171 | 49 | | |

field visit, review session etc were the dominant training methods in this course. A total of 645 SAAOs and NGOs personel were trained (272 from GOB, 343 from SPIRA and 30 from PGB). Among the participants 581 and 64 were male and female respectively (Table 3).

Benchmark and final evaluation tool was applied to assess the knowledge improvement of individual participants. Average knowledge improvement of the participants from GOB, SPIRA and PGB were 260, 303 and 188% respectively (Table 4). Table 5 presents the performance status of 1-week rice production for different categories of participants.

**Three-day rice production management training.**
Eleven 3-day training programmes on rice production management were conducted in 2016-17. A total of 252 participants were trained through this course. Among them 230 were from SPIRA and the rest 22 were form PGB funded project. The participants of these courses were upazila agriculture officer (UAO), additional agriculture officer and agriculture extension officer (AEO) of DAE (Table 6). Two 3-day training programmes on same subject were conducted for the BRRI scientists. Through this training 56 BRRI scientists were trained. Among them 39 and 17 were male and female respectively (Table 7).

**Three-day experimental design and data analysis training**

In 2016-17, two 3-day training programmes on experimental design and data analysis were conducted. Fifth-eight scientists were trained in the course. Table 8 presents the details of the training courses.

**Three-day modern rice production training for Imams**

One 3-day training programme on modern rice production was conducted in 2016-17. A total of 30 participants were trained through this course. Table 9 presents the details of the training courses.

**Farmers training**

BRRI Training Division also conducted some farmers' training. During the reporting period 12 day-long rice production training programme were conducted in collaboration with DAE using GOB fund. In total, 360 (342 male and 18 female) farmers were trained through this programmes (Table 10).

**Training programme in total**

During the reporting period, in total 58 training programmes have been conducted by the Training Division (Table 11).

**Table 3. One week rice production training conducted by BRRI in 2016-17.**

| Project | Batch (no.) | No. of participants | | | Designation | Organization |
|---|---|---|---|---|---|---|
| | | Total | Male | Female | | |
| GOB | 14 | 272 | 246 | 26 | SAAO | DAE |
| SPIRA | 15 | 343 | 306 | 37 | SAAO, NGO | PKSF |
| PGB | 1 | 30 | 29 | 1 | SAAO | DAE |
| Total | 30 | 645 | 581 | 64 | | |

**Table 4. Knowledge gain and improvement through 1-week rice production training.**

| Project | Evaluation (average mark %) | | Improvement (%) |
|---|---|---|---|
| | Benchmark | Final evaluation | |
| GOB | 20 | 68 | 260 |
| SPIRA | 19 | 72 | 303 |
| PGB | 24 | 69 | 188 |
| Average | 21 | 70 | 250 |

**Table 5. Performance status of 1-week rice production training.**

| Project | Category of results/ certificates | | |
|---|---|---|---|
| | Distinction | Satisfactory | Participatory |
| GOB | 66 | 148 | 58 |
| SPIRA | 119 | 182 | 42 |
| PGB | 8 | 15 | 7 |
| Total | 193 | 345 | 107 |

**Table 6. Particulars of three-day rice production management training course.**

| Project | Batch (no.) | Participant (no.) | | | Designation | Organization |
|---|---|---|---|---|---|---|
| | | Total | Male | Female | | |
| SPIRA | 10 | 230 | 194 | 36 | UAO, AAO, AEO, NGO officer | DAE, PKSF |
| PGB | 1 | 22 | 21 | 1 | UAO, AAO, AEO | DAE |
| Total | 11 | 252 | 215 | 37 | | |

**Table 7. Particulars of three-day rice production management training course for BRRI scientists during 2016-17.**

| Project | Batch (no.) | Participant (no.) | | | Designation | Organization |
|---|---|---|---|---|---|---|
| | | Total | Male | Female | | |
| PGB | 2 | 56 | 39 | 17 | SO, SSO | BRRI |
| Total | 2 | 56 | 39 | 17 | | |

**Table 8. Particulars of three-day experimental design and data analysis training course during 2016-17.**

| Project | Batch (no.) | Participant (no.) | | | Designation | Organization |
|---|---|---|---|---|---|---|
| | | Total | Male | Female | | |
| PGB | 2 | 58 | 41 | 17 | SO, SSO | BRRI |
| Total | 2 | 58 | 41 | 17 | | |

**Table 9. Particulars of three day modern rice production training course for Imams of mosque during 2016-17.**

| Project | Batch (no.) | Participant (no.) | | | Designation | Organization |
|---|---|---|---|---|---|---|
| | | Total | Male | Female | | |
| GOB | 1 | 30 | 30 | 0 | Imam | Different mosque |
| Total | 1 | 30 | 30 | 0 | | |

**Table 10. Rice production training courses for farmers in 2016-17.**

| Project | Training (no.) | Participants (no.) | | |
|---|---|---|---|---|
| | | Total | Male | Female |
| GOB | 12 | 360 | 342 | 18 |
| Total | 12 | 360 | 342 | 18 |

**Table 11. Total training progrmmes conducted by Training Division in 2016-17.**

| Programme | No. of training | Duration | No. of participants | | | Designation |
|---|---|---|---|---|---|---|
| | | | M | F | Total | |
| Modern rice production training course (GOB) | 14 | 1-week | 246 | 26 | 272 | SAAO |
| Hands-on training on modern rice production training (SPIRA) | 15 | 1-week | 306 | 37 | 343 | SAAO, NGO |
| Rice production management training (SPIRA) | 10 | 3- day | 194 | 36 | 230 | DAE and NGO officer |
| Integrated rice production training (PGB) | 1 | 1-week | 29 | 1 | 30 | SAAO |
| Rice production management training (PGB) | 3 | 3-day | 78 | 61 | 17 | SO, SSO, DAE officer |
| Experimental design and data analysis training (PGB) | 2 | 3-days | 58 | 41 | 17 | SO, SSO |
| Modern rice production training (GOB) | 1 | 3-day | 30 | 0 | 30 | Imam |
| Farmers training | 12 | 1 day | 342 | 18 | 360 | Farmers |
| Total | 58 | | 1249 | 152 | 1401 | |

## EFFECTIVENESS OF IMPARTED RICE PRODUCTION TRAINING

It is important to determine the impact of different aspects of imparted rice production training for its better planning and execution in future. This study was conducted at the end of each batch to collect the relevant information. After the completion of data collection, information was compiled and analyzed. This study reveals that both one- week RPT and three days rice production management training course are very much helpful for the trainees to build up their capacity for modern rice production activities.

### Performance of BRRI speakers

Forteen batches of one-week RPT and ten batches from rice production management training were considered for this evaluation. At first, batch wise analysis was done on the basis of five criteria for each speaker. The criteria were: a. presentation style; b. question handling; c. use of training materials; d. time management and e. quality and relevance of handout and its timely supply. Average of five criteria was used to determine the performance of individual speaker in each batch. The overall performances of BRRI's speakers were very good to excellent.

## BANGLADESH RICE KNOWLEDGE BANK (BRKB)

Training Division is working to develop and update information on all BRRI released technologies in a digital form through BRKB. The work is aimed to update the BRKB with latest rice information. In the reporting period seven new fact sheets on newly released rice varieties were developed and uploaded in BRKB website.

# BRRI RS, Barisal

SUMMARY

Hybridization for the development of varieties under tidal submergence was done and 11 $F_1$s were obtained involving parents BR23, BRRI dhan52, BRRI dhan62, BRRI dhan76, BRRI dhan77, BRH11-9-11-4-5B, BR7988-14-1-4-4-2, Balam, Dudhkalam, Local Mala and Borsha in T. Aman 2016. Hybridization for the development of introgression of dense and erect panicle gene in indica rice was done and 14 $F_1$s were obtained involving parents BRRI dhan28, BRRI dhan29, BRRI dhan62, BRRI dhan72, BRRI dhan67, MK1, MK2, MK3, MK4, MK5, MK6, MK7, MK8, AKT3 in Boro 2016-17.

Three trials were conducted under RYT during Aman 2016. In these trials- six lines in RYT (SD), five lines in RYT (RLR), four lines in RYT (MER) were evaluated against standard checks. Tested line BR(Bio)8032-AC3-4-1-3 gave the highest yield (3.72 t/ha) compared to check variety BRRI dhan39 (3.12 t/ha) in RYT (SD). In other RYT tested lines were not satisfactory compared to the check. During Boro 2016-17 RYT, four lines in RYT (FB), two lines in RYT (DR), six lines in RYT (MER-1), four lines in RYT (SD) and five lines in RYT (LD-BB) were tested against standard check. The lines BR8626-19-5-1-2 (RYT-FB); BR8333-15-3-2-2 (RYT-DR); BR8631-12-3-5-P2 (RYT-MER-1); BR(Bio)9785-BC2-19-3-5 (RYT-SD); BR(Bio)8333-BC5-2-16, 8333-BC5-3-10 and BR(Bio)8333-BC5-2-22 were promising in this season. One PVT was conducted during T. Aman 2016. In this trial 15 advanced lines were evaluated against standard check. Based on yield performance, BRBa4-1 and BRBa4-3 gave 5.11 and 5.33 t/ha yield respectively. These lines may be recommended for further process. In Boro 2016-17 two lines viz BR(Bio)8072-AC5-4-2-1-2-1 and BR(Bio)8072-AC8-1-1-3-1-1 were tested in PVT (SD), which produced similar yield to the check. One PVT and two OT and one PYT were conducted under Transforming Rice Breeding (TRB) programme. A total of 385 entries were grown T. Aman 2016 of which 322 lines were selected for re-observational trial (OT). In Boro 2016-17 a total of 322 entries were grown of which 26 fixed lines were selected for further process and the rest entries remained for re-observational trial (OT). Six advanced lines along with three checks were tested in PYT for Boro 2016-17 under TRB. The highest yield was obtained by BR9942-38-4 (7.55 t/ha) which was higher than other lines and standard checks.

False smut disease was increased with the increasing of N-level. No false smut disease was observed at 1st and 2nd seeding time but increased at late planting. Lower number of balls on panicle was observed when N2 (1/3rd less than optimum N) and C3 (Azoxystrobin+Propiconazole) was applied at 3rd seeding time. Twenty chemicals were tested on BRRI dhan34 against rice blast disease of which eight were promising. Three and five ALART programmes were evaluated during T. Aman 2016 and Boro 2016-17 respectively.

For Boro rice yield, N is the most limiting nutrient in tidal flooded soil. By the addition of organic manure, fertilizer application can be reduced up to 25% without sacrificing yield of Boro rice varieties. Most of the HYVs performed well without Zn application in Char Badna soil conditions. The status of available P, K and Zn was quite high at Sagardi farm. However, the farm soil was highly deficient in available S indicating that S should be applied every season for optimum crop yield.

Among the six sowing dates, 30 November and 15 December were better in increasing plant height and yield irrespective of variety and location. Irrespective of location irrigation water productivity varied from 0.54 to 1.08 kg/m$^3$ and the total water productivity varied from 0.42 to 0.80 kg/m$^3$ for all the tested varieties.

BRRI released HYVs were demonstrated under GOB and PGB, SPIRA, HP projects to disseminate to the farmers. Most of the farmers were motivated with the varieties BRRI dhan48 for Aus; BRRI dhan62 and BRRI dhan52 for T. Aman, and BRRI dhan60, BRRI dhan64 and BRRI hybrid dhan3 for Boro. BRRI RS, Barisal conducted 16 farmers' training and six field days. Seeds of BRRI hybrid dhan3 were produced at Sagardi farm and at farmer's field. In T. Aman 2016, a total of 12,000 kg and 11.045 kg, and in Boro 2016-17, a total of 14,100 kg and 4,250 kg breeder seed and TLS were produced respectively.

## Hybridization

**Development of tidal submergence tolerant rice**. Hybridization for the development of varieties for tidal submergence of T. Aman rice was done and 11 $F_1$s were obtained involving parents BR23, BRRI dhan52, BRRI dhan62, BRRI dhan76, BRRI dhan77, BRH11-9-11-4-5B, BR7988-14-1-4-4-2, Balam, Dudhkalam, Local Mala and Borsha in T. Aman 2016. Nine $F_1$s out of 11 were selected and confirmed (Table 1).

**Introgression of dense and erect panicle gene in indica rice (*Oryza sativa* l.).** Hybridization for the development of introgression of dense and erect panicle gene in indica rice was done and 14 $F_1$s were obtained involving parents BRRI dhan28, BRRI dhan29, BRRI dhan62, BRRI dhan72, BRRI dhan67, MK1, MK2, MK3, MK4, MK5, MK6, MK7, MK8, AKT3 in Boro 2016-17 (Table 2).

## Regional yield trial (RYT)

**RYT for development of short duration high yielding rice, T. Aman 2016.** From the six tested lines, the highest yield was obtained by BR(Bio)8032-AC3-4-1-3 (3.72 t/ha) compared to check variety BRRI dhan39 (3.12 t/ha).

**RYT for development of rainfed lowland rice, T. Aman 2016.** Five advanced lines along with two checks were tested but all the advanced lines and check except BRRI dhan49 produced lower yield than the target yield because of high tide and aged seedling.

**RYT for development of micronutrient enriched rice, T. Aman 2016.** Four advanced lines viz BR7528-2R-HR16-3-98-1, BR8410-16-4-17-9-1, BR8442-9-5-2-3-B1 and BR7528-2R-HR16-2-24-1 produced lower yield than standard checks BRRI dhan72, BRRI dhan32 and BRRI dhan39.

Table 1. List of $F_1$s selected and confirmed.

| Parentage | BR no. |
|---|---|
| BRRI dhan77/BRRI dhan52 | BRBa011 |
| BRRI dhan52/BRH11-9-11-4-5B | BRBa012 |
| BRRI dhan52/Balam | BRBa013 |
| BRRI dhan52/BRRI dhan77 | BRBa014 |
| BRRI dhan76/BRRI dhan62 | BRBa015 |
| BR23/BRRI dhan52 | BRBa016 |
| BRRI dhan52/Dud Kalam | BRBa017 |
| BRRI dhan52/BRRI dhan76 | BRBa018 |
| BRRI dhan52/Borsha | BRBa019 |

Table 2. List of $F_1$s produced during T. Aman 2016.

| Parentage | Amount of $F_1$ seeds |
|---|---|
| BRRI dhan72 × MK3 | 9 |
| BRRI dhan72 × MK8 | 6 |
| BRRI dhan29 × MK7 | 5 |
| BRRI dhan62 × MK7 | 4 |
| BRRI dhan28 × MK4 | 23 |
| BRRI dhan67 × MK4 | 102 |
| BRRI dhan28 × MK8 | 2 |
| BRRI dhan72 × MK2 | 3 |
| BRRI dhan28 × MK6 | 4 |
| BRRI dhan72 × AKT 3 | 54 |
| BRRI dhan28 × MK7 | 14 |
| BRRI dhan62 × MK8 | 27 |
| BRRI dhan72 × MK7 | 5 |
| BRRI dha29 × MK3 | 43 |
| Total | 301 |

**RYT for development of favourable Boro rice, Boro 2016-17.** Four advanced lines were evaluated against three standard checks in RYT (FB). The highest yield was obtained by BR8626-19-5-1-2 (8.30 t/ha) and BRRI dhan58 (ck) (6.96 t/ha) which is higher than the other checks BRRI dhan28 and BRRI dhan29.

**RYT for development of disease resistant rice, Boro 2016-17.** Two advanced lines BR8938-19-4-3-1-1 and BR8333-15-3-2-2 along with IR BB60 (Res. ck), BRRI dhan28 (Sus. ck) and BRRI dhan29 (Sus. ck) were tested. Advanced line BR8333-15-3-2-2 gave higher yield (7.16 t/ha) than all the standard checks.

**RYT for development of micronutrient enriched rice-1 and 2, Boro 2016-17.** Among the six advanced lines under micronutrient enriched rice-1 the highest yield was obtained by BR8631-12-3-5-P2 (6.24 t/ha) which is higher than the other lines and check varieties. Under micronutrient enriched rice-2, the highest yield was obtained by check variety BRRI dhan58 (6.17 t/ha) followed by other check and lines.

**RYT for development for short duration rice, Boro 2016-17.** Among the four advanced lines BR(Bio)9785-BC2-19-3-5 gave higher yield (5.55 t/ha) where other three lines produced more or less similar yield compared to the standard check BRRI dhan28 (5.18 t/ha).

**RYT for development of long duration rice (BB), Boro 2016-17.** Five advanced lines along with one standard check BRRI dhan28 were tested for development of long duration rice (BB). The highest yield was found in BR(Bio)8333-BC5-2-16 (7.20 t/ha) followed by BR(Bio)8333-BC5-3-10 (7.16 t/ha) and BR(Bio)8333-BC5-2-22 (6.93 t/ha) which was higher than the other lines and check BRRI dhan28 (5.24 t/ha).

**Proposed variety trial (PVT)**

**PVT for short duration Boro rice, 2016-17.** Two lines along with one check were evaluated in this trial. Proposed lines BR(Bio)8072-AC5-4-2-1-2-1 and BR(Bio)8072-AC8-1-1-3-1-1 produced similar yield (7.39 t/ha) which was non significantly higher than the check variety BRRI dhan28 (7.09 t/ha).

**Transforming Rice Breeding (TRB)**

**Observational trial (OT) for T. Aman 2016.** A total of 385 entries were grown in BRRI RS, Barisal. Based on performance 322 lines were selected for re-observational trial (OT).

**OT for Boro 2016-17.** A total of 322 entries were grown in BRRI RS, Barisal. BRRI dhan28, BRRI dhan47, BRRI dhan62 and BRRI dhan74 were used as checks at each of 30 entries. Based on the performance 26 fixed lines (Table 3) were selected for further process and the rest entries remained for re-observational trial (OT).

**Preliminary yield trial (PYT) for T. Aman 2016.** Fifteen advanced lines along with one check BRRI dhan49 were tested at Sagordi farm, Barisal. All the advanced lines gave higher yield than the standard check because the check was completely damaged due to high tide. Based on yield performance BRBa4-1 and BRBa4-3 which gave 5.11 and 5.33 t/ha yield respectively may be recommended for further process.

**Preliminary yield trial (PYT) for Boro 2016-17.** Six advanced lines along with three checks BRRI dhan28 (Sus. ck), BRRI dhan29 (Sus. ck) and IR BB60 (Res. ck) were tested. The highest yield was obtained by BR9942-38-4 (7.55 t/ha) which was higher than the other lines and standard checks.

## PEST MANAGEMENT

**Disease management**

Integrated approach on rice false smut disease management in T. Aman 2016. Table 4 presents the results. False smut disease was increased with the increase of N-level. No false smut disease was observed at 1$^{st}$ and 2$^{nd}$ seeding time but increased at late planting. Lower number of balls on panicle was observed when N2 (1/3$^{rd}$ less than optimum N) was applied at 3$^{rd}$ seeding time (planting time). Tested chemicals were effective to control the disease. Lower number of false smut balls was recorded

**Table 3. List of entries selected from observational trial (OT) in Boro 2016-17 for further process.**

| Designation | GD (day) | PH (cm) | Yield (t/ha) | Sl # | Designation | GD (day) | PH (cm) | Yield (t/ha) |
|---|---|---|---|---|---|---|---|---|
| BRBa3-2-1 | 137 | 103.8 | 6.53 | 14. | BRBa3-1-7 | 139 | 101.8 | 5.51 |
| BRBa3-2-3 | 137 | 105 | 6.84 | 15. | BRBa3-2-2 | 138 | 104.8 | 5.62 |
| BRBa3-2-4 | 136 | 103.2 | 6.34 | 16. | BRBa3-2-6 | 137 | 101 | 5.17 |
| BRBa3-2-5 | 137 | 102.2 | 6.01 | 17. | BRBa3-4-3 | 138 | 102.2 | 5.60 |
| BRBa3-3-1 | 138 | 98.4 | 6.10 | 18. | BRBa3-4-5 | 139 | 102 | 5/65 |
| BRBa3-4-2 | 137 | 106.6 | 6.09 | 19. | BRBa3-4-6 | 139 | 99.4 | 5.58 |
| BRBa3-4-7 | 139 | 103.4 | 6.25 | 20. | BRBa25-2 | 139 | 102.6 | 5.67 |
| BRBa25-3 | 137 | 103.4 | 6.36 | 21. | BRBa28-2 | 138 | 107 | 5.61 |
| BRBa29-4 | 139 | 103.6 | 6.05 | 22. | BRBa30-1 | 139 | 99.4 | 5.00 |
| BRBa38-2 | 136 | 109 | 5.01 | 23. | BRBa44-2-1 | 139 | 105.4 | 5.45 |
| BRBa3-1-1 | 136 | 110 | 5.60 | 24. | BRBa22-1 | 116 | 99.4 | 2.37 |
| BRBa3-1-4 | 138 | 101.4 | 5.16 | 25. | BRBa48-1 | 121 | 98.2 | 2.23 |
| BRBa3-1-6 | 138 | 107.4 | 5.31 | 26. | BRBa75-3 | 116 | 92.6 | 2.87 |

GD=Growth duration; PH= Plant height.

**Table 4. Interection effect of STxN-label, STx chemical and on the false smut ball formation on panicle, T. Aman 2016.**

| ST | N-level | #ball | ST | Chem | #ball | N-level | Chem | #ball |
|---|---|---|---|---|---|---|---|---|
| ST4 | N3 | 15.25 A | ST4 | C4 | 20.56 A | N3 | C4 | 10.67 A |
| ST4 | N1 | 10.58 B | ST4 | C1 | 10.00 B | N3 | C1 | 5.67 B |
| ST4 | N2 | 8.33 BC | ST4 | C3 | 8.44 BC | N1 | C3 | 4.92 BC |
| ST3 | N3 | 6.25 BC | ST4 | C2 | 6.56 BC | N2 | C4 | 4.67 BC |
| ST3 | N1 | 4.92 CD | ST3 | C1 | 5.00 C | N1 | C1 | 4.25 BC |
| ST3 | N2 | 2.25 DE | ST3 | C4 | 4.89 CD | N1 | C4 | 3.75 BC |
| ST1 | N1 | 0.00 E | ST3 | C2 | 4.44 CD | N3 | C2 | 3.58 BC |
| ST1 | N2 | 0.00 E | ST3 | C3 | 3.56 CD | N1 | C2 | 2.58 BC |
| ST1 | N3 | 0.00 E | ST1 | C1 | 0.00 D | N2 | C3 | 2.50 BC |
| ST2 | N1 | 0.00 E | ST1 | C2 | 0.00 D | N2 | C2 | 2.08 BC |
| ST2 | N2 | 0.00 E | ST1 | C3 | 0.00 D | N3 | C3 | 1.58 C |
| ST2 | N3 | 0.00 E | ST1 | C4 | 0.00 D | N2 | C1 | 1.33 C |
| | | | ST2 | C1 | 0.00 D | | | |
| | | | ST2 | C2 | 0.00 D | | | |
| | | | ST2 | C3 | 0.00 D | | | |
| | | | ST2 | C4 | 0.00 D | | | |
| LSD (0.05)= 3.5369 | | | LSD (0.05)= 4.2923 | | | LSD (0.05)= 3.717 | | |

ST1=15 June, ST2=30 June, ST3=15 July and ST4=30 July; N1= Optimum, N2= <1/3rd of optimum and N3=>1/3rd of optimum; C1= Nativo (T1), C2= Azoxystrobin (T2), C3= Azoxystrobin+Propiconazole and C4= Control (T4).

when Azoxystrobin along with Propiconazole (C3) was applied at the 3rd planting time. Treatment C3 (Azoxystrobin+Propiconazole) reduced false smut disease even at N3 (1/3rd higher than optimum N).

**Screening of chemicals against blast disease of rice in T. Aman 2016.** Twenty chemicals were tested on BRRI dhan34 against rice blast disease to find out effective chemical(s). Out of those 20 test chemicals eight viz Metrobin, Royal, Aiker, Sunzoxy, Navera, Seltima, Mcvo and Alivo significantly reduced neck blast over negative control (plain water used) and were similar to standard check chemical Nativo. Further test of those effective chemicals was suggested for the next season.

**Demonstration of blast disease management practices at farmers' field.** Under blast management programme in during Boro 2016-17, Nativo performed better in reducing leaf blast disease incidence, which was 76.0% over control. About 50% panicles of untreated control plot (disease) were infected by neck blast where disease severity scale varied from 3-5. Nativo suppressed 79.8% neck blast incidence over control (Table 5).

**Survey and monitoring of rice diseases.** Survey of rice disease was conducted at Barisal region in 2016-17. Blast was recorded as major diseases. Sheath blight, brown spot and false smut (later cultivated crop) were also observed as a promising disease. High yielding variety BRRI dhan34 and local variety Kumragoir were highly infected by blast disease during the survey period. Database would be created to develop forecasting models.

## Insect pest management

Rice insect pests and their natural enemies were monitored by using light traps during July 2016 to June 2017 at Sagardi farm of BRRI RS, Barisal. Total population of green leafhopper (GLH, 23820) was higher followed by yellow stem borer (YSB, 17877), brown plant hopper (BPH, 8530), long horned cricket (LHC, 3111), leaf folder (LF, 2005), rice bug (RB, 1351) and white backed plant hopper (WBPH, 896). Among the natural enemies total population of Staphylinid beetle

**Table 5. Efficacy of fungicide against leaf and neck blast (NB) disease on BRRI dhan47 in Boro 2015-16 at Agailjhara, Barisal.**

| Treatment | Rate g/ha | Active ingredient (a.i.) | % leaf infection | Neck blast reduction over control (%) |
|---|---|---|---|---|
| Nativo | 250 | Trifloxystrobin+ Tabuconazole | 12.0 (76.0*) | 82.0 |
| Untreated control | None | None | 50.0 | About 50% panicles were infected by NB and DS scale varied from 3-5 |

*Percent reduction of leaf area infection over untreated control.

(SPB, 9386), Green mirid bug (GMB, 8513) and Carabid beetle (CRB, 5986) were most prevalent. Other natural enemies such as Pigmi grass hopper (PGH, 628), damsel fly (DSF, 217), Spider (SPD, 157) and lady bird beetle (LBB, 81) were also present in a small amount.

## CROP-SOIL-WATER DEVELOPMENT

### Nutrient management

**Long-term missing element trial.** It is observed from the yield data that all the nutrients (N, P, K, S and Zn) should be applied during T. Aman season to maintain soil nutrient levels as well as for optimum yield of BRRI dhan49. For Boro rice yield, N is the most limiting nutrient in tidal flooded soil.

**Maximizing rice yield through the application of balanced fertilizer and organic amendment in tidal flooded soil.** Grain yield of the tested varieties increased significantly from that of control (no fertilizer) due to the application of balanced chemical fertilizer alone or in combination with cow dung in the tidal flooded soils of Char Badna farm. Large difference in the grain yields of the control and treated plots (2.6-3.9 t/ha) implies that the tidal flood prone char land soils must be fertilized properly with chemical and/or organic fertilizer in order to achieve desired yield of the HYV rice, particularly in Boro season. By the addition of organic manure, fertilizer application can be reduced up to 25% without sacrificing yield of Boro rice varieties.

**Screening of modern rice varieties for efficient zinc utilization in tidal flooded soil.** Result shows that there were variations among the response to Zn application of the tested varieties, i.e., Zn application did not increase the yield in all varieties. However, the effect of Zn was statistically insignificant. Thus it may be concluded that in Char Badna soil conditions most of the HYVs performed well without Zn application. In other words, the soil available Zn content (0.80 mg/kg) is sufficient to maintain optimum grain yield of Boro rice in this farm.

**Development of soil fertility maps of experimental farms, Sagordi and Char Badna.** Eight soil samples were collected to a depth of 15 cm from each of A, B and C blocks of Sagordi farm during Boro 2016-17. It was observed that the farm soil was neutral in reaction with low organic matter content and low to medium total nitrogen. The status of available P, K and Zn was quite high. However, the farm soil was highly deficient in available S indicating that S should be applied every season for optimum crop yield.

**Premium quality rice trial and blast management.** For both the varieties of BRRI dhan50 and BRRI dhan63, treatment combinations of K3N0 (full dose basal plus additional 20% top-dress of MoP at 10 days before PI along with no chemical spray) gave the higher yield (3.25 t/ha and 3.36 t/ha respectively) than the other treatments.

### Water management

**Planting time for Boro rice cultivation in saline areas (APSIM model).** Among the six sowing dates, 30 November and 15 December sowing dates were better in increasing plant height and yield irrespective of variety and location. Between the two selected locations, tested varieties produced comparatively higher yield at Barisal site due to its high fertility and less or no salinity effects. The non-salinity tolerant variety BRRI dhan28 produced the highest yield (6.09 t/ha) at Barisal site whereas, at Amtali site, the salinity tolerant varieties BRRI dhan67 and BINA dhan10 produced the highest yield (5.96 t/ha and 6.17 t/ha respectively) due to their salinity tolerance ability. Irrespective of location irrigation water productivity varied from 0.54 to 1.08 $kg/m^3$ and the total water productivity varied from 0.42 to 0.80 kg/$m^3$ for all the tested varieties.

**Exploration of potential irrigation water source for Boro cultivation in Barisal region.** Out of surveyed 14 unions, Durgapasha, Kobai, Rongosri, Padrishibpur, Niamoti, Vorpasha have the potential source of irrigation water and also there is available canal water and it does not get dried in dry season. If this water is used then other unions also can be partially or fully irrigated during Boro season. But there are some problems, which may be hindrance for increasing crop intensity in those areas. Farmers are not aware about Boro cultivation because of the low price of paddy and higher input costs. Some have no pumping facility. If pumps or other equipments are supplied to those farmers then they can use it for pumping the river or canal water in Boro season especially in Lebukhali areas.

**Assessment of suitable water resources availability for irrigation to increase crop production in tidal areas of Barisal region.** Water salinity was measured from 21 locations of Barisal, Jhalokhati, Pirojpur, Patuakhali and Barguna districts from December to May taking consideration into Buriswar, Biskhali and Boleswar rivers. Through particular latitude, salinity level was the highest in the Tetulia river followed by Boleshor and Biskhali river. The highest salinity (9.78 dS/m) was found at Padma Bazar, Patharghata. There was low salinity in the Biskhali river. In the Paira Bondor the water salinity was 22.9 dS/m which was unsuitable for irrigation. Salinity proceeds through time towards the upstream of the river. Therefore, there is potential for growing Rabi crops in the downstream where salinity remains below 1 dS/m before March.

## TECHNOLOGY TRANSFER

**Advanced line adaptive research trial (ALART)**

**ALART (T. Aman 2016).** Three ALART programmes were conducted during T. Aman 2016. In ALART (RLR-1) three advanced lines along wth BRRI dhan39 as check were tested. Advanced line BR8214-23-1-3-1 gave the highest yield (5.73 t/ha) followed by BR8214-19-3-4-1 (4.93 t/ha), which was significantly higher than the check variety BRRI dhan39 (3.93 t/ha). On average, all the entries matured within 129-141 days. The growth duration of the highest yielder BR8214-23-1-3-1 was 139 days, which was eight days later than the check variety BRRI dhan39 (131 days) (Table 6). The ALART (MER) and ALART (Biotechnology) were invalidated for this season at Barisal due to tidal pressure along with heavy rain after transplanting.

**ALART (Boro 2016-17).** Five ALART programmes were conducted during Boro 2016-17. In ALART (BIO-LD), four advanced lines along with a standard check variety BRRI dhan29 were tested. Advanced line BR(Bio)9786-BC2-122-1-3 gave the highest yield (7.64 t/ha) followed by BR(Bio)9786-BC2-59-1-2 (7.58 t/ha), which was higher than the check variety BRRI dhan29 (7.14 t/ha) but there was no statistical significant difference among them. In case of ALART (BIO-SD), check variety BRRI dhan28 gave the highest yield (6.29 t/ha) followed by the 2$^{nd}$ highest averaged yield (5.75 t/ha) by a line BR(Bio)9787-BC2-63-2-4 though there was no significant yield difference between them. Three advanced breeding lines along with two standard check varieties were evaluated in ALART (FBR). The check variety BRRI dhan29 gave the highest grain yield (7.15 t/ha), which was non-significant followed by BRRI dhan29-SC3-8-HR1 (Com) (6.75 t/ha). This line gave little bit higher yield than the

**Table 6. Data of ALART RLR-1, T. Aman 2016.**

| Genotype | GY (t/ha) | GD (Day) | Pl. ht (cm) | 1000 gr. wt | Pan/$m^2$ | Gr./pan | Ster. (%) |
|---|---|---|---|---|---|---|---|
| IR70213-10-CPA 4-2-2-2 | 3.99 | 129 | 88.83 | 29.33 | 226.67 | 122.37 | 13.64 |
| BR8214-19-3-4-1 | 4.93 | 141 | 112.30 | 28.03 | 193.67 | 147.77 | 16.10 |
| BR8214-23-1-3-1 | 5.73 | 139 | 113.27 | 27.87 | 210.33 | 147.30 | 14.34 |
| BRRI dhan39 (ck) | 3.93 | 131 | 92.93 | 24.83 | 228.00 | 100.83 | 11.36 |
| CV (%) | 5.54 | 0.21 | 4.18 | 2.09 | 8.49 | 8.96 | 19.63 |
| LSD (0.05) | 0.51 | 0.57 | 8.51 | 1.15 | 36.41 | 23.21 | 5.43 |

another check variety BRRI dhan58 (6.62 t/ha). In ALART (PQR) check variety BRRI dhan63 gave the highest yield (6.94 t/ha) followed by another check variety BRRI dhan50 (6.37 t/ha), which was significantly higher than two test lines BR7372-18-2-1-HR1-HR6 (Com) (5.16 t/ha) and BR8076-1-2-2-3 (5.12 t/ha).

**Seed production and dissemination programme (SPDP) with USG**

**SPDP with USG in Aman 2016.** Over four locations, the mean grain yield of BRRI dhan41, BRRI dhan52 and BRRI dhan54 were 4.70, 5.43 and 4.29 t/ha respectively. In total 180 kg and 200 kg quality seeds of BRRI dhan41 and BRRI dhan52 were retained for next year use respectively. Farmers were not interested to adopt BRRI dhan54 due to lower yield.

**SPDP with USG in Boro 2016-17.** The mean grain yield of BRRI dhan47, BRRI dhan64 and BRRI dhan67 were 6.10, 5.93 and 6.47 t/ha respectively. A total of 120 kg of BRRI dhan67 and 80 kg of BRRI dhan47 quality seeds were retained for next year use.

**Demonstration, seed production and scaling up of MV rice in Barisal region**

Among the five demonstrated varieties the mean yield of BRRI dhan52 was the highest (5.38 t/ha) and BRRI dhan62 obtained the lowest yield (4.07 t/ha) in Aman 2016. Farmers preferred BRRI dhan52 for highest yield and the ability to survive under the submerged conditions. In Boro 2017, among the five demonstrated varieties the mean yield of BRRI dhan67 was the highest (6.99 t/ha) and the lowest yield was obtained by BRRI dhan28 (5.68 t/ha). Farmers preferred BRRI dhan67 for its highest yield and the ability to survive under the saline conditions. Farmers were willing to store those seeds for next season use and agree to cultivate along with surrounding farmers.

**On farm seed multiplication of latest BRRI varieties for dissemination**

Twelve BRRI released varieties were multiplied in Aman 2016 at BRRI RS, Barisal farms. Eight BRRI developed varieties were multiplied during Boro 2017 at BRRI RS, Barisal farms. Among these varieties, amount of seed for BRRI dhan47 (1540 kg) and BRRI dhan67 (1100 kg) were the highest, because BRRI dhan47 has the high adoption rate and BRRI dhan67 is getting popularity in Barisal regions.

**Demonstration, seed production and scaling up of MV rice under PGB-IADP**

In Aus 2016, BRRI dhan26 and BRRI dhan48 were demonstrated. Average yield of BRRI dhan26 was 3.4 $tha^{-1}$ (ranged from 3.31 to 3.48 $tha^{-1}$) and BRRI dhan48 was 5.0 $tha^{-1}$ (ranged from 4.83 to 5.10 $tha^{-1}$). During T. Aman 2016, BRRI dhan52, BRRI dhan62 and BRRI hybrid dhan4 were demonstrated along with other varieties. BRRI dhan52 produced an average of 5.59 $tha^{-1}$grain yield with growth duration of 139 days. On the other hand, BRRI dhan62 gave 4.43 $tha^{-1}$ grain yield with much shorter growth duration of only 99 days. Farmers chose BRRI dhan62 due to its shorter growth duration, zinc content and satisfactory grain yield. They also liked BRRI dhan52 as it survived after two weeks of tidal inundation. One hybrid rice (BRRI hybrid dhan4) was cultivated at different locations of Pirojpur and Bagerhat districts that yielded 6.40 t/ha. In Boro 2016-17, irrespective of location average grain yield of BRRI dhan28, BRRI dhan47, BRRI dhan58, BRRI dhan61, BRRI dhan64, BRRI dhan67 and BRRI hybrid dhan3 were 6.56, 5.98, 7.11, 6.16, 7.12, 6.71 and 8.43 t $ha^{-1}$, respectively. Farmers were motivated with the varieties BRRI dhan48 in Aus, BRRI dhan52 and BRRI dhan62 in Aman and, BRRI dhan60, BRRI dhan64 and BRRI hybrid dhan3 in Boro due to satisfactory grain yield. A total of 900 kg and 1200 kg seeds of BRRI released rice varieties were produced under PGB project in T. Aman 2016 and Boro 2016-17 seasons respectively and were provided to farmers.

**Demonstration of Zn-rich rice under harvest plus project**

Demonstration of BRRI dhan62 and BRRI dhan72 was conducted at Najirpur and Mollahat during T. Aman 2016 season. Yield of BRRI dhan62 was 4.37 t/ha, ranged from 4.17-4.82 t/ha. Average growth duration of this variety was 97 days. In Mollahat (Bagerhat), yield of BRRI dhan72 was ranged from 5.15 to 5.95 t/ha was on average 5.56 t/ha. Average growth duration of this variety was 129 days. In Boro 2016-17 a total of 10 demonstration trials of BRRI dhan64 were conducted at farmers' field of different villages of Najirpur (Pirojpur) and Fakirhat (Bagerhat) upazilas. The yield of BRRI dhan64 was ranged from 5.65 to 6.99 t/ha. Average yield was 6.30 t/ha. Growth duration of this variety was 150 days, ranged from 146 to 152 days. Farmers were motivated to cultivate Zn-rich variety BRRI dhan62 and BRRI dhan64.

**Farmer's training under different projects/GoB**

BRRI RS, Barisal conducted 16 farmers' training programmes in different locations of Barisal region during the reporting period. These programms were conducted at Bamna, Barguna (2); Ujirpur, Barisal (2); Babuganj, Barisal (2), Barisal sadar (2) and at Agoiljhara, Barisal (2) under GoB fumd; at Nazirpur, Pirojpur (2) and Mollahat, Bagerhat (2) under PGB project, one under SPIRA and one (25 farmers; 18 male and seven female) at Mollahat, Bagerhat under Harvest plus project. In total 390 persons (300 males and 90 females) were trained. Awareness for adopting improved rice cultivation technologies and accelerate the dissemination of BRRI varieties was done through those trainings.

**Farmers' field day under different projects/GoB**

Six field days were conducted of which three under PGB-IADP (2 at Najirpur, Pirojpur and one at Fakirhat, Bagerhat), one under HarvestPlus Bangladesh (Mollahat, Bagerhat,) projects and two under SPIRA project (one at Babuganj, Barisal and one at Bamna, Borguna). More than 900 (550 male and 350 female) farmers, extension personnel, administrative people, public leaders was participated on these programmes. Most of the farmers were motivated to cultivate BRRI dhan48 in Aus for high yielding (5.1 t/ha) and no lodging at harvesting period. Farmers liked BRRI dhan62 due to its shorter growth duration (99 days), zinc content and satisfactory grain yield (4.43 t/ha). They also liked BRRI dhan52 (yield 5.12 t/ha) as it survives after two weeks of tidal inundation. Farmers were motivated to cultivate BRRI dhan60, BRRI dhan64 and BRRI hybrid dhan3 in Boro due to satisfactory grain yield.

**Seed production**

**Hybrid seed production.** A total of 300 kg (150 kg in T. Aman 2016 and 150 kg in Boro 2016-17) of BRRI hybrid dhan3 was produced and provided to the farmers of this region to cultivate and disseminate.

**Breeder seed production.** In T. Aman 2016, a total of 12,000 kg and in Boro 2016-17, a total of 14,100 kg breeder seed was produced. BRRI released varieties would be disseminated quickly to farmers through this programme (Table 7).

**TLS production.** A total of 11.045 kg during T. Aman 2016 and in Boro 2016-17, a total of 4,250 kg TLS were produced. BRRI released varieties would be disseminated quickly to farmers through this programme (Table 7).

SCIO-ECONOMIC AND POLICY

**Stability analysis of BRRI released variety in Aman 2016**

In T. Aman, the highest yield was observed in BRRI dhan31 (7.00 t $ha^{-1}$) followed by BRRI dhan52 (6.87 $tha^{-1}$). The lowest yield was found in BRRI dhan57 (3.20 $tha^{-1}$). Most of the cases yield was low and growth duration was larger compared to standard yield and growth duration. This might be occurred due to tidal inundation. The highest yield was observed in BRRI hybrid dhan3 (9.52 t $ha^{-1}$) followed by BRRI dhan74 (8.95 $tha^{-1}$) in Boro 2016-17 season. The lowest yield was found in BRRI dhan64 (3.89 $tha^{-1}$). In most of the cases yield was low compared to standard yield. This might be occurred due to early maturity of crop than the standard.

**Table 7. Breeder seed and TLS production during T. Aman 2016 and Boro 2016-17.**

| T. Aman 2016 | | | Boro 2016-17 | | |
|---|---|---|---|---|---|
| Variety | Breeder (kg) | TLS (kg) | Variety | Breeder (kg) | TLS (kg) |
| BR 22 | - | 353 | BR 26 | 5000 | - |
| BR 23 | 1200 | 696 | BRRI dhan28 | 5000 | 450 |
| BRRI dhan34 | 2000 | 752 | BRRI dhan29 | 2000 | - |
| BRRI dhan41 | 1000 | 511 | BRRI dhan47 | - | 600 |
| BRRI dhan44 | 600 | 190 | BRRI dhan50 | - | 400 |
| BRRI dhan49 | - | 1417 | BRRI dhan58 | - | 700 |
| BRRI dhan52 | 4500 | 850 | BRRI dhan60 | 1100 | - |
| BRRI dhan53 | - | 244 | BRRI dhan61 | 1000 | - |
| BRRI dhan54 | - | 328 | BRRI dhan62 | - | 800 |
| BRRI dhan62 | - | 266 | BRRI dhan63 | - | 200 |
| BRRI dhan73 | 1700 | 429 | BRRI dhan67 | - | 1100 |
| BRRI dhan75 | - | 366 | - | - | - |
| BRRI dhan76 | 500 | 3023 | - | - | - |
| BRRI dhan77 | 500 | 1620 | - | - | - |
| Total | 12000 | 11045 | | 14100 | 4250 |

# BRRI RS, Bhanga

## SUMMARY

In improvement of rice for shallow flooded DWR environment, five $F_1$s were confirmed, their five $F_2$ populations were grown and single panicle of $F_3$ population was collected from each $F_2$ plant. In breeding for developing high yielding rice varieties for single Boro cropping pattern, four $F_1$s were confirmed, their four $F_2$ populations were grown and single panicle of $F_3$ population was collected from each $F_2$ plant.

In proposed variety trial (PVT), the advanced breeding lines BR(Bio)8072-AC8-1-1-3-1-1 produced 0.41 t/ha higher yield than the check variety BRRI dhan28 with almost similar growth duration. In regional yield trials (RYT) during T. Aman 2016 season, the advanced breeding line IR05N412 produced higher grain yield than the check varieties BRRI dhan49 and the line BR7528-2R-HR16-3-98-1 was found promising in case of micro-nutrient enriched rice. Among RYTs in Boro 2016-17 season, the promising lines were BR8109-29-2-2-3 for favourable Boro, BR8590-5-3-3-4-2 and BRC266-5-1-1-1 for premium quality rice, BR8253-18-1-3-2-1 and BR7671-37-2-2-3-7-3-P11 for micro nutrient enriched rice, BR8938-19-4-3-1-1 for disease resistance rice, BR(Bio)9785-BC2-6-2-2 and BR(Bio)9785-BC2-20-1-3 for short duration, BR(Bio)8333-BC5-2-16 and BR(Bio)8333-BC5-3-10 for long duration, GSR IR1-DQ136-Y8-Y1 and GSR IR1-17-D6-Y1-D1-11 for advanced yield trial.

Based on yield of 25 hill for stability analysis of BRRI varieties, BRRI dhan46 gave the highest grain yield in long duration Aman varieties, BRRI dhan71 gave the highest yield (710.7 gm) in short duration Aman varieties and BRRI dhan49 produced the highest grain yield (486.3 gm) in medium duration Aman varieties. Similarly BR16 gave the highest grain yield (683.4 gm) in long duration Boro varieties and BRRI hybrid dhan3 yielded the highest (783.3 gm) in short duration Boro varieties.

In evaluation of Aman establishment time as relay cropping with jute in Jute-Relay Aman-Onion cropping pattern in shallow deep water rice ecosystem, the highest REY (27.43 t/ha) was obtained from $T_3$ treatment, that was BRRI dhan49 relayed with jute before two weeks of harvesting followed. For identification of potential rice variety in Jute-Relay Aman-Onion cropping pattern under shallow deep water rice ecosystem, the highest REY was obtained from BRRI dhan72 (28.43 t/ha).

In farmers' field trials, yield of BRRI released T. Aman and Boro varieties were as follows: 5.5 t/ha with 119 days of BRRI dhan71, 4.98 t/ha with 137 days for BRRI dhan73 and 5.41 t/ha with 116 days of BRRI hybrid dhan4 during T. Aman 2016; BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan5 were 8.56 t/ha with 143 days, 8.83 t/ha with 143 days and 9.49 t/ha with 144 days respectively in Fakirhat and Mollarhat upazilas of Bagerhat district and different upazilas of Gopalganj district. In Gopalganj, the mean grain yield was 7.23 t/ha with 150 days of BRRI dhan58, 6.95 t/ha with 148 days of BRRI dhan63.

BRRI RS, Bhanga farm produced about 30.37 tons of seeds of which about 15.02 tons of breeder seeds were of BRRI dhan28 and BRRI dhan29, and the rest were TLS during Boro season in 2016-17.

## VARIETY DEVELOPMENT

Five $F_1$s were confirmed in case of 'Improvement of rice for shallow flooded DWR environment' during T. Aman 2016 at BRRI, Gazipur and their five $F_2$ populations were grown during Boro 2016-17 at BRRI RS, Bhanga. From each $F_2$ plant single panicle of $F_3$ population was collected for field RGA in T. Aman 2017 season (Table 1). Four $F_1$s were confirmed in case of 'Breeding for developing high yielding rice varieties for single Boro cropping pattern' during T. Aman 2016 and their four $F_2$ populations were grown during Boro 2016-17 in BRRI RS, Bhanga. From each $F_2$ plant single panicle of $F_3$ population was collected for field RGA in T. Aman 2017 season (Table 2).

**Table 1. List of $F_1$s confirmed, improved rice for shallow flooded DWR environment, T. Aman 2016, BRRI HQ, Gazipur.**

| BRBh# | Parent |
|---|---|
| BRBh01 | BRRI dhan52/Bazail65 |
| BRBh02 | BRRI dhan52/Laxmidigha |
| BRBh03 | PCR/Laxmidigha |
| BRBh04 | BRRI dhan52/Hijoldigha |
| BRBh05 | BR8159-20-8-5-8-2/Barshadhan |

Table 2. List of $F_1$s confirmed, breeding for developing high yielding rice varieties for single Boro cropping pattern, T. Aman 2016, BRRI RS, Bhanga.

| BRBh# | Parent |
|---|---|
| BRBh06 | BRRI dhan58/IR35238-B-1-1-P19 |
| BRBh07 | BRRI dhan63/BR7812-19-1-6-1-P3 |
| BRBh08 | BRRI dhan29/IR35238-B-1-1-P19 |
| BRBh09 | BRRI dhan29/ BR7812-19-1-6-1-P3 |

**PVT (T. Aman).** BR(Bio)8072-AC8-1-1-3-1-1 produced 0.41 t/ha higher than the check variety BRRI dhan28 with almost similar growth duration in case of Biotechnology trial (Table 3). But in case of micronutrient enriched rice, none of the tested entries produced higher grain yield than the check variety BRRI dhan28 (Table 4). The line BR7831-59-1-1-4-5-1-9-P1 yielded almost similar and had three days shorter growth duration than check variety BRRI dhan28.

**Regional yield trial T. Aman.** The advance breeding line IR05N412 produced higher grain yield than the check variety BRRI dhan49 with almost 20 days shorter growth duration (Table 5).

**Micronutrient enriched rice.** The advanced breeding line BR7528-2R-HR16-3-98-1 produced higher grain yield than the check varieties BRRI dhan32 and BRRI dhan39 with almost similar growth duration (Table 6).

**Favorable Boro.** The advanced breeding line BR8109-29-2-2-3 significantly out-yielded the check varieties BRRI dhan29 and BRRI dhan58 by 1.90 and 1.05 t/ha with seven days shorter growth duration and six days delayed maturity, respectively (Table 7).

Table 3. Grain yield and growth duration of PVT short duration (Biotechnology), Boro 2016-17, BRRI RS, Bhanga.

| Entry | Growth duration (day) | Yield (t/ha) |
|---|---|---|
| BR(Bio)8072-AC5-4-2-1-2-1 | 136 | 7.31 |
| BR(Bio)8072-AC8-1-1-3-1-1 | 136 | 7.55 |
| BRRI dhan28 (ck) | 135 | 7.14 |

Table 4. Grain yield and growth duration of PVT, micronutrient enriched rice (MER), Boro 2016-17, BRRI RS, Bhanga.

| Entry | Growth duration (day) | Yield (t/ha) |
|---|---|---|
| BR7831-59-1-1-4-5-1-9-P1 | 134 | 6.93 |
| BR7831-59-1-1-4-9-1-2-P3 | 141 | 5.41 |
| BRRI dhan28 (ck) | 137 | 7.10 |

Table 5. Grain yield and ancillary characters of RYT-RLR, T. Aman 2016, BRRI RS, Bhanga.

| Entry | Plant height (cm) | No. of tillers/ $m^2$ | No. of panicles/ $m^2$ | Growth duration | Yield (t/ha) |
|---|---|---|---|---|---|
| BR10238-5-1 | 147 | 270 | 245 | 133 | 3.52 |
| BR10247-14-18 | 151 | 304 | 281 | 132 | 3.02 |
| BR9392-6-2-1B | 154 | 342 | 315 | 132 | 2.87 |
| IR05N412 | 131 | 265 | 252 | 114 | 4.26 |
| IR12N177 | 132 | 329 | 277 | 113 | 3.25 |
| BRRI dhan49 (ck) | 127 | 333 | 317 | 133 | 3.72 |
| CV(%) | 3.8 | 24.8 | 25.3 | 0.4 | 11.6 |
| LSD | 9.69 | 138.73 | 129.29 | 0.94 | 0.73 |

Table 6. Grain yield and ancillary characters of RYT-MER (Micronutrient enriched rice), Aman 2016, BRRI RS, Bhanga.

| Entry | Plant height (cm) | No. of tillers/ $m^2$ | No. of panicles/ $m^2$ | Growth duration | Yield (t/ha) |
|---|---|---|---|---|---|
| BR7528-2R-HR16-2-24-1 | 127.1 | 253 | 236 | 112 | 4.85 |
| BR7528-2R-HR16-3-98-1 | 124.2 | 220 | 175 | 121 | 5.07 |
| BR8410-16-4-17-9-1 | 117.5 | 251 | 239 | 107 | 4.83 |
| BR8442-9-5-2-3-B1 | 125.4 | 293 | 270 | 114 | 3.89 |
| BRRI dhan32 (ck) | 150.5 | 289 | 234 | 121 | 3.68 |
| BRRI dhan39 (ck) | 111.8 | 343 | 312 | 123 | 4.95 |
| BRRI dhan72 (ck) | 119.8 | 284 | 246 | 120 | 5.59 |
| CV(%) | 0.9 | 8.1 | 9.8 | 0.7 | 5.2 |
| LSD | 2.03 | 39.97 | 42.72 | 1.54 | 0.44 |

**Premium quality rice.** Among the four advanced breeding lines, BR8590-5-3-3-4-2 produced about 0.43 t/ha higher and almost similar yield with almost similar growth duration than the check varieties BRRI dhan50 and BRRI dhan63, respectively (Table 8). In another PQR trial, the line BRC266-5-1-1-1 significantly produced higher grain yield having almost similar growth duration than the check variety BR16 (Table 9).

**Micro nutrient enriched rice.** Among six advanced breeding lines, the lines BR8253-18-1-3-2-1 and BR8631-12-3-5-P2 yielded statistically identical with almost similar growth duration to the check BRRI dhan74 (Table 10). The line BR8253-18-1-3-2-1 significantly produced about 1.3 t/ha higher yield with a few days longer growth duration than the check variety BRRI dhan28. In another MER trial, none of the entries out-yielded significantly the check varieties BRRI dhan28 and BRRI edhan58 (Table 11).

**Table 7. Grain yield and ancillary characters of RYT-1, development of rice varieties for favourable Boro environment, 2016-17, BRRI RS, Bhanga.**

| Entry | Plant height (cm) | No. of tillers/m² | No. of panicles/m² | Growth duration | Yield (t/ha) |
|---|---|---|---|---|---|
| BR7671-37-2-2-3-7-P3 | 100.8 | 466 | 380 | 160 | 6.56 |
| BR8109-29-2-2-3 | 97.5 | 463 | 313 | 160 | 8.32 |
| BRRI dhan28 (ck) | 89.8 | 446 | 360 | 149 | 6.31 |
| BRRI dhan58 (ck) | 95.9 | 324 | 284 | 154 | 7.27 |
| BRRI dhan29 (ck) | 93.9 | 358 | 306 | 167 | 6.42 |
| CV (%) | 4.1 | 14.2 | 11.7 | 2.0 | 4.5 |
| LSD | 7.37 | 109.68 | 72.47 | 5.96 | 0.59 |

DS: 4 Dec 2016, D/T: 25 Jan 2017.

**Table 8. Grain yield and ancillary characters of RYT-2, development of premium quality rice (PQR-1), Boro 2016-17, BRRI RS, Bhanga.**

| Entry | Plant height (cm) | No. of tillers/m² | No. of panicles/m² | Growth duration | Yield (t/ha) |
|---|---|---|---|---|---|
| BR8079-7-19-1-5-1 | 95.9 | 423 | 338 | 152 | 5.74 |
| BR8590-5-2-5-2-2 | 106.7 | 360 | 281 | 152 | 6.13 |
| BR8590-5-3-3-4-2 | 95.1 | 441 | 355 | 148 | 6.66 |
| BR8608-39-2-1 | 100.4 | 365 | 302 | 156 | 5.22 |
| BRRI dhan50 (ck) | 89 | 470 | 383 | 147 | 6.23 |
| BRRI dhan63 (ck) | 85.1 | 441 | 342 | 147 | 6.77 |
| CV (%) | 7.2 | 18.3 | 17.7 | 1.5 | 6.0 |
| LSD | 12.51 | 138.69 | 107.24 | 4.19 | 0.67 |

DS: 4 Dec 2016, DT: 23 Jan 2017.

**Table 9. Grain yield and ancillary characters of RYT-3, Development of premium quality rice (PQR-2), Boro 2016-17, BRRI RS, Bhanga.**

| Entry | Plant height (cm) | No. of tillers/m² | No. of panicles/m² | Growth duration | Yield (t/ha) |
|---|---|---|---|---|---|
| BR8523-36-2-2-6 | 115.7 | 295 | 257 | 147 | 6.12 |
| BRC266-5-1-1-1 | 108.1 | 392 | 306 | 155 | 8.79 |
| BRC266-5-1-2-1 | 101.2 | 423 | 331 | 152 | 6.89 |
| BR16 (ck) | 96.1 | 529 | 412 | 156 | 7.93 |
| CV (%) | 4.1 | 7.5 | 8.4 | 0.6 | 5.5 |
| LSD | 8.56 | 61.14 | 54.5 | 1.85 | 0.81 |

DS: 4 Dec 2016, DT: 23 Jan 2017.

**Table 10. Grain yield and ancillary characters of RYT-4, micronutrient enriched rice (MER-1), Boro 2016-17, BRRI RS, Bhanga.**

| Entry | Plant height (cm) | No. of tillers/m² | No. of panicles/m² | Growth duration | Yield (t/ha) |
|---|---|---|---|---|---|
| BR7831-59-1-1-4-5 | 119.5 | 367 | 324 | 150 | 7.22 |
| BR7815-18-1-3-2-1 | 103.4 | 351 | 311 | 149 | 6.15 |
| BR8253-18-1-3-2-1 | 93.6 | 241 | 220 | 151 | 8.05 |
| BR8609-2-B-9-1-B5 | 101 | 277 | 248 | 152 | 7.41 |
| BR8631-12-3-5-P2 | 100.5 | 365 | 326 | 154 | 7.85 |
| BR8631-12-3-6-P3 | 95.5 | 410 | 344 | 149 | 7.22 |
| BRRI dhan28 (ck) | 99.0 | 405 | 333 | 148 | 6.75 |
| BRRI dhan74 (ck) | 93.4 | 446 | 382 | 152 | 8.27 |
| CV (%) | 9.6 | 11.4 | 11.7 | 1.0 | 5.1 |
| LSD | 16.94 | 71.2 | 63.51 | 2.51 | 0.66 |

DS: 2 Dec 2016, DT: 23 Jan 2017.

**Table 11. Grain yield and ancillary characters of RYT-5, micronutrient enriched rice (MER-2), Boro 2016-17, BRRI RS, Bhanga.**

| Entry | Plant height (cm) | No. of tillers/m$^2$ | No. of panicles/m$^2$ | Growth duration | Yield (t/ha) |
|---|---|---|---|---|---|
| BR7671-37-2-2-3-7-3-P10 | 100 | 473 | 374 | 159 | 5.55 |
| BR7671-37-2-2-3-7-3-P11 | 100 | 535 | 416 | 159 | 6.00 |
| BRRI dhan28 (ck) | 95.9 | 356 | 295 | 149 | 5.89 |
| BRRI dhan58 (ck) | 95.3 | 326 | 272 | 155 | 7.98 |
| CV (%) | 3.0 | 12.6 | 9.1 | 1.6 | 5.6 |
| LSD | 5.86 | 106.29 | 61.85 | 4.88 | 0.71 |

DS: 2 Dec 2016, DT: 23 Jan 2017.

**Disease resistance.** Both the advanced breeding lines produced higher yield than the resistant check IRBB60 and BRRI edhan58 (Table 12). None of the advanced breeding lines out-yielded the check BRRI dhan29. But, the line BR8938-19-4-3-1-1 produced about 0.55 t/ha higher yield with seven days longer growth duration than the check variety BRRI dhan28.

**Short duration-Biotech.** Among the four advanced breeding lines, the line BR(Bio)9785-BC2-6-2-2 significantly produced about 0.8 t/ha higher grain yield with almost similar growth duration than the check variety BRRI dhan28 and BRRI dhan58 (Table 13).

**Long duration-Biotech.** Among the five advanced breeding lines, BR(Bio)8333-BC5-2-16, BR(Bio)8333-BC5-3-10 and BR(Bio)8373-BC5-2-22 produced about 2.14 t/ha, 1.71 t/ha and 1.45 t/ha higher grain yield, respectively with 17-19 days longer growth duration than the check variety BRRI dhan28 (Table 14).

**Advance yield trial.** Among the eight advanced breeding lines, GSR IR1-DQ136-Y8-Y1 produced significantly higher grain yield than the check varieties BRRI dhan29 and BRRI dhan58 with almost identical growth duration (Table 15). The advanced breeding line, IR98785-10-1-1-3 yielded significantly 1.31 t/ha higher yield with almost similar growth duration than the check variety BRRI dhan28.

## SOCIO ECONOMICS

### Stability analysis

In long duration Aman varieties, BRRI dhan46 produced the highest grain yield (678 gm) followed by BR22 (588 gm) and BR23 (523 gm) based on yield of 25 hill. In short duration Aman varieties, BRRI dhan71 yielded the highest (710.7 gm) followed by BRRI dhan39 (674 gm) and BRRI dhan66 (648 gm). In medium duration Aman varieties, BRRI dhan49 gave the highest grain yield (486.3 gm) followed by BRRI dhan51 (434 gm) and BR25 (410 gm). During Boro season in long duration varieties, BR16 gave the highest grain yield (683.4 gm), which was followed by BR15 (681 gm) and BRRI dhan47 (672 gm) based on yield of 25 hills. In short duration Boro varieties, BRRI hybrid dhan3 yielded the highest (783.3 gm), followed by BR6 (638.9 gm) and BRRI hybrid dhan5 (627.8 gm).

### Farming systems research

In evaluation of Aman establishment time as relay cropping with jute in Jute-Relay Aman-Onion cropping pattern in shallow deep water rice ecosystem, the highest REY (27.43 t/ha) was obtained from $T_3$ treatment, that was BRRI dhan49 relayed with jute before two weeks of harvesting followed by $T_2$ treatment (26.63 t/ha), that was BRRI dhan49 relayed with jute before three weeks of harvesting, and $T_6$ treatment (26.53 t/ha), that was

**Table 12. Grain yield and ancillary characters of RYT-6, disease resistant rice, Boro 2016-17, BRRI RS, Bhanga.**

| Entry | Plant height (cm) | No. of tillers/m$^2$ | No. of panicles/m$^2$ | Growth duration | Yield (t/ha) |
|---|---|---|---|---|---|
| BR8333-15-3-2-2 | 96.5 | 324 | 281 | 161 | 6.39 |
| BR8938-19-4-3-1-1 | 95.7 | 364 | 311 | 153 | 6.64 |
| BRRI dhan29 (ck) | 109.7 | 329 | 272 | 164 | 7.91 |
| BRRI dhan28 (ck) | 98.2 | 423 | 357 | 146 | 6.09 |
| IRBB60 (Res ck) | 97.6 | 376 | 300 | 160 | 6.12 |
| CV (%) | 15 | 22 | 16.1 | 4.1 | 22.6 |
| LSD | 28.05 | 147.55 | 83.2 | 12.11 | 0.9 |

DS: 4 Dec 2016, DT: 24 Jan 2017.

**Table 13. Grain yield and ancillary characters of RYT-7, short duration Boro, Biotechnology Division Boro 2016-17, BRRI RS, Bhanga.**

| Entry | Plant height (cm) | No. of tillers/m² | No. of panicles/m² | Growth duration | Yield (t/ha) |
|---|---|---|---|---|---|
| BR(Bio)9785-BC2-19-3-1 | 90.5 | 421 | 360 | 149 | 7.24 |
| BR(Bio)9785-BC2-19-3-5 | 91.1 | 455 | 407 | 150 | 7.07 |
| BR(Bio)9785-BC2-20-1-3 | 97.4 | 450 | 389 | 151 | 7.31 |
| BR(Bio)9785-BC2-6-2-2 | 91.3 | 382 | 342 | 149 | 7.57 |
| BRRI dhan28 (ck) | 97.3 | 416 | 360 | 148 | 6.77 |
| CV (%) | 3.6 | 7.3 | 8.6 | 1.3 | 4.2 |
| LSD | 6.31 | 58.3 | 60.13 | 3.7 | 0.57 |

DS: 2 Dec 2016, DT: 23 Jan 2017.

**Table 14. Grain yield and ancillary characters of RYT-8, long duration Boro, Biotechnology Division, Boro 2016-17, BRRI RS, Bhanga.**

| Entry | Plant height (cm) | No. of tillers/m² | No. of panicles/m² | Growth duration | Yield (t/ha) |
|---|---|---|---|---|---|
| BR(Bio)8333-BC5-1-1 | 99.8 | 396 | 319 | 167 | 7.67 |
| BR(Bio)8333-BC5-1-20 | 99.3 | 355 | 317 | 166 | 7.37 |
| BR(Bio)8333-BC5-2-16 | 104.8 | 320 | 263 | 166 | 8.84 |
| BR(Bio)8333-BC5-2-22 | 105.3 | 358 | 302 | 167 | 8.15 |
| BR(Bio)8333-BC5-3-10 | 102.7 | 374 | 317 | 168 | 8.41 |
| BRRI dhan28 (ck) | 99.7 | 418 | 250 | 149 | 6.70 |
| CV (%) | 3.9 | 25.7 | 16.3 | 1.0 | 7.8 |
| LSD | 7.17 | 173.04 | 87.22 | 3.11 | 1.11 |

DS: 2 Dec, 2016, DT: 23 Jan 2017.

**Table 15. Grain yield and ancillary characters of RYT-9, advanced yield trial (AYT), Boro 2016-17, BRRI RS, Bhanga.**

| Entry | Plant height (cm) | No. of tillers/m² | No. of panicles/m² | Growth duration | Yield (t/ha) |
|---|---|---|---|---|---|
| BR8109-29-2-2-3 | 97.6 | 332 | 281 | 161 | 7.28 |
| BR8780-10-5-1 | 88.3 | 333 | 277 | 164 | 7.32 |
| GSR IR1-17-D6-Y1-D1-11 | 97.5 | 273 | 226 | 160 | 7.62 |
| GSR IR1-5-D7-Y3-S1 | 94 | 302 | 237 | 162 | 6.89 |
| GSR IR1-DQ130-Y5-Y1 | 91.7 | 361 | 292 | 159 | 7.26 |
| GSR IR1-DQ136-Y8-Y1 | 93.6 | 333 | 282 | 156 | 8.22 |
| IR98814-11-1-3-1 | 94.7 | 287 | 254 | 155 | 7.21 |
| IR98785-10-1-1-3 | 94.8 | 282 | 230 | 153 | 6.67 |
| BRRI dhan28 (ck) | 94 | 360 | 312 | 149 | 5.36 |
| BRRI dhan29 (ck) | 97.5 | 354 | 296 | 162 | 7.36 |
| BRRI dhan58 (ck) | 95.3 | 319 | 270 | 154 | 7.37 |
| CV (%) | 4.7 | 14.9 | 16.9 | 1.4 | 7.0 |
| LSD | 7.51 | 81.6 | 77.38 | 3.66 | 0.85 |

BRRI dhan57 relayed with jute before two weeks of harvesting (Table 16).

In identification of potential rice variety in Jute-Relay Aman-Onion cropping pattern under shallow deep water rice ecosystem, the highest REY was obtained from BRRI dhan72 (28.43 t/ha) followed by BRRI dhan71 (26.37 t/ha) and BRRI dhan39 (26.31 t/ha) (Table 17).

## Technology dissemination

Demonstration of modern rice varieties in Aman 2016 and Boro 2016-17 seasons were done in greater Faridpur region. Mean grain yield with growth duration of BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan5 were 8.56 t/ha with 143 days, 8.83 t/ha with 143 days and 9.49 t/ha with 144 days respectively in Fakirhat and Mollarhat upazilas of Bagerhat district and different upazilas of Gopalganj district. Again mean grain yield with growth duration of BRRI dhan67 were 7.6 t/ha with 138 days and 7.4 t/ha with 138 days in Fakirhat upazila of Bagerhat district and Nazirpur upazila of Pirojpur district respectively. Mean grain yield of BRRI dhan58

**Table 16. Yield performance for different sowing times of Jute-Relay Aman-Onion cropping pattern, 2016-17.**

| Treatment | Yield (t/ha) | | | REY (t/ha) |
|---|---|---|---|---|
| | Jute | Relay Aman | Onion | |
| $T_1$ | 2.6 | 3.61 | 8.5 | 25.36 |
| $T_2$ | 2.8 | 3.79 | 8.8 | 26.63 |
| $T_3$ | 2.7 | 4.55 | 9.0 | 27.43 |
| $T_4$ | 2.5 | 2.76 | 8.6 | 24.38 |
| $T_5$ | 2.8 | 3.13 | 9.0 | 26.30 |
| $T_6$ | 2.7 | 3.82 | 8.9 | 26.53 |

$T_1$= BRRI dhan49+4 weeks before jute harvest, $T_2$= BRRI dhan49+3 weeks before jute harvest, $T_3$= BRRI dhan49+2 weeks before jute harvest, $T_4$= BRRI dhan57+4 weeks before jute harvest, $T_5$= BRRI dhan57+3 weeks before jute harvest, $T_6$= BRRI dhan57+2 weeks before jute harvest, Jute = Tk 43.75/kg, Rice (Paddy) = Tk 15/kg, Onion = Tk 25/kg.

**Table 17. Yield performance for potential rice variety in Jute-Relay Aman-Onion cropping pattern under shallow deep water rice ecosystem, 2016-17.**

| Treatment | Yield (t/ha) | | | REY |
|---|---|---|---|---|
| | Jute | Relay Aman | Onion | |
| $T_1$ | 2.83 | 2.49 | 8.34 | 24.64 |
| $T_2$ | 2.73 | 4.28 | 8.44 | 26.31 |
| $T_3$ | 2.75 | 3.53 | 8.37 | 25.50 |
| $T_4$ | 2.93 | 3.75 | 8.44 | 26.37 |
| $T_5$ | 2.97 | 4.87 | 8.94 | 28.43 |

Jute = Tk 43.75/g, Rice (Paddy) = Tk 20/g, Onion = Tk 25/kg.

was 7.23 t/ha with 150 days and BRRI dhan63 gave 6.95 t/ha yield with 148 days in on-farm condition of different upazilas of Gopalganj district during Boro 2016-17 season. In T. Aman 2016, BRRI dhan71 gave 5.5 t/ha yield with 119 days BRRI dhan73 gave 4.98 t/ha yield with 137 days yield BRRI hybrid dhan4 gave and 5.41 t/ha yield with 116 days in the farmers' fields of different upazilas of Gopalganj district.

Demonstration trials of BRRI dhan74 and BRRI dhan72 were set up in farmers' fields during Boro 2016-17 in greater Faridpur region. BRRI RS, Bhanga supplied quality seeds to farmers and shouldered cost of fertilizers, insecticides and training under this project. At maturity of the crop one field day was arranged with the help of DAE. During field day, the trial farmers shared their experience to neighbouring farmers that generated interest among them to these varieties and thereby a demand for quality seed was generated.

BRRI RS, Bhanga farm produced about 30.37 tons of seeds of which about15.02 tons of breeder seed of BRRI dhan28 and BRRI dhan29 and the rest were TLS during Boro season in 2016-17.

# BRRI RS, Comilla

SUMMARY

During the reporting period altogether 47 crosses were made and 65 crosses were confirmed in T. Aman and Boro seasons at BRRI RS, Comilla. One 1,465, 705, 335, 190, 260 and 21 plant progenies with desirable plant type and high yield potential were selected from $F_2$, $F_3$, $F_4$, $F_5$, $F_6$ and $F_7$ generations, respectively. One hundred sixty-three homozygous lines were bulked under the varietal development programme. Thirty-three genotypes were selected from observational trial (OT) having desirable characters and high yield potential. Thirteen genotypes were selected from IRLON and 30, 10, 10, 10, 15, 10, 16 and 11 genotypes with diverse genetic background having earliness, good grain type, compact panicle, lodging resistance, disease and insect resistance and high yield potential were selected from MAGIC INDICA 2014 (First generation module 1), MAGIC INDICA 2014 (First generation module 2), MAGIC PLUS 2014 (First generation module 1), MAGIC PLUS 2014 (First generation module 2), MAGIC GLOBAL 2015 (Second generation module 1), MAGIC GLOBAL 2015 (Second generation module 2), MAGIC INDICA 2015 (Second generation Module 1), MAGIC INDICA 2015 (Second generation module 2) during T. Aman season. A total of 62 advanced lines were selected from different yield trials in T. Aus, T. Aman and Boro season during 2016-17. The incidence of false smut disease (% panicle infection) was higher in 3rd planting time (15 July) than planting 1st and 2nd time (15 June and 30 June). The incidence of false smut disease was increased in late planting i.e after June. BRRI dhan49 required higher and BRRI dhan75 required lower N than the recommended dose. BRRI dhan62 needed higher N and P and lower K. The newly released BRRI dhan75 produced maximum grain yield and maximum straw yield at N levels of $N_{200}$ kg urea/ha

VARIETY DEVELOPMENT

All the yield trials from preliminary yield trial (PYT), secondary yield trials (SYT), regional yield trial (RYT), advanced yield trials (AYT) were conducted in RCB designed. Spacing was maintained 25 × 15 cm in Boro and T. Aman and 20 × 15 cm in T. Aus season. Replication was 2 or 3 depending on space limitation and no. of seedling used.

**TRB project**

**From T. Aus.** Twelve entries were selected from observational trial and out of them the highest yield was 7.2 t/ha having growth duration of 112 days. However yield range was found 5.06-7.2 t/ha among the selected lines. Three lines were selected from PYT#1 where four were selected from PYT#2. Lines selected from PYT#2 were found with growth duration around 122 days and those were selected from T. Aman season.

**In T. Aman.** Fourteen lines were selected from observational trial where yield range was found 4.09-8.31 t/ha. From PYT1-BB, one line BR8821-11-2-3-2 was selected (5.97 t/ha) where yield of the check variety BRRI dhan39 was 4.31 t/ha (Table 1). Two lines from PYT2-BB, BR8821-5-22-5-1 (4.76 t/ha) and BR8826-4-23-4-29 (4.61 t/ha) were selected compared with the check BRRI dhan39 (4.30 t/ha) (Table 2). In both the trial growth duration of selected lines were 5-10 days earlier than the check variety.

**From the HQ**

**T. Aman.** Three lines were selected from RYT PQR and two lines from RYT-RLR for further evaluation.

**BRRI RS, Comilla breeding programme**

**T Aman.** Ten lines were selected from observational trial-Com out of 65 lines tested. The highest yield was 6.71 t/ha from the line BRC361-36-2-1-3 that gave more than 1.0 t/ha than the check variety BRRI dhan49 followed by BRC357-9-1-1-1 (6.50 t/ha) (Table 3). Yield range of those 10 lines was 5.03 - 6.71 t/ha. BRC315-14-2-3-1-1 gave more tha 0.8 t/ha yield than the check variety BRRI dhan49 in PYT-Com selected for further evaluation. In SYT-Com BRC313-6-1-1-1 gave the highest yield of 5.57 t/ha having growth duration of 138 days better than all the four check varieties.

In AYT#6-water stagnation six genotypes were selected out of 14 genotypes as compared with standard check BRRI dhan44 (Table 4).

**Table 1. Yield and agronomic performance of selected line from PYT#1 BB, T. Aman 2016-17, BRRI RS, Comilla.**

| Designation | Pl ht (cm) | Growth duration (day) | Yield (t/ha) |
|---|---|---|---|
| BR8821-11-2-3-2 | 118 | 121 | 5.97 |
| BRRI dhan39 (ck) | 115 | 126 | 4.65 |
| IRBB65 (Resistant check) | 95 | 128 | 3.41 |

**Table 2. Yield and agronomic performance of selected line from PYT#2 BB, T. Aman 2016-17, BRRI RS, Comilla.**

| Designation | Pl ht (cm) | Growth duration (day) | Yield (t/ha) |
|---|---|---|---|
| BR8821-5-22-5-1 | 131 | 132 | 4.76 |
| BR8826-4-23-4-29 | 109 | 127 | 4.61 |
| BRRI dhan39 (ck) | 112 | 137 | 4.30 |
| IRBB65 (Resistant check) | 94 | 125 | 3.69 |

**Table 3. Yield and agronomic performance of breeding materials of observational yield trial (OYT# Com) T. Aman 2016-17, BRRI, Comilla.**

| Dsignation | Pl ht (cm) | Maturity (day) | Phenotypic acceptance | Yield (t/ha) |
|---|---|---|---|---|
| BRC378-2-1-2 | 116 | 141 | 3-4 | 6.12 |
| BRC378-29-1-1 | 137 | 141 | 4 | 5.32 |
| BRC355-9-1-1-1 | 110 | 138 | 3 | 5.19 |
| BRC355-12-1-2-2 | 128 | 136 | 3-4 | 5.46 RD |
| BRC355-12-2-1-1-1 | 126 | 139 | 3 | 5.03 |
| BRC357-9-1-1-1 | 139 | 143 | 4 | 6.50 |
| BRC357-9-1-1-2 | 148 | 140 | 4 | 5.32 |
| BRC358-11-2-2-1 | 156 | 138 | 4 | 5.10 |
| BRC361-36-2-1-3 | 136 | 150 | 3 | 6.71 |
| Guti Swarna-HR1 | 122 | 140 | 3 | 5.93 |
| IR95069-5-B-4-12-20-20-3-HR1 | 143 | 136 | 4 | 5.71 |
| BRRI dhan49 | 116 | 143 | 3 | 5.53 |

## BRRI HQ and TRB project

**Boro.** BR8609-2-B-9-1-B5 from RYT-MER was selected on phenotypic acceptability and yield (6.08 t/ha) with growth duration of 147 days where growth duration of the check variety BRRI dhan28 was 146 days with 4.78 t/ha yield. In this trial, BRRI dhan74 gave 6.06 t/ha yield with growth duration of 149 days. In RYT-FB BR8626-19-5-1-2 (6.89 t/ha) was selected as compared with the check variety BRRI dhan28 (6.03 t/ha). Duration of the selected line was 145 days where the check had 141 days. In RYT-1 Biotech all the tested entries out yielded the check BRRI dhan28 5-7 days longer heaving growth duration than the check. This trial will be repeated. The highest yield was obtained from BR(Biotech) 8333-BC5-3-10 (7.17 t/ha) and all the tested lines gave higher yield than BRRI dhan28 but growth duration was much longer than BRRI dhan28 (3.53 t/ha). This trial will be repeated using BRRI dhan29 as check. PQR one lines were selected viz BR8590-5-2-5-2-2 (6.26 t/ha) having growth duration of 148 days. Yield potential was found more than both the check varieties BRRI dhan50 (5.15 t/ha) and BRRI dhan63 (5.84 t/ha). From RYT-BB none was selected. From SYT1-GSR and SYT2-GSR, all the lines had growth duration longer than the check BRRI dhan28 and BRRI dhan58.

**Table 4. List of selected materials selected for stagnant water T. Aman 2016-17, BRRI RS, Comilla.**

| Genotype | Pl ht (cm) | Yield (t/ha) |
|---|---|---|
| BR7846 -14 -1-2-1-1 | 128 | 2.62 |
| BR7847 -17-3-3-2-3 | 126 | 5.02 |
| BR7849 -35-2-2-1-1 | 124 | 2.73 |
| BR7849 -48-1-2-1-2 | 127 | 3.26 |
| BR7841 -34-1-1-2-2 | 123 | 2.69 |
| BR7841 -53-1-2-1-1 | 128 | 2.75 |
| BRRI dhan44 (ck) | 121 | 2.95 |

## BRRI RS, Comilla breeding programme

**Boro.** From the observational trial-Com, 45 lines were tested along with four check varieties viz BRRI dhan28, BRRI dhan29, BRRI dhan58 and BRRI dhan63. Twenty-two lines were selected having good phenotypic acceptability and yield potential. The highest yield was found in BRC326-L-1 (7.83 t/ha) and BRC326-l-2 (7.78 t/ha). Those lines have the growth duration of 142 days. From the PYT1-Com (IRLON source), three lines IR11A318 (7.29 t/ha), IR11N293 (6.72 t/ha) and IR11A307 (6.75 t/ha) selected for further evaluation. Green super rice lines comprising PYT2-Com (Multi stress tolerant) and PYT3-Com (mostly GSR2 materials) showed excellent performance.

Almost all the lines gave higher yield than the check varieties BRRI dhan28 and BRRI dhan63 having growth duration similar to BRRI dhan63. All those GSR entries need advanced test and also tests need to be done in the farmers' field to find out suitability in different regions. In SYT1-Com, three lines were selected compared with BRRI dhan29 for further evaluation (Table 5).

BRRI RS, Comilla also conducted PVT from Comilla breeding programme during Boro season. The experiment was conducted in ten locations in Comilla and Noakhali regions including one in *haor* area at Bijoynagar, B Baria. Field Evaluation Committee evaluated this trial in due time for release as variety from BRRI RS, Comilla.

In SYT2-Com, six lines were selected viz BRC302-2-1-2-1, BRC269-15-1-1-3, BRC319-6-1-1, BRC319-9-1-3, BRC302-2-1-2-2 and BRC302-18-1-2-1 for further evaluation. Table 6 shows the agronomic characters.

Spike gene experiment was done using two spike lines with its parents and standard check as BRRI dhan28. All the entries were found with good yield performance than the check BRRI dhan28 (Table 7).

## PEST MANAGEMENT

### Survey and monitoring of rice diseases

The experiment was conducted to know the present status of different rice diseases under various climatic environments.

A survey was conducted in seven upazilas of Comilla district during T. Aman 2016 season. Rice disease data were recorded from six rice growing areas of each upazila. Twenty-five spots of each area were selected for conducting the survey and the disease data were recorded by following SES scale.

Different rice diseases such as bacterial blight, sheath blight, brown spot and leaf scald were found in different rice varieties in the surveyed areas. On average, disease incidence of bacterial blight, sheath

**Table 5. List of selected materials from SYT1-Com T. Aman 2016-17, BRRI RS, Comilla.**

| Designation | Pl ht (cm) | Yield (t/ha) | Growth duration (day) |
|---|---|---|---|
| CT19558-2-44-5-4-M-1-M | 98 | 7.31 | 149 |
| LPD 104-B-B1-8-2-1-1 | 101 | 6.98 | 148 |
| IR 10N304IR | 101 | 7.25 | 154 |
| BRRI dhan28 (ck) | 97 | 3.50 | 144 |
| BRRI dhan69 (ck) | 96 | 7.17 | 149 |

**Table 6. List of selected materials from SYT2-com T. Aman 2016-17, BRRI RS, Comilla.**

| Designation | Pl ht (cm) | Yield (t/ha) | Growth duration (day) |
|---|---|---|---|
| BRC302-2-1-2-1 | 93 | 6.23 | 147 |
| BRC269-15-1-1-3 | 97 | 6.44 | 148 |
| BRC319-6-1-1 | 114 | 6.61 | 147 |
| BRC319-9-1-3 | 113 | 6.18 | 147 |
| BRC302-2-1-2-2 | 103 | 6.74 | 149 |
| BRC302-18-1-2-1 | 99 | 6.07 | 146 |
| BRRI dhan28 (k) | 99 | 4.53 | 145 |
| BRRI dhan58 (ck) | 99 | 5.19 | 151 |
| BRRI dhan69 (ck) | 99 | 6.76 | 153 |

**Table 7. List of selected materials from spike gene experiment T. Aman 2016-17, BRRI RS, Comilla.**

| IR64 | 91 | 5.22 | 136 |
|---|---|---|---|
| IR64-NIL5{NSIC 158 (QTSN4-1-Y-P4)} | 93 | 4.79 | 138 |
| NSIC 158 | 93 | 5.47 | 136 |
| IR101686-1-1 {NSIC 158C (QTSN4-1-Y-P4)} | 99 | 5.22 | 134 |
| BRRI dhan 28 (ck) | 100 | 3.00 | 129 |

blight, brown spot and leaf scald were 5-70, 10-80, 10-80 and 20-50% respectively (Table 8). Among the major diseases, sheath blight disease was found in all the surveyed plots and it was observed as severe (7-9 scale) in some areas of Burichong and Deviddar upazila. Leaf scald disease (DI 20-50%, DS 1-3) was observed in different locations of Barura upazila in BR22 rice variety.

In Boro season, a survey was conducted at different upzilas of Comilla district (Barura, Adarshaw sadar, Sadar Dhakkin, Laksham, Nangolkot, Deviddar and Muradnagar) to investigate disease status. In all areas neck blast disease was prevalent (incidence: 10-30% with severity index 7-9) compared to bacterial blight and sheath blight disease. The highest incidence (30%) of neck blast disease was recorded in BRRI dhan28, BRRI dhan64, BRRI dhan58 and the lowest (10%) in BRRI dhan29 with 5-7 severity index. The seven BLB disease (incidence: 70-80%) was found in hybrid rice/SL8 at Adarshaw sadar and Sadar Dhakkin.

### Integrated approach on rice false smut disease management

This study was aimed to develop integrated management option for controlling false smut disease. The experiment was conducted with BRRI dhan49 against false smut disease under natural condition at BRRI RS, Comilla farm (AEZ17, land type- MHL) in T. Aman 2016. Land preparation and other agronomic managemnt were followed as per BRRI recommended practices. Fertilizer doses were applied with a usual split application of urea in three times at 15, 30 and 45 days after transplanting. The experiment was laid out in factorial RCB design with three replications. Thirty-day-old seedlings were transplanted with spacing of 25 × 15 cm. Each plot size was 3 × 3 m. Three fungicides, Nativo ($T_1$), Tilt ($T_2$), Azoxystrobin+ Dipekonazole ($T_3$) with control ($T_4$) were tested under three N-levels (N1= 1/3rd higher than optimum dose, N2 = Optimum dose, N3= 1/3rd less than optimum) and three planting time (15 June, 30 June and 15 July). The first spray was done at booting to heading stage and second spray was applied 15 days after first spray. The data of disease severity, incidence false smut on panicle, yield and yield components were recorded.

No false smut disease occurred in 1st (15 June) and 2nd (30 June) planting. Combination of Azoxystrobin and Dipekonazole resulted in lowest percent panicle infection and number of smut ball at 3rd (15 July) planting time compared to other chemicals.

The incidence of false smut disease (% panicle infection) was higher in 3rd planting times (15 July) than 1st and 2nd planting times (15 June and 30 June). The incidence of false smut disease was increased in late planting i.e. after o June.

**Table 8. Incidence and severity of rice diseases in different regions of Comilla district during T. Aman 2016.**

| Location | Variety | BB[1] | | ShB[2] | | FSm[3] | | BS[4] | | Leaf scald[5] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % DI | DS | % DI | DS | % DI | DS | % DI | DS | % DI | DS |
| Barura | BR11, BR22, BRRI dhan49 Bajal, Kalijira | 10-40 | 1-3 | 10-70 | 1-5 | 1-3 | 1 | 10-50 | 1 | 20-50 | 1-3 |
| Debiddar | BR11, BR22, BRRI dhan49, Samba masuri, Kalijira | 10-40 | 1-5 | 20-80 | 3-7 | 2-3 | 1 | 10-80 | 1-3 | - | - |
| Muradnagar | BR22, BRRI dhan49 | 20-40 | 3 | 30-70 | 3-5 | | 1 | 10-40 | 1 | - | - |
| Burichong | BR5, BR11, BR22, BRRI dhan49, Samba masuri, Kalijira, Paijom | 10-70 | 3-7 | 20-80 | 3-9 | 2-3 | 1 | 10-80 | | - | - |
| Sadar | BR5, BR10, BR11, BR22, BR23, BRRI dhan41, BRRI dhan 54, BRRI dhan49, Samba masuri | 5-60 | 3-5 | 30-60 | 1-3 | - | - | 30-80 | 1 | - | - |
| Sadar Dakkhin | BR11, BR22, BRRI dhan49 | 10-50 | 3-5 | 20-70 | 1-5 | 1-2 | 1 | 20-70 | 1 | - | - |
| Laksham | BR11, BR22, BRRI dhan49, Bajal, Motabajal, Kalijira | 5-10 | 1-3 | 20-70 | 1-5 | 1 | 1 | 20-70 | 1 | - | - |

[1]Predominant on BR22, BR11; [2]Predominant on BR11, BR22, BRRI dhan49, Bajal; [3]Predominant on BRRI dhan49; [4]Predominant on BR22, local varieties; [5]Predominant on BR22. '-'indicates no disease observed.

**Long-term effects of some macro and micronutrients on yield and nutrition of upland rice in T. Aman season.**

Nutrient use-efficiency varies depending on genotypes. So, trials were conducted at BRRI RS, Comilla (Grey Terrace Soil, AEZ 15) during T. Aman 2015-16 seasons for determining N, P, K, Zn and S requirement of some BRRI developed rice varieties. In T. Aman, BRRI dhan49 and BRRI dhan62 were compared with BRRI dhan75. Six fertilizer treatments viz $T_1$= N omission (-N), $T_2$= P omission (-P), $T_3$= K omission (-K), $T_4$= S omission (-S), $T_5$= Zn omission (-Zn) , $T_6$= NPKZnS (STB) were imposed in the main plot and rice varities in the subplots following split-plot design with three replications. In T. Aman, BRRI dhan75 gave slightly higher grain yield than BRRI dhan49.

BRRI dhan49, BRRI dhan62 and BRRI dhan62 produced respectively 4.55, 3.78 and 4.62 t/ha grain yield with added NPKZnS fertilizers (Table 9), however, three varieties were not similar in lifecycle. Omission of N, P, K, Zn and S from complete treatment had a great effect on grain yield of tested varieties indicating that a maintenance dose of fertilizer is enough for these entries (Table 1). Straw yield was significantly affected by the omission of N, P and K from complete treatment and the significantly the lowest straw yield was obtained with N omission plot. The experimental results show shat the applied fertilizer was higher than actual requirement. (Table 10).

**Effect of N rates on the yield of some newly released BRRI varieties in T. Aman season**

This investigation was undertaken to determine the N response behaviour of newly released varieties compared with BRRI modern rice varieties at BRRI RS, Comilla.

The experiment was conducted in T. Aman season 2015-16 at BRRI RS farm, Comilla (AEZ-17, land type-MHL). The newly released varieties BRRI dhan75 under six N doses (0, 40, 80, 120, 160 and 200 kg urea/ha). The experiment was laid out in a RCB design with three replications. Nitrogen was applied in three splits i.e. 34% at basal, 33% at 25 DAT and rest 33% at seven days before PI stage. A blanked dose of P, K, S and Zn were applied as soil test based (STB) at the time of final land preparation.

A significant interaction effect was observed between variety and N level. Table 11 indicates the effect of the tested newly released BRRI variety were BRRI dhan75 BRRI RS farm, Comilla soil condition at most of the levels. The newly released BRRI dhan75 produced maximum grain yield and maximum straw yield at N levels of $N_{200}$ kg urea/ha (Table 11).

**Long-term effects of some macro and micronutrients on yield and nutrition of upland rice in Boro season**

Nutrient use-efficiency varies depending on genotypes. So, trials were conducted at BRRI RS, Comilla during Boro 2016-17 seasons for determining N, P, K, Zn and S requirement of some BRRI released rice varieties. In Boro season, BRRI dhan58 and BRRI dhan69 were compared with BRRI dhan75. Six fertilizer treatments viz. $T_1$= N omission (-N), $T_2$= P omission (-P), $T_3$= K omission (-K), $T_4$= S omission (-S), $T_5$= Zn omission (-Zn) , $T_6$= NPKZnS (STB) were imposed in the main plot and rice varieties in the subplots following split-plot design with three replications. In Boro, BRRI dhan75 gave slightly higher grain yield than BRRI dhan58 and BRRI dhan69.

BRRI dhan58, BRRI dhan69 and BRRI dhan75 produced respectively 8.02, 8.78 and 9.03 t/ha grain yield with added NPKZnS fertilizers (Table 11), however, the three varieties were not similar in life cycle. BRRI dhan58 (GD 149 days), BRRI dhan69 (GD 151 days) and BRRI dhan75 (GD 157 days). Omission of N, P, K, Zn and S from complete treatment had a great effect on grain yield of tested varieties indicating that a maintenance dose of fertilizer is enough for these entries (Table 12). Straw yield was significantly affected by the omission of N, P and K from complete treatment and the lowest straw yield was obtained with N omission plot. The results show that the applied fertilizer was higher than actual requirement one left. (Table 13).

**Table 9. Effect of N, P, K, Zn and S and their omission on grain yield of BRRI varieties, BRRI RS, Comilla.**

| | Grain yield (t/ha) | | |
|---|---|---|---|
| Treatment | BRRI dhan49 | BRRI dhan62 | BRRI dhan75 |
| PKSZn (-N) | 2.06 | 2.28 | 2.90 |
| NKSZn (-P) | 3.32 | 2.95 | 3.54 |
| NPSZn (-K) | 3.39 | 2.97 | 3.68 |
| NPKZn(-S) | 4.22 | 3.26 | 4.34 |
| NPKS(-Zn) | 4.03 | 3.38 | 4.18 |
| NPKZnS | 4.55 | 3.78 | 4.62 |
| LSD(0.05) | | 0.71 | |
| CV (%) | | 8.23 | |

**Table 10. Requirement of fertilizer N, P, K, Zn and S for observed yield of BRRI varieties by SSNM technique, BRRI RS farm, Comilla, T. Aman 2015-16.**

| Variety | Nutrient requirement (kg/ha) | | | | | Average grain yield (t/ha) |
|---|---|---|---|---|---|---|
| | N | P | K | S | Zn | |
| BRRI dhan49 | 112 | 19 | 46 | 4 | 1.3 | 3.60 |
| BRRI dhan62 | 68 | 13 | 32 | 7 | 1.0 | 3.11 |
| BRRI dhan75 | 77 | 14 | 38 | 5 | 1.1 | 3.88 |
| Applied nutrients | 145 | 31 | 77 | 13 | 1.5 | |

**Table11. Effects of N rates on the grain and straw yield (t/ha) of newly released BRRI dhan75 T. Aman variety at BRRI RS farm, Comilla, 2015-16.**

| N rate (kg/ha) | Grain yield (t/ha) | Straw yield (t/ha) |
|---|---|---|
| $N_0$ | 3.51 | 3.85 |
| $N_{40}$ | 5.15 | 6.05 |
| $N_{80}$ | 4.93 | 6.03 |
| $N_{120}$ | 4.72 | 5.98 |
| $N_{160}$ | 5.28 | 6.59 |
| $N_{200}$ | 5.48 | 6.65 |
| $LSD_{0.05}$ | 0.77 | 1.62 |
| CV% | 8.43 | 15.19 |

**Table 12. Effect of N, P, K, Zn and S and their omission on grain yield of BRRI released varieties, BRRI RS, Comilla.**

| Treatment | Grain yield (t/ha) | | |
|---|---|---|---|
| | BRRI dhan58 | BRRI dhan69 | BRRI dhan75 |
| PKSZn (-N) | 2.67 | 2.99 | 3.49 |
| NKSZn (-P) | 6.33 | 6.43 | 6.08 |
| NPSZn (-K) | 6.34 | 6.76 | 7.48 |
| NPKZn(-S) | 7.90 | 7.89 | 8.35 |
| NPKS(-Zn) | 7.98 | 8.23 | 8.67 |
| NPKZnS | 8.02 | 8.78 | 9.03 |
| LSD(0.05) | | 0.44 | |
| CV (%) | | 6.88 | |

## Effect of N rates on the yield of some newly released BRRI varieties in Boro season

This investigation was undertaken to determine the N response behaviour of newly released varieties compared the BRRI modern rice varieties at BRRI RS, Comilla.

The experiment was conducted in Boro 2016-17 at BRRI RS farm, Comilla. The newly released variety BRRI dhan75 was tested under six N doses (0, 40, 80, 120, 160 and 200 kg urea/ha). The experiment was laid out in a RCB design with three replications. Nitrogen was applied in three splits i.e. 34% at basal, 33% at 25 DAT and rest 33% at seven days before PI stage. A blanked STB dose of P, K, S and Zn were applied at the time of final land preparation.

A significant interaction effect was observed between varieties and N level. Table 14 indicates effect of the tested newly released BRRI dhan75 BRRI RS farm, Comilla soil condition at most of the N levels. BRRI dhan75 produced maximum grain yield and maximum straw yield at N levels of $N_{160}$ kg urea/ha (Table 14).

## Effectiveness of combining agronomic and genetic bio-fortification of rice with zinc

Grain and straw yields varied largely because of locations (Table 15). Higher grain yields were observed in BRRI RS, Comilla zinc spraying resulting in 0.87-1.31 t $ha^{-1}$ grain yield increase in Comilla site. Grain yield increase with Zn spraying was about 2-10% for BRRI dhan58 and about 6-18% for BRRI dhan74 compared to control. We have found more increase in grain yield than reported by Ram *et al.* (2016). They have reported 1.6-4.2% increase in grain yield because of Zn spraying. Other studied parameters also varied because of waxal Zn spraying.

**Table 13. Requirement of fertilizer N, P, K, Zn and S for observed yield of BRRI released varieties by SSNM technique, BRRI RS farm, Comilla, Boro 2016-17.**

| Varietiy | Nutrient requirement (kg/ha) | | | | | Average grain yield (t/ha) |
|---|---|---|---|---|---|---|
| | N | P | K | S | Zn | |
| BRRI dhan58 | 111 | 25 | 67 | 12 | 1.2 | 6.59 |
| BRRI dhan69 | 120 | 35 | 81 | 11 | 1.4 | 6.85 |
| BRRI dhan75 | 115 | 44 | 62 | 9 | 1.0 | 7.19 |
| Applied nutrients | 145 | 31 | 77 | 13 | 1.5 | |

**Table14. Effects of N rates on the grain and straw yield (t/ha) of BRRI dhan75 in Boro season at BRRI farm, Comilla, 2016-17.**

| N rate (kg/ha) | Grain yield (t/ha) | Straw yield (t/ha) |
|---|---|---|
| $N_0$ | 4.20 | 4.04 |
| $N_{40}$ | 6.25 | 5.92 |
| $N_{80}$ | 7.39 | 7.50 |
| $N_{120}$ | 7.65 | 7.27 |
| $N_{160}$ | 8.20 | 8.23 |
| $N_{200}$ | 7.25 | 8.17 |
| $LSD_{0.05}$ | 0.43 | 0.92 |
| CV% | 6.85 | 11.69 |

In both the location, grain Zn content increased with waxal spraying that decreased greatly with polishing (Table 16). Grain Zn content in brown rice of BRRI dhan58 under control condition was about 17 m $g^{-1}$ that increased to about 19 m $g^{-1}$ through spraying treatment. Brown rice Zn content with genetically modified BRRI dhan74 varied from 22.02-23.78 m $g^{-1}$ under control condition, which increased to 24.25-25.79 m $g^{-1}$ after Zn spraying. Grain polishing by 9-12% reduced Zn content by about 20-29% indicating that achievement of nutritional target is very much difficult in Bangladesh because in most cases over polishing is done in rice mill. Similar views were expressed by Bashir *et al.* (2013). Ramberg and McAnalley (2002) also reported that essential nutrients concentration decreases with the degree of milling. Nonetheless, 0.53-0.95 ppm more Zn in grains were found with spraying treatment even after 9-12% polishing compared to the control (Fig. 1).

## TECHNOLOGY TRANSFER

In T. Aman 2,325 kg of BR22, 525 kg of BRRI dhan32, 975 kg of BRRI dhan48, 5,175 kg of BRRI

**Table 15. Some plant parameters as influenced by Zn spraying in two locations.**

| Variety | Grain yield (t $ha^{-1}$) | | Straw yield (t $ha^{-1}$) | | Panicle (no. $m^{-2}$) | | Filled grain (%) | | 1000-grain weight (g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Zn spray | Control | Zn spray | Control | Zn spray | Control | Zn spray | Control | Zn spray |
| | | | | | *Comilla* | | | | | |
| BRRI dhan58 | 7.95 | 8.82 | 9.06 | 9.08 | 430 | 432 | 81.08 | 84.27 | 21.80 | 24.73 |
| BRRI dhan74 | 7.47 | 8.78 | 8.10 | 9.03 | 361 | 372 | 93.90 | 91.40 | 31.63 | 31.93 |
| LSD (Trt) | 0.67 | | 0.97 | | - | | - | | - | |
| LSD (Var) | - | | - | | 25 | | 12 | | 3.5 | |

LSD at the 5% level of probability.

**Table 16. Zinc content (ppm) in rice grain as influenced by bio-fortification and polishing of rice in two locations of Bangladesh.**

| | Brown rice | | 9-10% polished | | 11-12% polished | |
|---|---|---|---|---|---|---|
| | Control | Zn spray | Control | Zn spray | Control | Zn spray |
| | | | *BRRI-Comilla* | | | |
| BRRI dhan58 | 16.49 | 18.88 | 13.66 | 14.61 | 12.35 | 13.03 |
| BRRI dhan74 | 23.78 | 25.79 | 20.01 | 20.78 | 18.30 | 18.80 |
| LSD (Var*Trt) | 0.43 | | NS | | NS | |
| LSD (Var) | - | | 1.93 | | 2.09 | |
| CV(%) | 4.9 | | 6.5 | | 5.8 | |

LSD at the 5% level of probability.

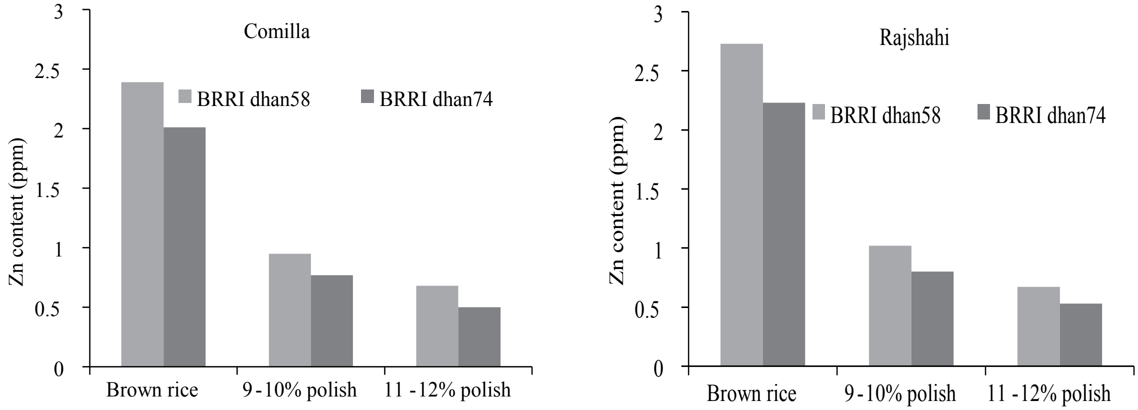



Fig. 1. Increased Zn content (ppm) in rice grains with and without polishing compared to no Zn spray in BRRI RS, Comilla and BRRI RS, Rajshahi, Boro 2016-17.

dhan49 and 1,650 kg of BRRI dhan62 and 2,625 kg of BRRI dhan75 and in Boro, 7,950 kg of BRRI dhan28, 4,862 kg of of BRRI dhan29, 3,215 kg of BRRI dhan58, 4,493 kg of BRRI dhan74 and 2587 kg of BRRI dhan69 breeder seeds were produced.

In reporting year, 380 farmers were trained and 30 Imams were also trained about rice cultivation procedure. BRRI RS, Comilla also participated in three 'krishi projukti mela' held in Comilla region.

# BRRI RS, Habiganj

SUMMARY

In RYT (Bioteh) four entries gave higher yield ( 4.1-5.0 t/ha) than BRRI dhan39 (4.0 t/ha). Both the lines BR9159-8-5-40-14-57 (6.93 t $ha^{-1}$) and BR9159-8-5-40-13-52 (6.78 t $ha^{-1}$) yielded higher than BRRI dhan49 (6.73 t $ha^{-1}$) and BRRI dhan52 (5.51 t $ha^{-1}$) in PVT. In RYT (Biotech) SD, BR(Bio)9785-BC2-19-3-1 (5.8 t $ha^{-1}$) and BR(Bio)9785-BC2-19-3-5 (5.8 t $ha^{-1}$) yielded higher than BRRI dhan28 (5.3 t $ha^{-1}$). Application of poultry manure and cowdung @ 1.0 and 3.0 t/ha respectively with 50% chemical fertilizer gave statistically similar yield like recommended chemical fertilizer dose. The soil pH, organic carbon and total nitrogen remain almost similar in both control and fertilized plot. The soil available P and exchangeable K decreased extremely in control plot compared to long-term fertilized plot. BRRI dhan62 in early transplanting gave the lowest yield but BRRI dhan28 produced the highest yield with same transplanting date in Boro season. Relative equivalent yield (REY) was increased about 17% by inclusion improved variety in the improved pattern than traditional pattern. Rice yield increased up to 8.18% in addition of 500 kg $ha^{-1}$ fish in rice-fish integrated farming than cultivating rice alone. Two peak of BPH, GLH, YSB and WBPH observed in November and April-May. Peak of CBB and STB was observed in December and another peak of CBB found in April. On average, the highest number (26.98%) of white leafhopper (WLH) reduced in perching used field followed by LR (20.87%), LHC (20.28%), GH (20.69%) and YSB (18.73%). Perching had no effect on rice hispa (RH) and rice bug (RB). Average reduction of dam. fly, drag.fly and SPD observed 15.08, 12.04 and 9.46% respectively in perching used field. But no or little reduction observed in case of CBB and LBB.


VARIETY DEVELOPMENT

**Regional yield trial (RYT) HYV (Biotechnology), T. Aman 2016.** Six genotypes along with one standard check BRRI dhan39 were evaluated. Out of six, four entries gave higher yield (4.1-5.0 t/ha) than BRRI dhan39 (4.0 t/ha). Among them four genotypes BR(Bio)8019-AC4-1-2-2 gave the highest yield (5.0 t/ha) with two days longer growth duration than the check BRRI dhan39.

**PVT of submergence and water stagnation tolerant rice, T. Aman 2016.** Two submergence cum water stagnant tolerant entries along with two checks BRRI dhan49 and BRRI dhan52 were transplanted in the farmers field of Habiganj. Both the lines BR91598-5-40-14-57 (6.93 t $ha^{-1}$) and BR9159-8-5-40-13-52 (6.78 t $ha^{-1}$) yielded higher than BRRI dhan49 (6.73 t $ha^{-1}$) and BRRI dhan52 (5.51 t $ha^{-1}$) with 2-7 days lower growth duration (Table 1).

**Secondary yield trial (SYT) short duration, Boro 2016-17.** Three advanced breeding lines along with BRRI dhan28 as check were grown. Out of three, IR12A255 (4.7 t $ha^{-1}$) yielded higher than BRRI dhan28 (4.1 t $ha^{-1}$) with 13 days longer growth duration. Yield was not satisfactory both in checks and lines because of unfavourable weather condition and inundation prevailed in the reproductive stage.

**Secondary yield trial (SYT) deep water and other materials, Boro 2016-17.** Two advanced breeding lines along with BRRI dhan28 and BRRI dhan78 as checks were grown. BR9390-6-2-2B (4.0 t $ha^{-1}$) and BRH11-9-11-4-5B (4.7 t $ha^{-1}$) yielded higher than BRRI dhan78 (3.2 t $ha^{-1}$) but lower than BRRI dhan28 (4.8 t $ha^{-1}$) with 11 days longer growth duration. Yield was not satisfactory because of the experiment was submerged 5-7 days due to early flash flood at the reproductive stage.

**RYT of favourable Boro rice (FBR), Boro 2016-17.** Four advanced breeding lines along with BRRI dhan28, BRRI dhan58 and BRRI dhan29 as checks were grown. Out of four, BR8109-29-2-2-3 yielded slightly higher (4.7 t $ha^{-1}$) than BRRI dhan28 (4.6 t $ha^{-1}$) with five days longer growth duration but lower than BRRI dhan58 (5.3 t $ha^{-1}$) and BRRI dhan29 (5.4 t $ha^{-1}$). Yield was not satisfactory both in checks and lines because of unfavourable weather condition and inundation prevailed in the reproductive stage.

**Table 1. Yield data of PVT submergence and water stagnation tolerant rice, T. Aman 2016, Habiganj.**

| Designation | Growth duration (day) | Yield (t/ha) |
|---|---|---|
| BR9159-8-5-40-14-57 | 130 | 6.93 |
| BR9159-8-5-40-13-52 | 130 | 6.78 |
| BRRI dhan49 (ck) | 132 | 6.73 |
| BRRI dhan52 (ck) | 137 | 5.51 |

DS: 13 Jul 2016, DT: 13 Aug 2016.

**RYT of premium quality rice (PQR), Boro 2016-17.** Four genotypes along with BRRI dhan50 and BRRI dhan63 as standard checks were grown. BR8079-19-1-5-1 (6.0 t $ha^{-1}$) yielded higher than BRRI dhan50 (4.3 t $ha^{-1}$) and BRRI dhan63 (5.0 t $ha^{-1}$) but similar to BRRI dhan63 (6.1 t $ha^{-1}$) with 1-10 days shorter growth duration followed by BR8590-5-2-5-2-2. Yield was not satisfactory both in checks and lines because of unfavourable weather condition and inundation prevailed in reproductive stage.

**RYT of disease resistant rice (DRR), Boro 2016-17.** Two advanced breeding lines along with IRBB60, BRRI dhan28 and BRRI dhan29 were grown. BR8333-15-3-2-2 (5.0 t $ha^{-1}$) and BR8938-19-4-3-1-1 (4.3 t $ha^{-1}$) yielded higher than IRBB60 (R. ck) (3.6 t $ha^{-1}$) with five days late growth duration and resistant to bacterial blight disease but lower than BRRI dhan28 (5.5 t $ha^{-1}$) and BRRI dhan29 (6.0 t $ha^{-1}$). Yield was not satisfactory because the experiment remained submerged for 5-7 days due to early flash flood in the reproductive stage.

**Regional yield trial (RYT) short duration, Biotechnology, Boro 2016-17.** Four advanced breeding lines along with the check BRRI dhan28 was grown. Out of four, BR(Bio)9785-BC2-19-3-1 (5.8 t$ha^{-1}$) and BR(Bio)9785-BC2-19-3-5 (5.8 t $ha^{-1}$) yielded higher than BRRI dhan28 (5.3 t $ha^{-1}$) with 1-2 days shorter growth duration (Table 2). Yield was not satisfactory both in checks and lines because of unfavourable weather condition and inundation prevailed in the reproductive stage.

**PVT of favourable Boro rice (FBR), Boro 2016-17.** One advanced breeding line along with BRRI dhan28 as check was grown. The genotype BR7358-5-3-2-1-HR2(Com) (4.63 t $ha^{-1}$) yielded lower than BRRI dhan28 (5.13 t $ha^{-1}$) with four days higher growth duration.

**PVT of micronutrient enriched rice (MER), Boro 2016-17.** Two advanced breeding lines along with BRRI dhan28 as check were grown. The genotypes BR7831-59-1-1-4-5-1-9-P1 (4.66 t $ha^{-1}$) and BR7831-59-1-1-4-9-1-2-P3 (3.53 t $ha^{-1}$) yielded lower than BRRI dhan28 (4.94 t $ha^{-1}$) with 2-3 days higher growth duration.

**PVT of favourable Boro rice (FBR) short duration, Biotechnology, Boro 2016-17.** Two advanced breeding lines along with the check BRRI dhan28 were grown. BR7831-59-1-1-4-5-1-9-P1 (3.06 t $ha^{-1}$) and BR7831-59-1-1-4-9-1-2-P3 (3.12 t $ha^{-1}$) yielded lower than BRRI dhan28 (4.69 t $ha^{-1}$) with two days higher growth duration.

## SOCIO-ECONOMIC

**Stability analysis of BRRI released Boro varieties**
Thirty-seven BRRI released rice varieties were tested in a RCB design with three replications. The yield range of BRRI released Boro varieties was 2.7-4.7 t $ha^{-1}$. Among the inbred varieties, BRRI dhan45 (4.7 t $ha^{-1}$), BRRI dhan74 (4.3 t $ha^{-1}$), BRRI dhan28 (4.2 t $ha^{-1}$) and BR19 (4.0 t $ha^{-1}$) yielded higher with the growth duration 145, 147, 145 and 165 days respectively. BRRI hybrid dhan5 (4.6 t $ha^{-1}$) yielded higher than BRRI hybrid dhan2 (3.8 t $ha^{-1}$) and BRRI hybrid dhan3 (3.5 t $ha^{-1}$) with similar growth duration. Yield was not satisfactory both in checks and lines because of unfavourable weather condition and inundation prevailed in the reproductive stage.

## CROP-SOIL-WATER MANAGEMENT

**Yield maximization through INM practices in T. Aman 2016**
The experiment was conducted at BRRI RS farm, Habiganj during T. Aman 2016 with five different treatments i.e., $T_1$ =Fertilizer control, $T_2$=Recommended chemical fertilizer dose,

**Table 2. Yield and ancillary data of RYT, short duration (Biotech) materials, Boro 2016-17, BRRI RS, Habiganj.**

| Designation | Plant height (cm) | Tiller/ hill (no.) | Panicle/hill (no.) | GD (day) | Yield (t/ha) |
|---|---|---|---|---|---|
| BR(Bio)9785-BC2-6-2-2 | 97.6 | 16.3 | 15.3 | 142 | 5.4 |
| BR(Bio)9785-BC2-19-3-1 | 97.3 | 15.0 | 14.3 | 143 | 5.8 |
| BR(Bio)9785-BC2-20-1-3 | 99.8 | 14.7 | 13.7 | 144 | 5.2 |
| BR(Bio)9785-BC2-19-3-5 | 97.4 | 14.7 | 14.0 | 143 | 5.8 |
| BRRI dhan28 (ck) | 95.9 | 15.3 | 14.7 | 144 | 5.3 |
| LSD (5%) | 8.1 | 5.1 | 5.4 | | 1.7 |

DS: 24 Nov 2016, D/T: 6 Jan 2017.

$T_3$=poultry manure 1.0 t/ha+50% recommended chemical fertilizer, $T_4$= Cowdung 2.0 t/ha+50% recommended chemical fertilizer and $T_5$=Cowdung 3.0 t/ha+50% recommended chemical fertilizer. The plant height was the highest in recommended fertilizer followed by $T_5$. The tiller and panicle production were insignificant within the organic and inorganic fertilizer treatment but significantly higher than the control treatment. Although recommended chemical fertilizer gave the highest grain yield but it was statistically similar with $T_3$ and $T_5$ treatment. Among the fertilizer treatment $T_4$ gave lower grain yield where CD was applied @ 2.0 t/ha with 50% chemical fertilizer and the lowest yield was observed in control treatment (Table 3).

**Long-term missing element trial for diagnosing the limiting nutrient in soil**

The experiment was conducted at BRRI RS, Habiganj with BRRI dhan29 and eight treatments. The treatments were $T_{1=}$ NPKS (Complete), $T_2$ = PKS (-N), $T_3$= NKS (-P), $T_4$= NPS (-K), $T_5$= NPK (-S) $T_6$=KS (-NP), $T_7$= PS (-NK) and $T_8$= All missing (-NPKS). After ten years and ten crop cycles, the soil pH, organic carbon and total nitrogen remained almost similar in both control and fertilized treatment (Table 4). The soil available P decreased extremely in control plot compared to long-term fertilized plot. The exchangeable K also decreased much in control plot than fertilized plot. The highest grain yield was obtained in $T_1$ (7.09 t $ha^{-1}$) where complete fertilizer was used than $T_3$ (6.72 t/ha). It was observed that beside nitrogen (N) potassium (K) is the most yield limiting nutrient for Boro rice in BRRI RS, Habiganj farm soil.

**Table 3. Effect of INM on yield and other parameters of T. Aman 2016.**

| Treatment | Plant height | Tiller/ $m^2$ | Panicle/ $m^2$ | GY (t/ha) |
|---|---|---|---|---|
| $T_1$ | 83.27 | 246 | 234 | 2.90 |
| $T_2$ | 99.05 | 324 | 303 | 5.69 |
| $T_3$ | 91.02 | 317 | 288 | 5.47 |
| $T_4$ | 92.21 | 316 | 289 | 5.01 |
| $T_5$ | 93.16 | 311 | 283 | 5.35 |
| LSD(0.05) | 7.13 | 22 | 28 | 0.35 |
| CV (%) | 4.1 | 3.8 | 5.3 | 3.8 |

$T_1$=Fertilizer control, $T_2$=Recommended chemical fertilizer dose $T_3$=poultry manure1.0 t/ha+50% recom. chemical fertilizer, $T_4$= Cowdung 2.0 t/ha+50% recommend ded chemical fertilizer and $T_5$=Cowdung 3.0 t/ha+50% recommended chemical fertilizer.

**Effect of planting time on BRRI dhan62 and BRRI dhan28 in low-land *haor* area**

The experiment was conducted at BRRI RS farm, Habiganj with the selection of five different sowing and transplanting time with the same dose of chemical fertilizer. The grain yield of BRRI dhan62 (3.62 to 4.70 t/ha) was lower than BRRI dhan28 (5.17 to 5.86 t/ha) in all transplanting dates. BRRI dhan62 in early transplanting (1st week of January) gave lowest yield but BRRI dhan28 gave the highest yield during Boro season. Yield was not satisfactory in case of both the varieties because of unfavourable weather condition and inundation prevailed in the reproductive stage.

**Fertilizer management of the advanced line BRH11-9-11-4-5B in single Boro rice**

The experiment was conducted at BRRI RS farm, Habiganj in Boro 2016-17 with different doses of chemical fertilizer and application time to know the yield of the tested genotype BRH11-9-11-4-5B**.** The grain yield were insignificant with application of different doses of chemical fertilizer. Increased doses of K and time of K application did not increase grain yield. The lowest grain yield observed in fertilizer control treatment.

## RICE FARMING SYSTEMS

**Productivity increase through improved Mukhikachu - T. Aman cropping pattern**

Improved pattern with BARI mukhikachu2 and BRRI dhan49 gave higher rice equivalent yield (REY) compared to traditional pattern with local mukhikachu and BR11. REY was increased about 17% by inclusion the improved variety in the improved pattern than the traditional pattern (Table 5). The highest total productivity (28 t/ha/yr) was also recorded with the treatment having improved varieties for Mukhikachu and T. Aman rice.

**Rice fish culture in low-land area for increasing farm productivity**

Rice yield increased up to 8.18% in addition of 500 kg $ha^{-1}$ fish from rice-fish integrated farming than cultivating rice alone and the growth increment of the fish was 50%.

**Table 4. Soil characters after ten years of the long-term missing element trials.**

| Treatment | Soil pH | OC (%) | Total N (%) | Ava. P (ppm) | Exch. K (meq/100g soil) |
|---|---|---|---|---|---|
| Control plot | 4.63 | 3.15 | 0.16 | 0.56 | 0.15 |
| Fertilized plot | 4.68 | 3.35 | 0.18 | 13.84 | 0.35 |

**Table 5. Crop yield, rice equivalent yield (REY) and total productivity of Mukhikachu - T. Aman cropping pattern.**

| Cropping pattern | Yield (t/ha) | | REY (t/ha) | Increase REY | Total productivity (t/ha) |
|---|---|---|---|---|---|
| | T. Aman | Mukhikachu | | | |
| Improved pattern | 5.50 | 22 | 24.6 | 17% | 27.5 |
| Traditional pattern | 4.50 | 19 | 21.0 | | 23.5 |

Price: Mukhikachu=20 Tk/kg, Rice=23 Tk/kg.

PEST MANAGEMENT

**Monitoring of pest and natural enemy incidence by using light trap**

Among the insect pests, BPH populations were found as the highest followed by GLH and YSB. Peak of BPH, GLH, YSB and WBPH was observed in November in light trap study. Another peak of GLH, WBPH and YSB was in April and BPH in May in (Fig. 1). Among the natural enemies carabid beetle (CBB) populations was found as the highest followed by staphylinid beetle (STB) and lady bird beetle (LBB). Peak of CBB and STB was observed in December and another peak of CBB was found in April. LBB had two peaks- one in November and the other in May (Fig. 2).

**Survey and monitoring of rice arthropods in Sylhet region**

The population of grass hopper was found as the highest in sweep net collection 22.11/20 sweep during Aus season. Green leafhopper population was found as the highest at 17.00 and 19.95/20 sweep in T. Aman and Boro season respectively. Among the natural enemies spider population was found as the highest at 10.33 and 10.60/20 sweep in T. Aman and Boro season respectively. During Aus season damsel fly population was found the highest at 13.89/20 sweep followed by spider and CBB at 3.67 and 2.33/20 sweep respectively.

**Incidence of insect pests and their natural enemies in perching used field and non-perching field**

On average the highest number of white leafhopper (26.98%) reduced in perching used field followed

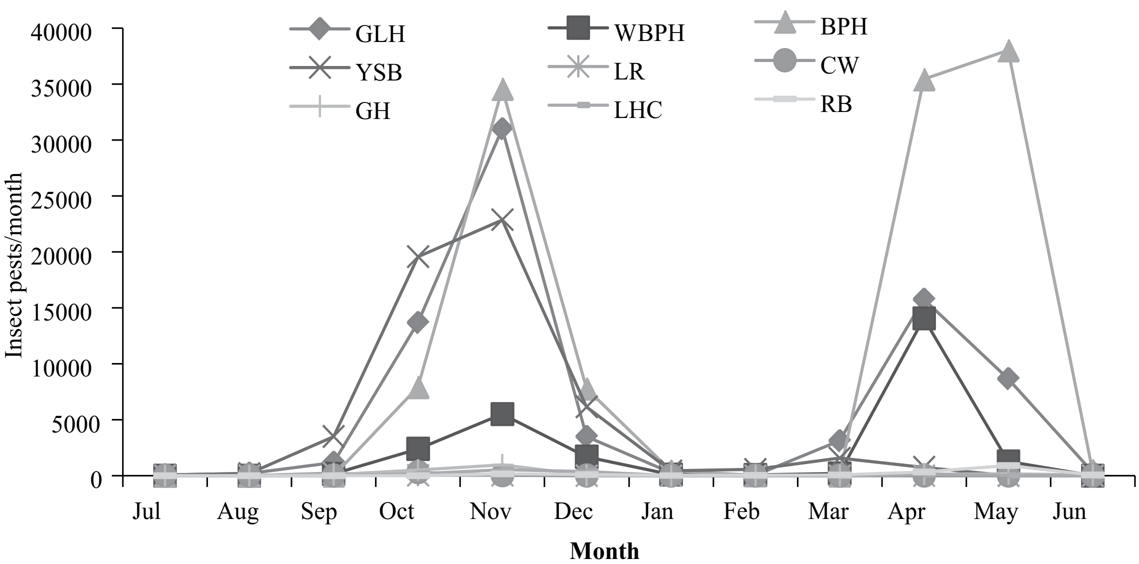


Fig 1. Incidence patterns of major insect pests in light trap, BRRI RS, Habiganj, July 16- June17.

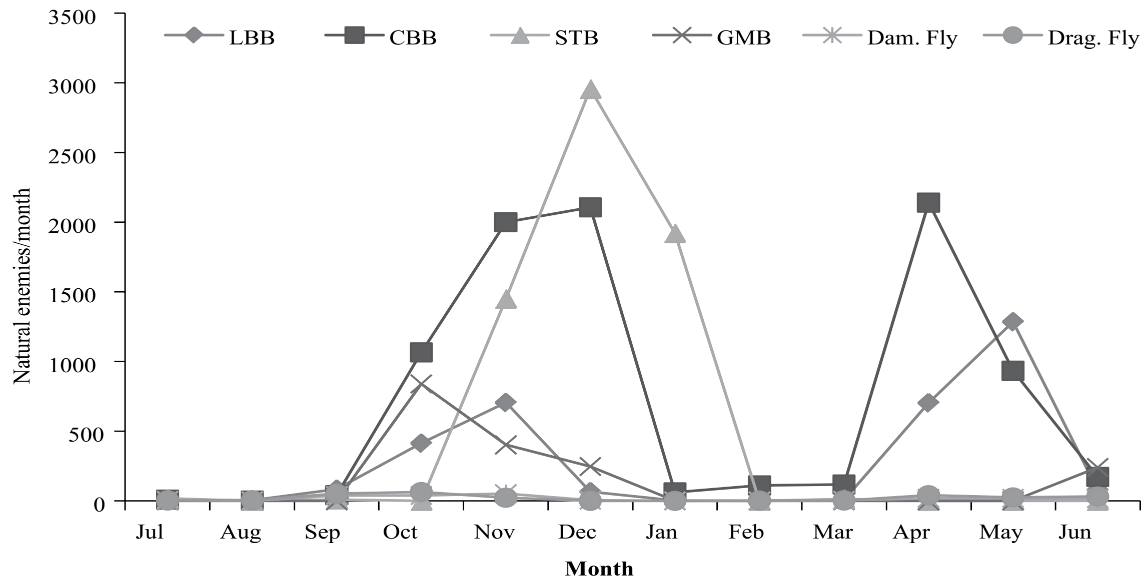



Fig. 2. Incidence pattern of natural enemies of rice insect pests in light trap, BRRI RS, Habiganj, July 2016-June 2017.

by leaf roller (20.87%), long horned cricket (20.28%), grasshopper (20.69%) and yellow stem borer (18.73%). Perching had no effect on rice hispa (RH) and rice bug (RB) (Fig. 3). Average reduction of dam.fly, drag.fly and SPD was observed 15.08, 12.04 and 9.46% respectively in perching used field. But no or little reduction observed in case of CBB and LBB (Fig 4.).

TECHNOLOGY TRANSFER

**Truthfully leveled (TLS) and breeders seed production**

More than 15 tones of TLS seed of different varieties were produced in the reporting year which was distributed and sold to the local farmers. About 23 tons of breeders seeds were produced from

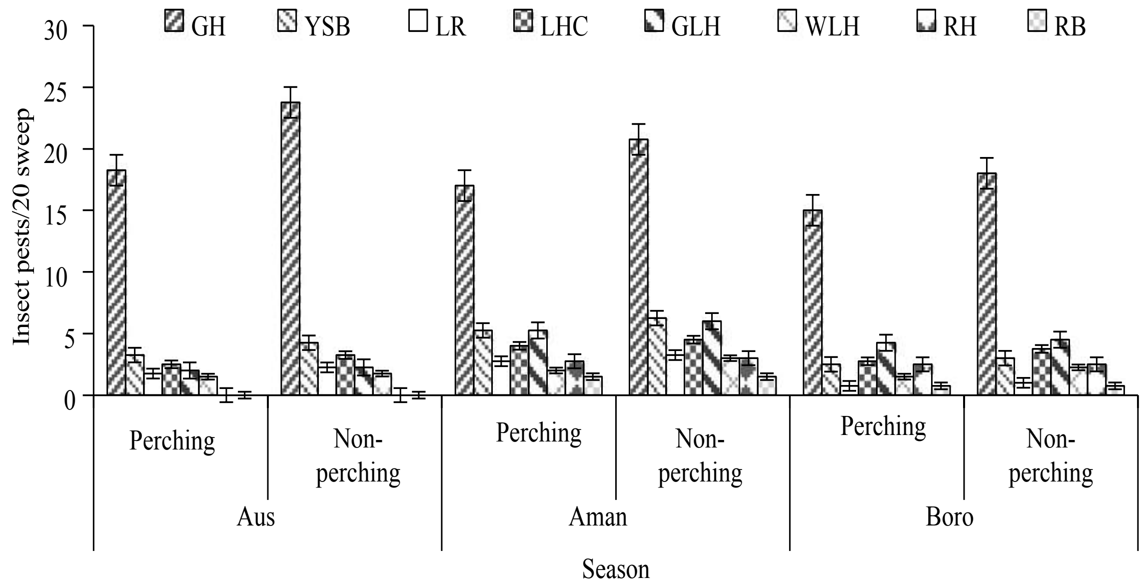



Fig. 3. Incidence of insect pests in perching used field and non-perching field, BRRI RS, Habiganj.

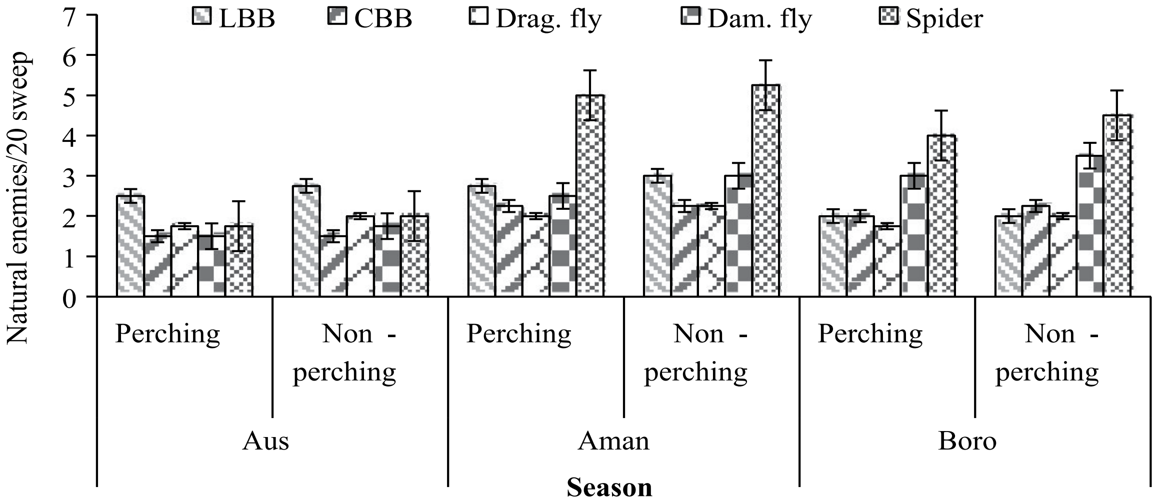



Fig. 4. Incidence of natural enemies in perching used field and non-perching field, BRRI RS, Habiganj.

two T. Aman and four Boro varieties during the reporting year and sent to the Genetic Resource and Seed Division, BRRI HQ, Gazipur.

**Training programme**

BRRI RS, Habiganj conducted 11 training courses on 'Modern rice cultivation technology' for 340 farmers in which they were trained up with rice production technology in different ecosystems especially on *haor* ecosystem. The training courses were conducted at BRRI training center and different upazilas of Habiganj, Sylhet, Moulvibazar and Sunamganj districts.

# BRRI RS, Rajshahi

In RYT Aus 2016, a total of 11 breeding lines and BRRI dhan62 were evaluated but none of promising lines was found for further evaluation. A total of 69 breeding lines were evaluated in RYT T. Aman 2016 under replicated trials of which 15 entries appeared promising for further advancement. Considering stress (drought) and control condition data, 10 genotypes (IR15L1123, IR14L374, IR14L108, IR12N205, IR12A268-9, IR102796-14-77-2-1-2, IR99784-255-29-, IR15L 1235, IR15L 1380 and IR15L 1064) were selected for PVS trial in the next T. Aman season. In RYT GSR at Aman season, the genotype HHZ5-DT20-DT3-Y2 has been found suitable for further evaluation. For proposed variety trial (PVT), none of proposed lines has been found suitable for variety in T. Aman season. During Boro, the genotype BR8109-29-2- appeared promising with favourable Boro rice, the breeding line BR8333-15-3-2-2 remained suitable for bacterial blight disease resistant and was recommended for further advancement. The genotype BR(Bio)9785-BC2-19-3-5 was also found as short duration biotechnology material. In PVT Boro, none of breeding material gave higher yield than the checks. During T. Aman season, urea super granule (USG) performed better compared to prilled urea under drought prone ceo-system. The bed planting non- puddled rice and conventional transplanted plots gave similar yield under wheat-mungban system while incorporation of 50% rice and wheat straw and 100% mungbean stover produced significant yield advantage over straw removal treatment. Among the different cropping patterns, the highest rice equivalent yield (REY) remained in Potato-Maize-T. Aman cropping pattern followed by Potato-Boro-T. Aman cropping pattern. Next to potato based patterns, Maize-Mungbean-T. Aman gave higher REY followed by Boro-T. Aus-T. Aman cropping pattern.

In the reporting period, BRRI RS, Rajshahi produced 34 tons seed of recently developed BRRI varieties and also arranged 11 farmers' training and several farmers' field days.





**Regional yield trial (RYT), B. Aus, 2016**

Five breeding lines were evaluated in RYT at BRRI RS farm, Rajshahi against standard checks of BRRI dhan43 and BRRI dhan65. The test entries did not perform better than the check varieties BRRI dhan65 (3.61 t/ha) and BRRI dhan43 (3.29 t/ha).

**Regional yield trial (RYT), T. Aus 2016**

The variety BRRI dhan62 along with two checks BR26 and BRRI dhan48 were evaluated in T. Aus season. BRRI dhan62 (3.72 t/ha) gave the higher yield than the check BR26 (3.41 t/ha) but produced lower yield than the check BRRI dhan48 (4.07 t/ha).

**Regional yield trial (RYT#3-Biotechnology), T. Aus 2016**

Six entries along with the check variety BRRI dhan48 were evaluated. The tested entries did not perform better than the check variety BRRI dhan48.

**Regional yield trial (RYT), T. Aman 2016**

Eleven regional yield trials with seven rain-fed lowland rice (RLR), three premium quality rice (PQR) and one micronutrient enriched rice (MER) were conducted.

**RYT#1 (RLR).** One genotype along with three checks Nizersail, BR22 and BRRI dhan54 were evaluated. The genotype BR7358-56-2-2-1-HR7 (Com) produced higher yield (4.50 t/ha) and had 24 days earlier growth duratijon than the local check Nizersail (1.82 t/ha and 142 days) but gave lower yield than the check varieties BR22 (4.68 t/ha) and BRRI dhan54 (4.54 t/ha).

**RYT#2 (RLR).** Six genotypes along with two checks BRRI dhan39 and BRRI dhan32 were evaluated. The highest grain yield was found in the genotype BR8204-5-3-2-5-2 (6.71 t/ha) followed by IR11F190 (6.34 t/ha). The genotypes BR8204-5-3-2-5-2 (6.71 t/ha) and IR11F190 (6.34 t/ha) gave higher yield than the check varieties BRRI dhan39 (5.71 t/ha and) and BRRI dhan32 (4.66 t/ha).

**RYT#3 (RLR).** Six genotypes along with check variety BR11 were evaluated. Out of six, two entries viz BR8189-10-2-3-1-5 (6.25 t/ha) and BR8189-10-2-3-1-6 (5.95 t/ha) yielded higher than the check BR11 (4.99 t/ha). These two genotypes (129) had seven days earlier growth duration than BR11 (136 days).

**RYT#4 (RLR).** Four genotypes along with the check varieties BRRI dhan66 and BRRI dhan49 were evaluated. None of the genotypes performed better yield than the check varieties.

**RYT#5 (RLR).** Five genotypes along with the check varieties BRRI dhan49 and Swarna were evaluated. The genotype BR8492-9-5-2-3 (5.03 t/ha and 130 days) gave the higher yield than the check varieties BRRI dhan49 (4.50 t/ha and 130 days) and Swarna (4.31 t/ha and 139 days). The genotype BR8492-9-5-3-2 (4.68 t/ha and 124 days) produced higher grain yield and 15 days earlier growth duration than the check Swarna.

**RYT#6 (RLR).** Five genotypes along with the two check varieties BR11 and BRRI dhan49 were evaluated. The genotype Suman swarna (Raj) (4.54) gave higher grain yield than the check BR11 (4.24 t/ha) and also produced similar grain yield with the check BRRI dhan49 (4.41 t/ha).

**RYT#7 (RLR).** Five genotypes along with the check variety BRRI dhan49 were evaluated. The genotype IR12N177 (5.51 t/ha and 115 days) produced the higher yield and had 12 days earlier growth duration than the check variety BRRI dhan49 (5.33 t/ha and 127 days).

**RYT#8-PQR_Kalizira.** Six genotypes along with the four check varieties BRRI dhan34, BINA dhan13, Kalizira and Tulsimala were evaluated. Out of six, four genotypes viz BR8493-12-7-4 (Com), BR8493-16-5-1, BR8850-10-8-3-3 and BR8850-20-3-5-1 yielded higher (3.51-3.86 t/ha) than the all check varieties (1.51-3.11 t/ha). Among these four genotypes, BR8493-12-7-4 (Com) gave the highest yield (3.86 t/ha) followed by BR8850-10-8-3-3 (3.74 t/ha) and BR8850-20-3-5-1 (3.52 t/ha).

**RYT#9-PQR_BRRI dhan34.** Ten genotypes along with the check variety BRRI dhan34 were evaluated. All tested genotypes gave higher yield (3.67-4.68 t/ha) than the check varietiy BRRI dhan34 (3.35 t/ha). Among them, the genotype BR8522-53-1-3 produced the highest yield (4.68 t/ha) followed by genotype BR8522-16-5-3-1-HR2 (Com) (4.59 t/ha) and BR8536-27-2-1-1 (4.34 t/ha).

**RYT#10-PQR_BRRI dhan37+Kataribhog.** Six genotypes along with the three check varieties BRRI dhan38, BRRI dhan70 and Kataribhog were evaluated. The genotype BR8512-3-1-1 produced similar yield (4.47 t/ha) with the check variety BRRI dhan70 (4.47 t/ha) and gave higher yield than Kataribhog and BRRI dhan38 (2.85-3.20 t/ha).

**RYT#11-PQR_MER.** Four genotypes along with the three check varieties BRRI dhan39, BRRI dhan32 and BRRI dhan72 were evaluated. Out of four genotypes, three genotypes, BR7528-2R-HR16-2-24-1 (6.07 t/ha), BR8410-16-4-17-9-1(6.47 t/ha) and BR7528-2R-HR16-3-3-98-1 (5.98 t/ha) produced the higher yield than the checks (5.12-5.75 t/ha).

**Regional yield trial (RYT#12-Biotechnology), T. Aman 2016**

Six genotypes along with check variety BRRI dhan39 were evaluated. The genotype BR(Bio) 8019-AC4-1-1-3 (5.72 t/ha and 112 days) produced similar grain yield and growth durations with the check variety BRRI dhan39 (5.61 t/ha and 113 days).

**International Rainfed Lowland Rice Observational Nursery (IRLON), T. Aman 2016**

Thirty-seven genotypes along with two checks; BRRI dhan56 and BRRI dhan66 were evaluated. Among the tested entries, the IRTP30449 gave higher yield and had eight days earlier growth duration (5.70 t/ha and 110 days) than the check variety BRRI dhan66 (5.15 t/ha and 118 days). The entries IRTP 30505 and IRTP 30496 produced similar yield but 4-8 days earlier growth duration with the check variety BRRI dhan66.

**International Irrigated Rice Observational Nursery (IIRON), T. Aman 2016**

Thirty-seven genotypes along with two checks BRRI dhan49 and BRRI dhan56 were evaluated. Among the tested entries IR11A307 (7.11 t/ha and 127 days) and IR11L236 (7.31 t/ha and 120 days) produced similar yield but 3-10 days earlier growth duration with the check variety BRRI dhan49 (6.92 t/ha and 130 days). The three entries CR2340-5, IR11N293 and MTU-1117 gave higher yield (6.22-6.49 t/ha) than the check variety BRRI dhan56.

**Proposed variety trial (PVT), T. Aman 2016**

The genotype WAS161-B-4-B-1-TGR51 (NERICA-L-32) along with check BRRI dhan39 was evaluated. The proposed line produced lower grain yield (4.52 t/ha) but four days earlier growth duration (112 days) than the check variety BRRI dhan39 (5.21 t/ha).

**Observational yield trial (OYT) of STRASA drought lines, T. Aman 2016**

**OYT#1.** A total of 195 advanced lines with three checks (BRRI dhan49, BRRI dhan66 and BRRI dhan71) were tested under both stress and control condition. Among them, five genotypes (IR15L1123 (5.95 t/ha), IR14L374 (5.63 t/ha), IR14L108 (5.77 t/ha), IR12N205 (5.71 t/ha), IR12A268 9 (5.82 t/ha) produced higher yield than all the checks (4.31-5.37 t/ha).

**OYT#2.** A total of 49 genotypes along with three checks; BRRI dhan49, BRRI dhan66 and BRRI dhan71 were grown in controlled and stressed conditions. Among them, two genotypes IR102796-14-77-2-1-2 (5.29 t/ha) and IR99784-255-29-1-1-1-2 (5.25 t/ha) produced higher yield than all the checks (3.56-5.15 t/ha).

**OYT#3.** A total of 79 genotypes along with three checks; BRRI dhan49, BRRI dhan66 and BRRI dhan71 were grown in controlled and stressed conditions. Among them, three genotypes (IR15L 1235 (5.66 t/ha), IR15L 1380 (5.43 t/ha) and IR15L 1064 (5.42 t/ha) produced higher grain yield than the checks BRRI dhan71 (5.32 t/ha) under stress condition.

**OYT#4.** A total of 85 advanced lines with three checks (BRRI dhan49, BRRI dhan66 and BRRI dhan71) were tested under both stress and control conditions. Yield ranges from 2.08-5.61 t/ha with growth duration ranges from 102-122 days and nine genotypes gave more than 5.00 t/ha grain yield in stressed condition.

**Participatory variety selection (PVS) trial of STRASA drought lines, T. Aman 2016**

A total of nine genotypes along with three checks; BRRI dhan56, BINA dhan7 and BRRI dhan49 were evaluated in controlled and stressed conditions. Grain yield ranges from 2.45-4.6 t/ha with growth duration 103-123 days and four genotypes produced more than 4.25 t/ha grain yield in stressed condition. Among them, IR95795-53-1-1-2 produced the highest grain yield (4.60 t/ha) followed by IR93822-9-2-3-1 (4.49 t/ha).

**Validation of BRRI released drought tolerant varieties under drought ecosystem**

Four genotypes (BRRI dhan56, BRRI dhan57, BRRI dhan66 and BRRI dhan71) were evaluated under drought condition at T. Aman 2016 season over five locations (Paba, Godagari, Tanore and Durgapur upazila) of Rajshahi region. BRRI dhan71 produced the highest yield (4.74 t/ha) followed by BRRI dhan66 (4.34 t/ha) and BRRI dhan56 (4.30 t/ha) whereas BRRI dhan57 gave the lowest yield (3.72 t/ha) with shorter growth duration (103 days).

**Preliminary yield trial (PYT), secondary yield trial (SYT) and regional yield trial (RYT) of GSR lines, T. Aman 2016**

One preliminary yield trial (PYT), one secondary yield trial (SYT) and one regional yield trial (RYT) were conducted.

**PYT.** Five genotypes along with the three checks BRRI dhan39, BRRI dhan71 and BRRI dhan75 were evaluated at on-farm condition of Paba and Godagari. In Paba, The genotype HHZ 22-Y3-DT1-Y1 (4.83 t/ha) produced similar yield with the checks BRRI dhan71 and BRRI dhan75 (4.71-4.74 t/ha) but it gave the higher yield with similar growth duration than the check variety BRRI dhan39 (3.79 t/ha).

**SYT.** Four genotypes along with the two check varieties BRRI dhan71 and BRRI dhan75 were evaluated at Paba, Godagari and Durgapur. In Durgapur site, the genotypes HHZ11-DT7-SAL1-SAL1 and HHZ5-SAL12-DT3-Y2 gave the higher yield (5.60-5.71 t/ha) than the check BRRI dhan75 (4.97 t/ha) but produced similar grain yield with the check variety BRRI dhan71 (5.59 t/ha).

**RYT of GSR lines.** Four genotypes along with the two check varieties BRRI dhan66 and BRRI dhan71 were evaluated at Paba, Godagari and Durgapur. In Paba site, the two genotypes HHZ5-DT20-DT3-Y2 (4.47 t/ha) and HHZ8-SAL12-Y2-DT1 (4.52 t/ha) gave the higher yield than the check varieties BRRI dhan66 (4.02 t/ha) and BRRI dhan71 (4.13 t/ha). In Godagari site, the genotype IR64683-87-2-2-3-3 (PSBRc82) gave the higher grain yield (4.73 t/ha) than the check varieties BRRI dhan66 and BRRI dhan71 (4.35-4.39 t/ha). In Durgapur site, the genotype HHZ5-DT20-DT3-Y2 (5.94 t/ha) gave the higher grain yield than the check varieties BRRI dhan66 and BRRI dhan71 (5.54-5.70 t/ha).

**Regional yield trial (RYT), Boro 2016-17**

Six regional yield trials: one favourable Boro rice (FBR), two micronutrient enriched rice (MER), two premium quality rice (PQR) and one disease resistant rice trials were conducted.

**RYT#1 (FBR).** Four genotypes along with three checks BRRI dhan28, BRRI dhan58 and BRRI dhan29 were evaluated. The genotype BR8109-29-2-2-3 (8.05 t/ha) produced the highest yield than all the check varieties (5.51-7.37 t/ha). The genotype BR8780-10-5-1 (7.07 t/ha) gave the highest yield than the checks BRRI dhan28 and BRRI dhan58 but growth duration was similar to BRRI dhan29. The genotypes BR7671-37-2-2-3-7-3-P3 and BR8626-19-5-1-2 (6.06-6.38 t/ha) produced the higher yield than the check variety BRRI dhan28 (5.51 t/ha).

**RYT#2 (MER-1).** Six genotypes along with two checks BRRI dhan28 and BRRI dhan74 were evaluated. None of the genotype performed better yield than the check variety BRRI dhan74.

**RYT#3 (MER-2).** Two genotypes along with two checks BRRI dhan28 and BRRI dhan58 were evaluated. None of the genotypes produced better yield than the check variety BRRI dhan58 but the genotypes BR7671-37-2-2-3-7-3-P10 and BR7671-37-2-2-3-7-3-P11 produced the highest yield (6.44-6.54 t/ha) than the check variety BRRI dhan28 (5.55 t/ha).

**RYT#4 (PQR-1).** Four genotypes along with two checks BRRI dhan50 and BRRI dhan63 were evaluated. The genotype BR8590-5-2-5-2-2 (5.69 t/ha) and BR8590-5-3-3-4-2 (5.71 t/ha) produced similar yield with check varieties BRRI dhan50 and BRRI dhan63 (5.37 -5.53 t/ha).

**RYT#5 (PQR-2_low GI).** Four genotypes including check variety BR16 were evaluated. None of the genotype produced better yield than the check but the tested genotype BRC266-5-1-2-1 produced above 6 t/ha yield with five days earlier growth duration than the check variety BR16.

**RYT#7 (Disease resistant rice).** Two genotypes along with three checks; IRBB60, BRRI dhan28 and BRRI dhan29 were evaluated. The bacterial blight (BB) resistance genotype BR8333-15-3-2-2 (7.73 t/ha) gave higher yield than all the check varieties (5.44-7.34 t/ha). The genotype BR8938-19-4-3-1-1 (7.40 t/ha and 151 days) produced higher yield than the checks IRBB60 and BRRI dhan28 but gave similar yield with 13 days earlier growth duration than the check variety BRRI dhan29 (7.34 t/ha and 164 days). Actually, there was no disease symptom in this trial.

**Regional yield trial (RYT) from Biotechnology Division, Boro 2016-17**

**RYT#1 (Short duration).** Five genotypes were investigated including check BRRI dhan2. The genotype BR(Bio)9785-BC2-19-3-5 (6.30 t/ha) gave the highest yield than the check variety BRRI dhan28 (5.88 t/ha). The genotype BR(Bio)9785-BC2-20-1-3 and BR(Bio)9785-BC2-19-3-1 (5.90-6.13 t/ha) produced the similar yield with the check variety BRRI dhan28 (5.88 t/ha).

**RYT#2 (Long duration).** Five genotypes along with the check BRRI dhan28 were evaluated. All the tested materials produced higher yield (7.18-7.66 t/ha) but longer growth duration than the check variety BRRI dhan28 (5.59 t/ha). Among them, the genotype BR(Bio)8333-BC5-2-16 (7.66 t/ha) produced the highest yield followed by the genotype BR(Bio)8333-BC5-2-22 (7.65 t/ha), BR(Bio)8333-BC5-1-20 (7.49 t/ha) and BR(Bio)8333-BC5-3-10 (7.48 t/ha). On the other hand, The genotype BR(Bio)8333-BC5-1-1 gave the lowest yield (7.18 t/ha).

**International Irrigated Rice Observational Nursery (IIRON), Boro 2016-17**

Thirty-nine genotypes along with three checks; BRRI dhan28, BRRI dhan29 and BRRI dhan58 were evaluated. None of the tested entries were able to give higher yield than the check variety BRRI dan29. The tested three entries (7.56-7.87 t/ha) gave higher yield and eight entries (7.05-7.55 t/ha) produced similar yield with the check variety BRRI dhan58 (7.02 t/ha). Ten entries (6.50-7.00 t/ha) gave similar yield with the check variety BRRI dhan28 (6.48 t/ha).

**Proposed variety trial (PVT), Boro 2016-17**

Three PVTs with one favourable Boro rice (FBR), one micronutrient enriched rice (MER) and one short duration were conducted.

**PVT#FBR.** One genotype along with check BRRI dhan28 was evaluated. The proposed line BR7358-5-3-2-1-HR2 (Com) produced similar yield and two days longer growth duration with the check variety BRRI dhan28.

**PVT#MER.** Two genotypes along with check variety BRRI dhan28 were evaluated. The tested MER line BR7831-59-1-1-4-5-1-9-P1 produced similar yield but with two days earlier growth duration (6.94 t/ha and 141 days) than the check variety BRRI dhan28 (6.86 t/ha and 143 days).

**PVT#Short duration.** Two genotypes along with check BRRI dhan28 were evaluated at Bilkumari, Tanore, Rajshahi. The proposed lines did not give higher yield than the check variety BRRI dhan28 (7.90 t/ha).

**SYT of GSR materials, Boro 2016-17**

**SYT#1.** Seven genotypes along with the two check varieties BRRI dhan28 and BRRI dhan58 were evaluated at on-farm, Paba and Tanore, Rajshahi. In Paba site, the genotype HHZ10-DT7-Y1 (7.34 t/ha) produced the higher grain yield than all the check varieties (6.12-7.01 t/ha). The genotype HHZ11-Y6-Y2-SUB1 (7.21 t/ha) gave the similar grain yield with the check BRRI dhan58 (7.01 t/ha) but produced higher grain yield than the check variety BRRI dhan28 (6.12 t/ha). None of genotypes produced significantly higher grain yield than the check variety BRRI dhan58 at Tanore site. The genotype HHZ10-DT7-Y1 (6.91 t/ha) produced similar grain yield with the check variety BRRI dhan58 (6.74 t/ha) but gave higher grain yield than the check variety BRRI dhan28 (5.96 t/ha).

**SYT#2.** Six genotypes along with the check variety BRRI dhan28 were evaluated at Paba and Tanore. In Paba site, the genotype HHZ17-Y16-Y3-Y2 (7.08 t/ha and 154 days) produced the higher grain yield but longer growth duration than the check variety BRRI dhan28 (6.76 t/ha and 143 days). The four genotypes HHZ14-Y7-Y1-DT2 (6.67 t/ha), HHZ15-DT4-DT1-Y1 (6.54 t/ha), HHZ17-Y16-Y3-Y2 (6.96 t/ha) and HHZ5-DT8-DT1-Y1 (6.61 t/ha) produced the higher grain yield than the check variety BRRI dhan28 (6.76 t/ha) at Tanore site.

## CROP-SOIL-WATER MANAGEMENT

**Nitrogen management in drought tolerant rice varieties, T. Aman 2016**

The experiment was laid out in split plot design with three replications. Four varieties viz BRRI dhan56, BRRI dhan57, BRRI dhan66 and BRRI dhan71 were assigned to the main plots and in sub plots fertilizer treatments viz $T_1$-application of USG at 3-5 days after transplanting, $T_2$-prilled urea application, and $T_3$-control were assigned.

Among the main plot treatments, BRRI dhan71 gave the highest yield (4.66 t/ha) followed by BRRI dhan56 (4.44 t/ha). Among the sub-plot treatments USG treated plots showed the highest yield (4.74 t/ha) followed by prilled urea treated plots (4.67 t/ha).

**Performance of drought tolerant rice varieties under different establishment methods and moisture conservation techniques, T. Aman 2016**

The experiment was laid out in split plot design with three replications. Three rice establishment methods viz. direct seeded rice (DSR), puddle transplanting (PT) and unpuddle transplanting (UT) were allocated in main plots and with pusa hydrogel and without hydorgel were allocated in sub plots.

Among the main plot treatments, the highest grain yield (4.87 t/ha) was observed in the direct seeded rice (DSR) (4.87 t/ha) followed by unpuddle transplanting (UT) (4.38 t/ha). In the sub-plot treatments, hydrogel treated plots (4.54 t/ha) gave higher yield than without hydrogel treated plots (4.14 t/ha).

## PEST MANAGEMENT

**Evaluation of new fungicides against sheath blight disease of rice**

Efficacy of 19 chemicals from different groups was tested against sheath blight of rice. Among the 19 test fungicides, the highest disease reduction was obtained by Ensure 40EC (89.05%) followed by Royal 75WDG (86.91%), (Nativa 75WG (86.46%), Agronil (86.09%), Sunchance 75WG (84.93%), Oxyzole (84.75%) and Fazilat 30EC (84.61%).

## RICE FARMING SYSTEMS

**Effect of conservation tillage and residue management options on the productivity of Wheat-Mungbean-T. Aman systems**

The trial was conducted at BRRI RS, Rajshahi during 2016-17 in split plot design with three replications. The tillage and crop establishment treatments were $T_1$: Bed planting wheat and mungbean and bed planting nonpuddled T. Aman, $T_2$: Strip tilled wheat and mungbean and strip tilled nonpuddled T. Aman and $T_3$; Broadcasting wheat and mungbean and conventional puddled T. Aman and the residue management options were $S_1$: 50% wheat and rice, 100% mungbean, $S_2$: 25% wheat and rice, 100% mungbean, $S_3$: Conventional (Removal of residues of all crops).

The grain yield of wheat was not affected significantly either by tillage or by the residue management options. The tillage and residue management options showed significant interaction on yield ranging from 3.44 in $T_3 \times S_3$ to 4.04 in $T_1 \times S_1$. In case of mungbean, the tillage and residue management options showed insignificant effect on seed yield of mungbean while the tillage and residue management showed significant interaction and the higher yield remained in $T_1 \times S_3$ (1.19 t/ha) nearly followed by $T_3 \times S_1$ (1.18 t/ha). The lowest seed yield remained in the treatment combinations of $T_1 \times S_2$ (0.88 t/ha). In rice, the grain yield remained higher in $T_1$ (4.89 t/ ha) followed by $T_3$ (4.76 t/ha). Overall results suggested that comparable grain yield of rice was found in bed planting nonpuddled rice and conventional transplanted plots. The results also revealed that the incorporation of 50% rice and wheat straw and 100% mungbean stover produced significant yield advantage over straw removal treatment.

**Long term effects of different cropping patterns on crop productivity and soil health**

The experiment was conducted at BRRI RS, Rajshahi during 2016-17. The tested cropping patterns were Potato-Boro-T. Aman, Maize-Mungbean-T. Aman, Potato-Maize-T. Aman, Wheat-Mungbean-T. Aman, Boro-T. Aus-T. Aman, Boro-Fallow-T. Aman (check). Among all the cropping patterns, the highest (25.8 t $ha^{-1}$) REY was found in Potato-Maize-T. Aman cropping pattern followed by Potato-Boro-T. Aman cropping pattern (Table 1). Next to potato based patterns, Maize-Mungbean-T. Aman gave higher REY followed by Boro-T. Aus-T. Aman cropping pattern.

**Farmers participatory evaluation of BRRI dhan39 under Jute+Rice relay cropping pattern**

The experiment was conducted in Charghat upazila of Rajshahi district to evaluate the productivity and profitability of realy Aman rice in jute in different farmer's field. The seeds of rice were directly seeded in jute field before 20-25 days of jute harvesting in the middle of July. Among the four farmers, two farmer destroyed rice field after harvesting of jute as they suspected the rice yield would be very low.

The average result of two farmers showed that BRRI dhan39 gave little higher yield when it was grown after jute harvest. The result also showed that BRRI dhan39 relayed with jute reduced cultivation cost of Tk 13,750/ha (Table 2). The gross margin also remained higher (Tk 9,600/ ha) in BRRI dhan39 relay with jute treatment. Thus we concluded that the farmers might be benefitted if they cultivate BRRI dhan39 in relay jute system.

**Table 1. Yield of different crops and REY of cropping patterns at BRRI RS Rajshahi, 2016-17.**

| Cropping pattern | Yield (t/ha) | | | |
|---|---|---|---|---|
| | Rabi | Kharf-I | Kharfi-II | REY |
| Potato-Boro-T. Aman | 21.7 | 5.25 | 4.48 | 25.0 |
| Maize-Mungbean-T. Aman | 10.6 | 0.86 | 4.64 | 17.0 |
| Potato-Maize-T. Aman | 23.2 | 5.70 | 4.32 | 25.8 |
| Wheat-Mungbean-T. Aman | 3.71 | 1.17 | 5.63 | 14.1 |
| Boro-T. Aus-T. Aman | 6.13 | 4.66 | 5.22 | 16.0 |
| Boro-Fallow-T. Aman (check) | 6.88 | - | 5.50 | 12.4 |
| LSD (0.05) | - | - | - | 1.8 |

Price: Potato: 12 Tk/kg, Maize: 15 Tk/kg, Mungbean: 60 Tk/kg, Boro rice: 15 Tk/kg, Wheat 20 Tk/kg, Aman rice: 17 Tk/kg, Aus rice: 17 Tk/kg.

**Table 2. Yield and economics of BRRI dhan39 under Jute+Rice and Jute-Rice cropping system.**

| Treatment | Grain yield (t/ha) | Cultivation cost (Tk) | Gross return (Tk) | Gross margin (Tk) |
|---|---|---|---|---|
| BRRI dhan39 relayed with jute | 4.50 | 35850 | 81750 | 45900 |
| BRRI dhan39 after jute harvest | 4.76 | 49600 | 85900 | 36300 |

Price: Rice 17 Tk/kg, Rice straw 1 Tk/kg.

## SOCIO-ECONOMIC STUDY

**Stability analysis of BRRI developed Aus varieties**

Nine varieties were evaluated at BRRI RS, Rajshahi to determine the stability index of BRRI developed Aus varieties. Among the nine varieties, BRRI dhan65 (5.61 t/ha) were top in rank followed by BRRI dhan48 (5.03 t/ha). After BRRI dhan48, the next three high yielding varieties were BRRI dhan42, BR21 and BRRI dhan43, respectively.

**Stability analysis of BRRI developed Aman varieties**

Thirty-seven Aman rice varieties were evaluated at BRRI RS, Rajshahi to determine the stability index. Among the 37 varieties, the grain yield remained higher in BRRI dhan72 (6.51 t/ha followed by BRRI hybrid dhan4 (6.25 t/ ha). After BRRI hybrid dhan4, the next four high yielding varieties were BRRI dhan76 (5.91 t/ha), BRRI dhan40 (5.83 t/ ha), BRRI dhan77 (5.79 t/ha) and BR11 (5.77 t/ha), respectively. BRRI dhan38, BRRI dhan37, BRRI dhan62 and BRRI dhan34 were the low yielding varieties and the yield ranged from 3.33 to 3.95 t/ha.

**Stability analysis of BRRI developed Boro varieties**

Thirty-six Boro rice varieties were evaluated at BRRI RS, Rajshahi to determine the stability index. Considering the yield performance, top five varieties were BRRI hybrid dhan2 (8.17 t/ha), BRRI hybrid dhan5 (7.69 t/ha), BRRI hybrid dhan3 (7.34 t/ha), BRRI dhan29 (6.45 t/ha) and BR7 (6.32 t/ha). Growth duration of these varieties ranged from 151 days in BRRI hybrid dhan5 with 161 days in BRRI dhan29. BR17, BR2, BR18 and BR12 were the low yielding varieties and the grain yield ranged from 3.64 to 4.40 t/ha.

## TECHNOLOGY TRANSFER

**Farmers training and seed distribution**

BRRI RS, Rajshahi Regional Station arranged 11 training programs at different upazilas of of the division. Most of the farmers were very much impressed by taking this rice production training.

**Demonstration of BRRI released varieties**

Field demonstrations were carried out at different locations of Rajshahi region during T. Aman 2016 and Boro 2016-17 seasons. Each season executed about 15 demonstrations with latest released BRRI varieties in Rajshahi region. The farmers of Rajshahi areas were very much interested about these BRRI released varieties. The DAE personnel can take initiative for rapid dissemination of the varieties.

**Truthfully leveled and breeders seed production**

Nucleus seed stock was collected from GRS Division of BRRI. Single seedling was transplanted per hill. For breeder seed production, all official formalities with SCA and BRRI authority were performed through proper channel. Breeder seed was produced in T. Aman and Boro seasons but TLS seed was produced in Aus, T. Aman and Boro seasons. Considering three seasons (Aus, T. Aman and Boro), breeder and TLS seed were produced 19 and 15 tons, respectively.

# BRRI RS, Rangpur

SUMMARY

In total, 858 tolerant progenies with better plant type and 41 fixed lines were selected from pedigree population for development of submergence (flash flood) and stagnant flood (SF) tolerance rice. In PVS mother trial under control submergence condition, PVS-8 (BRRI dhan52) and PVS-6 (IR85261-18-158-Gaz-3B-62), under rainfed condition, PVS-8 (BRRI dhan52) and PVS-9 (BRRI dhan44) were chosen by the farmers through PVS which was consistant with the grain yield. From pedigree nursery, 692 superior individual plants and 25 fixed lines were isolated from 40 crosses of $F_3$-$F_8$ populations for cold tolerance rice. Four entries with better plant growth and uniformity for PYT and six individual plants for OT in T. Aman and five entries with better plant growth and uniformity for PYT in Boro were selected (OT-NPT). Two genotypes viz BR8626-22-2-5-2 and BR8622-22-2-5-5 were selected from PYT (NPT) in Boro 2016-17. Out of 286 genotypes, 47 for PYT and 52 for OT were selected in T. Aman 2016 (OT-BRRI dhan49 NILs). For Aus, in RYT#1 (B. Aus) one genotype (BR7587-2B-3), and in RYT#3 (T. Aus-Biotechnology Division) two genotypes (BR(Bio)9785-BC2-8-4-2 and BR(Bio)9785-BC2-120-2-1) performed better than check varieties. For T. Aman, in RYT#2 (RLR) two genotypes (BR8192-10-1-2-3-4 and IR11F190), in RYT#4 (RLR) one entry (BR8521-30-3-1), in RYT#5 (RLR) one genotype (BR8492-9-5-3-2), in RYT#6 (RLR) two genotypes (Nepali Swarna-Rangpur and Swarna5-Rangpur), in RYT#7 (RLR) one genotype (BR10238-5-1), in RYT#8 (PQR-1, Kalizira type) two genotypes (BR8493-16-5-1 (Com) and BR8850-10-8-3-3), in RYT#9 (PQR-2, BRRI dhan34 type) two genotypes (BR8522-53-1-3 and BR8522-16-5-3-1-HR2(Com), in RYT#10 (PQR-3, BRRI dhan37+Kataribhog type) one genotype (BR8234-1-3-7-1-3-HR21(Com) and in RYT#12 (High yielding rice-Biotechnology Division) two genotypes (BR(Bio)8032-AC3-4-1-3 and BR(Bio)8032-AC3-1-2-2) performed better than the check varieties with similar or less growth duration. For Boro, in RYT#1 (FBR) two genotypes (BR8626-19-5-1-2 and BR8780-10-5-1), in RYT#2 (PQR-1) two entries viz BR8079-19-1-5-1 and BR8590-5-2-5-2-2, in RYT#3 (PQR-2) one genotype (BRC266-5-1-1-1), in RYT#4 (MER-1) two genotypes (BR8631-12-3-6-P3 and BR8631-19-1-1-4-5), in RYT#3 (Disease Resistance) one genotype (BR8938-19-4-3-1-1) and in RYT#7 (High Yielding Rice-Long duration-Biotechnology Division) one entry BR(Bio)8333-BC5-2-16 performed better than check varieties with similar or less growth duration. For Aman, in ALART RLR-1: BR8214-23-1-3-1 (4.5 t $ha^{-1}$), RLR-3: BR-RS(Raj)-PL4-B (4.8 t $ha^{-1}$), MER: BR7895-4-3-3-2-3 (4.8 t $ha^{-1}$) and Biotechnology: BR(Bio)9786-BC2-132-1-3 (5.4 t $ha^{-1}$) gave the highest yield. For Boro, in ALART Biotechnology- Long duration: BR(Bio)9786-BC2-124-1-1 (7.4 t $ha^{-1}$), Biotechnology- Short duration: BR(Bio)9787-BC2-63-2-4 (6.3 t $ha^{-1}$), CTR: BR7812-19-1-6-1-P2 (5.9 t $ha^{-1}$), FBR: BRRI dhan29-SC3-8-HR1(Com) (7.6 t $ha^{-1}$) gave the highest yield and (PQR): BRRI dhan50 genotype gave the highest yield (5.8 t $ha^{-1}$) followed by BR7372-18-2-1-HR1-HR6(Com) (5.6 t $ha^{-1}$). For T. Aman, in proposed variety trial (PVT-RLR) proposed line WAS161-B-4-B-1-TGR51 (NERICA-L-32) gave 1.0 t/ha, in PVT (Re-revaluation of BRRI dhan72 in Rangpur region) BRRI dhan72 gave 2.0 t/ha higher yield compared to their respective check variety BRRI dhan39 and in PVT (Submergence and Water stagnation) proposed lines (BR9159-8-5-40-13-52 and BR9159-8-5-40-13-57) gave 0.35 t/ha higher yield compared to check variety BRRI dhan49 at four locations under rainfed condition but in control condition gave 5.44 and 7.1 t/ha, respectively. Proposed line BR9159-8-5-40-13-57 has been released as T. Aman variety (Submergence tolerance) namely BRRI dhan79. For Boro, in PVT (FBR) proposed line BR7358-5-3-2-1-HR2 gave 0.7 t/ha and in PVT (MER) proposed line BR7831-59-1-1-4-5-1-9-P1 gave 0.2 t/ha higher yield compared to their respective check variety BRRI dhan28. For T. Aus, in OYT out of 81 advanced lines the highest yield was observed in BR9029-51-3-1 (5.815 t/ha) and lowest in ACC 133 (1.065 t/ha). In PYT#1 out of 14 entries the highest yield was found in BR9039-12-2-1 (5.51 t/ha) and in PYT#2 out of 19 entries yield was highest 5.20 t/ha in BR8776-17-4-2. For T. Aman under submergence and water stagnation tolerant rice, the highest predicted grain yield was found in BR9175-9-2-1-12-5 (6.12 t/ha) in OYT#1, IR13F450-3 (6.02 t/ha) in OYT#2, BR7934-10-1-1-1-2-2-5 (5.78 t/ha) in OYT#3 and IR94391-131-358-19-B-1-1-1 (4.93

t/ha) in OYT#4. For PYT, the highest predicted grain yield was observed in BR8157-50-1-6-2-1-27 (5.23 t/ha) in PYT#1, IR92471-SUB-SUB-39-3-B (5.38 t/ha) in PYT#2 and IR13F651 (5.29 t/ha) in PYT#3. For T. Aman under drought tolerant rice, in OYT out of 143 genotypes the highest yield was produced by IR96321-1099-402-B-4-1-1 (6.84 t/ha) which was better than BRRI dhan71 (4.75 t/ha) and lowest by IR94391-131-279-2-B-3-1-1 was (1.81 t/ha). For T. Aman under RLR, in OYT 93 genotypes were evaluated and among them the highest yield was found in IR83140-B-11-B (6.0 t/ha) which was more than check variety BRRI dhan49 (5.56 t/ha). In PYT#1 4.35 t/ha was given by BR9124-11-2-3-3 which was better than check variety BRRI dhan39 (3.80 t/ha) and PYT#2 yield 4.21 t/ha was produced by BR9123-23-2-2-5 which was more than check variety BR11 (4.09 t/ha). For T. Aman under BLB, in OYT out of nine fixed lines the highest yield was observed in BR10388-24-3-3 (4.04 t/ha) which was better than check variety BR23 (2.12 t/ha). Out of eight fixed lines the highest yielder was BR8821-10-2 (3.92 t/ha) in PYT#1 and out of 10 fixed lines BR8826-4-23-4-29 produced the highest yield (3.17 t/ha) in PYT#2. For Boro under BLB, in OYT 23 fixed lines were evaluated and among them highest yield was found in BR9650-22-1-2 (7.93 t/ha). The highest yield was found in BR9647-30-2-1 (6.45 t/ha) followed by BR9647-8-1-5 (6.18 t/ha) in PYT#1. In PYT#2, the highest yielded genotype was BR9943-2-1 (7.63 t/ha) followed by BR8938-30-2-4-2-1 (7.40 t/ha) where check variety BRRI dhan29 yielded 5.04 t/ha. A total of 200 cold tolerant lines were evaluated in Boro 2016-17 seasons. The highest yield was observed in BR8244-8-2-2-2-1-CS1-3-CS2-5-9-1 (8.33 t/ha) while the lowest in BR8565-3-1-3-3-CS1-4-CS2-1-6-1 (2.27 t/ha). In PYT, the highest yield was observed in BRRI dhan29 (6.65 t/ha) followed by a line BR8562-11-2-6-2-5-2 (6.47 t/ha). In nutrient management trial under submergence condition, modified dose (100 kg $ha^{-1}$ urea + 23 kg $ha^{-1}$ MoP) + 75 kg $ha^{-1}$ urea + 60 kg $ha^{-1}$ MoP performed better than the other nutrient management options. The highest survival (82.6%) was found in $T_5$ (20 days later submergence) while the lowest (18.1%) in $T_1$ (just transplanting day). $T_5$ (20 DAT) also showed the highest yield (4.70 t $ha^{-1}$) among the treatments. In case of survivability of submergence tolerant rice increased if submergence occurred after few days later. In fertilizer management of swarna varieties, yield difference was not found significant between $T_1$ (Research practice: Urea-TSP-MP-Gyp-Zn @ 180-70-90-70-10 kg/ha) and $T_2$ (Fermers practice: Urea-TSP-MP @ 220-60-70 kg/ha). Though Lal Gooty swarna gave the highest yield but it could not exceed the popular check variety BR11. BRRI dhan28 with 40-day-old seedling or BRRI dhan28 with 30-day-old seedling planting from 20 February to 2 March and BRRI dhan48 with 30-day or 20-day-old seedling planting from 2 March to 12 March may be suitable for early Aus rice after potato harvest in Rangpur region. A total of 10,327 kg TLS and 9,254 kg breeder seed of Aus (BRRI dhan48), T. Aman (BR11, BR22, BRRI dhan34, BRRIdhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan75) and Boro (BR16, BRRI dhan28, BRRI dhan29, BRRI dhan50, BRRI dhan55, BRRI dhan58, BRRI dhan63, BRRI dhan74) was produced.

## VARIETY DEVELOPMENT

**Growing and screening of pedigree generations (STRASA)**

Two $F_2$ and 349 progenies of 8 $F_4$, 8 $F_5$, 6 $F_6$, **7** $F_7$ and 3 $F_8$ populations were grown under controlled submergence condition. In total 858 tolerant progenies with better plant type and 41 fixed lines were selected from pedigree population ($F_2$-$F_8$, Table 1).

**Participatory variety selection (PVS) under control condition (STRASA)**

Six submergence and medium stagnant water tolerant high yielding rice genotypes along with three standard check varieties having submergence tolerance were evaluated in the control submergence tank at on station. In PVS function, two genotypes viz. PVS-8 (BRRI dhan52) and PVS-6 (IR85261-18-158-Gaz-3B-62) were selected by farmers. Male respondents had the following traits based on their preference–tall, better crop growth, less mortality, uniformity, lodging resistant, good grain quality no pest infestation. Female respondents considered the traits based on good grain and absent of pests. The worst two entries were PVS-7 (BRRI dhan52) and PVS-4 (IR 09F222).

Table 1. List of selected progenies from $F_2$ population and pedigree nurseries, T. Aman 2016, BRRI RS, Rangpur.

| BR no. | Parentage | Character | Progeny selected |
|---|---|---|---|
| | *$F_2$ population* | | |
| 11182 | BRRI dhan39/IR64-Sub1 | Submergence tolerant | 91 |
| 111842 | BR8154-20-8-5-8-2/BRRI dhan52 | do | 49 |
| | Total | | 140 |
| | *$F_4$ generation* | | |
| BR10209 | IR09F226/Chiherang-Sub1 | Submergence tolerant | 6 |
| BR10210 | IR09F236/Chiherang-Sub1 | do | 16 |
| BR10211 | BRRI dhan23/Chiherang-Sub1 | do | 47 |
| BR10212 | BRRI dhan39/Chiherang-Sub1 | do | 75 |
| BR10214 | BRRI dhan46/BRRI dhan51 | do | 31 |
| BR10216 | BRRI dhan51/DG1-349 | do | 64 |
| | | Sub-total | 239 |
| | *$F_5$ generation* | | |
| BR10192 | BR22/BRRI dhan52 | Submergence tolerant | 25 |
| BR10194 | BRRI dhan46/BRRI dhan51 | do | 44+ 1 Bulk |
| BR10195 | BRRI dhan46/BRRI dhan52 | do | 56 |
| BR10198 | BRRI dhan49/Saita | do | 1+1 Bulk |
| BR10201 | BRRI dhan39/KaloJoma | do | 8 |
| BR10204 | BRRI dhan39/DG1-349 | do | 57+1 Bulk |
| BR10206 | BR10206-2-4 | do | 69+ 2 Bulk |
| BR10208 | BR10208-3-2 | do | 55 + 3 Bulk |
| | | Sub-total | 315 + 8 Bulk |
| | *$F_6$ Population* | | |
| BR9788 | BRRI dhan51/BR11-Saltol-HR1 | Submergence tolerant | 44 + 4 Bulk |
| BR9789 | BRRI dhan51/BR11-Saltol-HR2 | do | 6 + 6 Bulk |
| BR9790 | BRRI dhan52/BR11-Saltol-HR1 | do | 19 + 4 Bulk |
| BR9791 | BRRI dhan52/BR11-Saltol-HR2 | do | 18 + 3 Bulk |
| BR9792 | BRRI dhan41/ BRRI dhan52 | do | 21 + 2 Bulk |
| BR9793 | BRRI dhan32/ BRRI dhan52 | do | 23 + 4 Bulk |
| | Sub-total | | 131 + 23 Bulk |
| | *$F_7$ generation* | | |
| BR9214 | BR22/IR85260-66-769-Gaz2 | Submergence tolerant | 5 + 2 Bulk |
| BR9219 | BRRI dhan52/ BRRI dhan51 | do | 3 + 2 Bulk |
| BR9177 | IR85260-391-148/Arail | do | 5 |
| BR9179 | Arail/IR67518 | do | 13 |
| BR9180 | BRRI dhan44/Ghegos | do | 5+ 2 Bulk |
| BR9182 | IR68544-25-21-3-1-1/Arail | do | 2+ 1 Bulk |
| | Sub-total | | 33 + 7 Bulk |
| | *$F_8$ generation* | | |
| BR9158 | BRRI dhan44/BRRI dhan52 | Submergence tolerant | 1 Bulk |
| BR9159 | BRRI dhan49/BRRI dhan52 | do | 1 Bulk |
| BR9167 | BRRI dhan44/Samba Mahsuri-Sub1 | do | 1 Bulk |
| Sub-total | | | 3 Bulk |
| Grand total | | | 858 PS + 41 Bulk |

**Participatory variety selection (PVS) under rainfed condition (STRASA)**

Six submergence and medium stagnant water tolerant high yielding rice genotypes along with three standard check varieties having submergence tolerance were evaluated under rainfed condition in the on station field. In PVS function, two entries PVS-8 (BRRI dhan52) and PVS-9 (BRRI dhan44) obtained the highest vote (Table 2).

**Table 2. Preference analysis of participatory variety selection (Early and Late), T. Aman 2014, BRRI RS, Rangpur and Kurul, Lalmonirhat.**

| Location | Farmers preference ranking and score | | | |
|---|---|---|---|---|
| | 1st Positive | 2nd Positive | 1st Negative | 2nd Negative |
| BRRI, Rangpur (On station-controlled condution) | BRRI dhan52 (0.250) | IR 85261-18-158-Gaz-3B-62 (0.150) | BRRI dhan51 (-0.258) | IR09F222 (-0.167) |
| BRRI, Rangpur (On station-rain fed condution) | BRRI dhan52 (0.183) | BRRI dhan44 (0.117) | IR 10F109 (-0.183) | IR09F222 (-0.183) |

In parenthesis data indicated preference score.

**Head to head trial of submergence tolerant high yielding rice varieties (STRASA)**

Three submergence tolerant high yielding varieties viz. BRRI dhan52, BINA dhan11 and BINA dhan12 along with respective original mega variety viz. BR11 were evaluated at Laxmanpara, Sadar, Rangpur and Rashidpur, Mithapukur, Rangpur farmers' field under the management practices of researchers. Tested over two locations BRRI dhan52 gave the highest yield at both locations followed by BR11. Among the varieties, BINA dhan11 was early maturing (Table 3).

**Pedigree nurseries of cold tolerant rice**

In total, 831 progenies rows comprising 352$F_3$, 280$F_4$, 99$F_5$, 91$F_7$, and 9$F_8$ were grown and 692 superior individual plants and 25 fixed lines were isolated from 40 crosses of $F_3$-$F_8$ populations (Table 4).

**Observational trial (OT-NPT)**

A total of 13 advanced breeding lines (NPT) were tested under this trial in T. Aman 2016 where the check varieties were five. Among them, four entries with better plant growth and uniformity for PYT and six individual plants for OT were selected (Table 5). In Boro 2016-17, a total of 12 advanced breeding lines (NPT) were tested with five standard checks. Among them, five entries with better plant growth and uniformity for PYT were selected (Table 5).

**Observational trial (OT) of BRRI dhan49 NILs under RLR ecosystem in Rangpur region**

A total of 286 genotypes in OT were evaluated at BRRI RS, Rangpur in T. Aman season. Forty-seven genotypes were selected based on growth duration, plant height, phenotypic acceptability at maturity (PAcp) and grain yield. The grain yield of the selected genotypes was varied from 3.6 to 6.1 t/ha. The growth duration of the selected genotypes was varied from 113 to 135 days. A total of 52 genotypes were also selected for OT.

**Preliminary yield trial (PYT-NPT) of Boro season**

A total of five genotypes were evaluated along with three standard check varieties namely, Minikit (Dinajpur), BRRI dhan28 and BRRI dhan58 in Boro 2016-17 at BRRI RS, Rangpur. Two genotypes viz. BR8626-22-2-5-2 and BR8622-22-2-5-5 were selected considering growth duration and grain yield for further evaluation.

**Regional yield trial (RYT)**

A total of 23 RYTs were conducted under Aus, T. Aman and Boro seasons to develop rice varieties promising for Broadcast Aus, Transplant Aus, Rainfed lowland (RLR), Premium quality (PQR), Disease resistance (DR), Micronutrient enriched (MN), High yielding rice (Biotechnology Division) against standard check varieties.

**Table 3. Yield and yield component of different varieties in head to head trial, T. Aman 2016 at sadar and Mithapukur, Rangpur.**

| Genotype | Duration (day) | | Plant ht (cm) | | Sterility (%) | | Yield (t/ha) | |
|---|---|---|---|---|---|---|---|---|
| | L1 | L2 | L1 | L2 | L1 | L2 | L1 | L2 |
| BRRI dhan52 | 141 | 145 | 130 | 132 | 20.8 | 18.5 | 4.62 | 5.67 |
| BR11 | 142 | 146 | 110 | 120 | 22.3 | 19.8 | 4.55 | 4.91 |
| Binadhan-11 | 122 | 127 | 114 | 125 | 21.2 | 22.7 | 4.62 | 4.62 |
| Binadhan-12 | 130 | 135 | 104 | 110 | 8.7 | 10.3 | 3.89 | 3.86 |

L1=Sadar and L2= Mithapukur, Rangpur.

**Table 4. List of selected progenies from pedigree nurseries, cold tolerant rice, Boro 2016-17, BRRI RS, Rangpur.**

| BR # | Parentage | Progeny selected |
|---|---|---|
| | *$F_3$ generation* | |
| 10972 | HUA565/BR7812-19-1-6-1-P2 | 7 |
| 10973 | BRRI dhan28/DASAN | 20 |
| 10974 | BRRI dhan29/IR2266-42-6-2 | 2 |
| 10977 | BRRI dhan28/ BR7812-19-1-6-1-P2 | 1 |
| 10979 | BR16/ BR7812-19-1-6-1-P4 | 33 |
| 10982 | BRRI dhan28/HbjBVI | 5 |
| 10983 | BR16/ IR2266-42-6-2 | 24 |
| 10985 | HUA564/BR18 | 19 |
| 10986 | VIIVIR8572/BRRI dhan28//BRRI dhan28 | 25 |
| 10987 | BRRI dhan61/IR7749-31-2-3-3-1 | 56 |
| 10989 | BRRI dhan60/ BR7812-19-1-6-1-P2 | 23 |
| 10990 | BR16/BR7830-16-1-5-3 | 4 |
| 10992 | HUA564/BR18 | 1 |
| 10997 | BRRI dhan60/ BR7830-16-1-5-3 | 16 |
| 10998 | BRRI dhan28/BR8252-7-1-5-2B2 | 18 |
| 10999 | BRRI dhan28/IR59418-78-21-3 | 26 |
| Sub-total | | 280 |
| | *$F_4$ generation* | |
| 10589 | IR83222-F11-9/BRRI dhan29 | 12 |
| 10594 | BRRI dhan55/BR7840-46-3-2-3 | 3 |
| 10595 | K39-96-1-1-1-2/BRRI dhan55 | 24 |
| 10596 | BR8264-1-1-3B2-HR4/BRRI dhan29 | 4 |
| 10597 | BR26/IR72579-B-3-2-3-3 (sal) | 106 |
| 10598 | BR8264-1-1-3B2-HR4/BR7323-4B-1 | 4 |
| 10599 | BRRI dhan27/ BR7323-4B-1 | 32 |
| 10600 | BRRI dhan29/IR10904-27-2-2-3 | 45 |
| 10601 | BR8264-1-1-3B2-HR4/BRRI dhan55 | 34 |
| 10603 | BRRI dhan29/CT6658-5-2-2SR-2-3-6MP | 2 |
| 10604 | BRRI dhan50/HUA564 (GSR) | 10 |
| 10605 | BRRI dhan29/HUA564 (GSR) | 17 |
| 10607 | BRRI dhan28/Weed tolerant rice | 15 |
| 10617 | BRRI dhan29/BR7840-3-2-4 | 1 |
| Sub-total | | 309 |
| | *$F_5$ generation* | |
| 10317 | BRRI dhan29/Hangangchal | 6 |
| 10318 | BR7974-1-3-1-P1/Hangangchal | 9 |
| 10319 | BR7974-1-3-1-P1/Atshotti | 4 |
| 10320 | BR7813-10-1-2-3-P1/Atshotti | 6 |
| 10321 | BR7813-10-1-2-3-P1/Namyeong | 58+4 Bulk |
| Sub-total | | 83+4 Bulk |
| | *$F_7$ generation* | |
| 9981 | BR7687-1-3-2/IR7858-98-2-2-1 | 2 Bulk |
| 9982 | BR7687-1-3-2/IR79262-24-3-2-3 | 3 Bulk |
| 9988 | BRRI dhan28/ZHONG99-76//OM1490 | 20+7 Bulk |
| 9989 | BRRI dhan29/ZHONG99-76//OM1490 | 8 Bulk |
| Sub-total | | 20+20 Bulk |
| | *$F_8$ generation* | |
| 9360 | BR7166-5B-6/Chunjing15 | 1 Bulk |
| Sub-total | | 1 Bulk |
| Total | | 692 progenies+25 bulk |

**Table 5. Grain yield and other characters of different entries under OT (NPT), T. Aman 2016 and Boro 2016-17, BRRI RS, Rangpur.**

| Genotype | Day to flowering | Duration (day) | Plant ht (cm) | Yield (t/ha) |
|---|---|---|---|---|
| *T. Aman 2016 (Selected)* | | | | |
| BR8470-1-2-4-2-Ran1-5 | 78 | 104 | 110 | 4.7 |
| BR8415-10-1-10-Rang4-5-4 | 85 | 111 | 112 | 4.7 |
| BR8626-22-2-5-2 | 85 | 111 | 105 | 5.0 |
| BR8626-22-2-5-10 | 88 | 114 | 115 | 4.9 |
| Jota Pari (ck) | 88 | 116 | 117 | 4.5 |
| Minikit (Dinajpur, ck) | 79 | 104 | 107 | 4.7 |
| Moushumi Katari (ck) | 93 | 120 | 113 | 4.2 |
| Swarna5 (ck) | 109 | 140 | 116 | 5.5 |
| BRRI dhan49 (ck) | 103 | 133 | 107 | 4.8 |
| *Boro 2016-17 (Selected)* | | | | |
| BR8415-10-1-10-1-Ran4-5-14 | 128 | 160 | 99 | 6.1 |
| BR8626-22-2-5-3 | 125 | 158 | 100 | 5.6 |
| BR8626-22-2-5-4 | 131 | 160 | 105 | 6.0 |
| BR8626-22-2-5-11 | 128 | 160 | 105 | 6.6 |
| BR8626-22-2-5-14 | 132 | 160 | 107 | 6.6 |
| Jota Pari (ck) | 128 | 160 | 90 | 4.4 |
| Minikit (Dinajpur) (ck) | 127 | 157 | 99 | 6.0 |
| Moushumi Katari (ck) | 134 | 160 | 90 | 5.3 |
| BRRI dhan 28 (ck) | 124 | 147 | 94 | 5.7 |
| BRRI dhan58 (ck) | 128 | 160 | 87 | 7.1 |

### Aus 2016

**RYT-1 (Broadcast Aus-B. Aus).** One genotype (BR7587-2B-3) performed better over the check variety BRRI dhan43**.**

**RYT-2. (T. Aus).** BRRI dhan62 produced similar yield with similar growth duration of BR26 and BRRI dhan48.

**RYT-3 (T. Aus-Biotechnology Division).** Two genotypes (BR(Bio)9785-BC2-8-4-2 and BR(Bio)9785-BC2-120-2-1) performed better over the check variety BRRI dhan48.

### T. Aman 2016

**RYT-1 (RLR-late).** The tested entry didn't perform better than the checks varieties.

**RYT-2 (RLR)**. Two genotypes (BR8192-10-1-2-3-4 and IR11F190) found high yielder with longer growth duration over the check varieties.

**RYT-3 (RLR).** None of the tested genotypes found high yielder over the check variety.

**RYT-4 (RLR).** One of the tested entry (BR8521-30-3-1) produced similar yield with shorter growth duration over the check variety BRRI dhan49.

**RYT-5 (RLR).** One genotype (BR8492-9-5-3-2) produced similar yield with shorter growth duration over the check variety BRRI dhan49.

**RYT-6 (RLR).** Two genotypes (Nepali Swarna-Rangpur and Swarna5-Rangpur) found high yielder over the check varieties.

**RYT-7 (RLR).** One genotype (BR10238-5-1) produced higher yield with longer growth duration over the check variety BRRI dhan49.

**RYT-8 (PQR-1, Kalizira type).** Two genotypes (BR8493-16-5-1(Com) and BR8850-10-8-3-3) found high yielder over the check varieties.

**RYT-9 (PQR-2, BRRI dhan34 type).** Two genotypes (BR8522-53-1-3 and BR8522-16-5-3-1-HR2 (Com)) found high yielder with shorter growth duration over the check variety BRRI dhan34.

**RYT-10 (BRRI dhan37+ Kataribhog type).** One genotype (BR8234-1-3-7-1-3-HR21(Com)) produced higher yield over the check varieties.

**RYT-11 (MER)**. None of the tested entries found high yielder over the check varieties.

**RYT-12 (High yielding rice-Biotechnology Division)**. Two genotypes (BR(Bio)8032-AC3-4-1-3 and BR(Bio)8032-AC3-1-2-2) performed better over the check variety.

**Boro 2016-17**

**RYT-1 (FBR).** Two genotypes (BR8626-19-5-1-2 and BR8780-10-5-1) found higher yield over check BRRI dhan58 with similar growth duration but similar yield with five days earlier than BRRI dhan29.

**RYT-2 (PQR-1).** Two entries viz. BR8079-19-1-5-1and BR8590-5-2-5-2-2 performed better than the check variety BRRI dhan63 with similar growth duration.

**RYT-3 (PQR-2).** One genotype (BRC266-5-1-1-1) found similar yield with eight days earlier than check variety BR16.

**RYT-4 (MER-1).** One genotype (BR8631-12-3-5-P2) produced similar yield with 10 days longer growth duration over the check variety BRRI dhan74 but two genotypes (BR8631-12-3-6-P3 and BR8631-19-1-1-4-5 ) produced higher yield with similar growth duration over BRRI dhan28.

**RYT-5 (MER-2)**. None of the tested entries found out yielded over the check variety BRRI dhan58.

**RYT-6 (Disease resistance).** One genotype (BR8938-19-4-3-1-1) produced higher yield with seven days shorter than BRRI dhan29.

**RYT-7, high yielding rice (Long duration-Biotech).** One entry (BR(Bio)8333-BC5-2-16) produced higher yield (6.5 t/ha) with the growth duration of 166 days.

**ALART for Aman 2016 and Boro 2016-17**

A total of ten ALARTs were conducted under T. Aman and Boro seasons to develop rice varieties promising for rainfed lowland Rice (RLR), micronutrient enriched (MER), favourable Boro (FB), cold tolerant rice (CTR), premium quality rice (PQR) and high yielding rice-short and long duration (Biotech) against standard check varieties.

**T. Aman 2016**

**Rainfed lowland rice-1 (RLR-1).** BR8214-23-1-3-1 genotype gave the highest yield (4.5 t $ha^{-1}$) followed by BR8214-19-3-4-1(4.3 t $ha^{-1}$).

**Rainfed low land rice-2 (RLR-2).** The tested entry could not perform better than the check varieties.

**Rainfed low land rice-3 (RLR-3)**. BR-RS(Raj)-PL4-B gave the highest yield (4.8 t $ha^{-1}$) followed by check variety BR11 (4.7 t $ha^{-1}$).

**Micronutrient enriched rice (MER).** BR7895-4-3-3-2-3 gave the highest yield (4.8 t $ha^{-1}$) followed by check variety BRRI dhan49 (4.6 t $ha^{-1}$).

**Biotechnology.** BR(Bio)9786-BC2-132-1-3 gave the highest yield (5.4 t $ha^{-1}$) followed by check variety BRRI dhan49 (4.7 t $ha^{-1}$).

**Boro 2016-17**

**Biotechnology- long duration.** BR(Bio)9786-BC2-124-1-1genotype gave the highest yield (7.4 t $ha^{-1}$) followed by BRRI dhan28 (7.3 t $ha^{-1}$).

**Biotechnology- short duration.** BR(Bio)9787-BC2-63-2-4 genotype gave the highest yield (6.3 t $ha^{-1}$) followed by BR(Bio)9787-BC2-63-2-2 (6.2 t $ha^{-1}$).

**Cold tolerant rice (CTR).** BR7812-19-1-6-1-P2 genotype gave the highest yield (5.9 t $ha^{-1}$) followed by BRRI dhan28 (5.6 t $ha^{-1}$).

**Favourable Boro rice (FBR).** BRRI dhan29-SC3-8-HR1(Com) genotype gave the highest yield (7.6 t $ha^{-1}$) followed by BR8340-16-2-1 (7.5 t $ha^{-1}$).

**Premium quality rice (PQR).** BRRI dhan50 genotype gave the highest yield (5.8 t $ha^{-1}$) followed by BR7372-18-2-1-HR1-HR6(Com) (5.6 t $ha^{-1}$).

**Proposed variety trial (PVT)**

A total of five PVTs were conducted under T. Aman and Boro seasons to develop rice varieties promising for rainfed lowland rice (RLR), Re-evaluation of BRRI dhan72 in Rangpur region, Submergence and Water Stagnation tolerance rice, Favourable Boro Rice-FBR and micronutrient enriched rice (MER) against standard check varieties.

**Observational yield trial (OYT, T. Aus 2016, TRB)**

A total of 81 advanced lines were evaluated with five standard check varieties in T. Aus at BRRI RS, Rangpur. Plant height ranged from 98 to 126 cm. Maturity duration ranged from 101 to 111 days. Yield ranged from 1.065 to 5.815 t/ha. The highest yield was observed in BR9029-51-3-1 and lowest in ACC 133.

**Preliminary yield trial (PYT#1, 2, T. Aus 2016, TRB)**

A total of 14 entries with the check variety BRRI dhan48 in PYT#1 and 19 entries with the check variety BRRI dhan26 in PYT#2 were evaluated in this trial at BRRI RS, Rangpur.

**PYT#1.** Plant height ranged from 90 to 117.33 cm and maturity duration ranged from 101 to 108 days. The highest yield was found in BR9039-12-2-1 (5.51 t/ha) and lowest in BR9039-30-1-1 (3.63 t/ha).

**PYT#2.** The highest plant height was found in BR8784-4-1-2 (135cm) and lowest in BR9025-27-1-3 (99.33 cm) and maturity durations ranged from 101 to 105 days. Yield ranged from 3.58 t/ha to 5.20 (BR8776-17-4-2) t/ha.

**Observational yield trial (OYT#1, 2, 3, 4, breeding for submergence (SUB) and water stagnation (SFT) tolerance, T. Aman 2016, TRB)**

A total of 25 advanced lines with two checks in OYT#1, 70 advanced lines with four checks in OYT#2, ten advanced lines with two checks in OYT#3 and eight advanced lines with two checks in OYT#4 were evaluated in Augmented RCB design in two locations except OYT#4 at one location.

**OYT#1.** Totally 14 genotypes were selected producing grain yield ranging from 5.07 t/ha to 6.12 t/ha (BR9175-9-2-1-12-5). In comparison, the check varieties BRRI dhan51 and BRRI dhan52 produced 5.04 and 5.26 t/ha grain yield, respectively. The growth duration of the selected entries ranged from 135 to 140 days. The survival % recorded at Darshona was more than 80% in all the selected entries.

**OYT#2.** Totally 42 genotypes were selected producing grain yield ranging from 4.19 t/ha to 6.02 t/ha (IR13F450-3). In comparison, four check varieties produced 4.69-5.20 t/ha grain yield. The growth duration of the selected entries ranged from 145 to 148 days. The survival % recorded at Darshona was more than 80% in all the selected entries.

**OYT#3.** Totally four genotypes were selected with yield ranging from 4.78 to 5.78 t/ha (BR7934-10-1-1-1-2-2-5). In comparison, two check varieties produced 4.63-5.14 (t/ha) grain yield. The growth duration of the selected entries ranged from 136 to 141 days. The survival % recorded at Darshona ranged from 56-87% in all the selected entries.

**OYT#4.** Totally 3 genotypes were selected grain yield ranging from 4.47 to 4.93 (IR94391-131-358-19-B-1-1-1) (t/ha) and the growth duration of these entries ranged from132 to 140 days. The survival % recorded at Darshona ranged from 98-100% in all the selected entries.

**Preliminary yield trial (PYT# 1, 2, 3, breeding for submergence (SUB) and water stagnation (SFT) tolerance, T. Aman 2016, TRB)**

Twelve entries with two check varieties in PYT#1, 18 entries with two check varieties in PYT#2 and 13 entries with two check varieties in PYT#3 were evaluated following RCB design with three replications at two locations.

**PYT#1.** Totally three genotypes were selected producing grain yield ranging from 4.94 to 5.23 (t/ha) and growth duration ranging from 140-144 days. The highest grain yield was produced 5.23 t/ha by BR8157-50-1-6-2-1-27.

**PYT#2.** Totally ten genotypes were selected producing pooled grain yield ranging from 4.79 to 5.38 t/ha (IR 92471-SUB-SUB-39-3-B). The growth duration ranged from 133 to 143 days.

**PYT#3.** Totally 10 genotypes were selected producing grain yield ranging from 4.24-5.29 t/ha. The highest grain yield was produced by IR13F651 which was 5.29 t/ha. The growth duration of the selected entries ranged from 125-145 days.

**Observational yield trial (OYT, Drought tolerant rice, T. Aman 2016, TRB)**

One hundred forty-three genotypes along with three standard checks were evaluated in this trial. Augmented design was followed with seven blocks. Plant height ranged from 80 to 204 cm and growth duration ranged from 113 to 138 days. The highest yield 6.84 t/ha was produced by IR96321-1099-402-B-4-1-1 and lowest by IR94391-131-279-2-B-3-1-1 which was 1.81 t/ha where BRRI dhan71 yielded 4.75 t/ha.

**Observational yield trial (OYT, RLR, T. Aman 2016, TRB)**

A total of 93 genotypes along with five standards checks were evaluated in this trial. Augmented design was followed with 6 blocks. The highest plant height was observed in IR98790-7-1-1-1 (144 cm) and lowest in IR83140-B-36-B (96 cm).

Growth duration ranged from 102 to 142 days. Yield was lowest in IR90477-74-1-2-3-2-AJY 2 (2.41 t/ha) and highest in IR83140-B-11-B (6.0 t/ha).

**Preliminary yield trial (PYT#1, 2, RLR, T. Aman 2016, TRB)**

A total of 28 genotypes along with two standard checks were evaluated at PYT#1 and 39 genotypes in PYT#2 with two standard checks.

**PYT#1.** Plant height ranged from 118 to 139 cm, growth duration ranged from 122 to 130 days. Yield ranged from 3.31 t/ha to 4.35 t/ha (BR9124-11-2-3-3) where check variety BRRI dhan39 yielded 3.80 t/ha.

**PYT#2.** Shortest plant was found in BR9046-22-1-1-3 (119 cm) and longest in BR9043-12-3-2-4 (130 cm), growth duration ranged from 127 days to 130 days. Yield ranged from 3.73 t/ha to 4.21 t/ha (BR9123-23-2-2-5) where check variety BR11 yielded 4.09 t/ha.

**Observational yield trial (OYT, BLB, T. Aman 2016, TRB)**

A total of nine fixed lines for bacterial blight (BB) were grown as OYT along with two check varieties. Plant height ranged from 91 to 130.2 cm and growth duration ranged from 102 to 152 days. Yield was found lowest in BRRI dhan33 (1.53 t/ha) and highest in BR10388-24-3-3 (4.04 t/ha) where another check variety BR23 yielded 2.12 t/ha.

**Preliminary yield trials (PYT#1, 2, BLB, T. Aman 2016, TRB)**

A total of eight genotypes for PYT#1 and ten lines for PYT#2 were grown along with two check varieties.

**PYT#1.** Shortest plant was observed in BR8821-11-2-3-2 (88.4 cm) and longest in BR9632-7-2-3 (106.13 cm). Growth duration ranged from 117 to 128 days. Among the genotypes highest yielded genotypes was BR8821-10-2 (3.92) and lowest was BR8821-15-20-6-4 (2.71 t/ha).

**PYT#2.** Plant height ranged from 78.8 to 111 cm and growth duration ranged from 117 to 132.67 days. Genotype BR8826-4-23-4-29 yielded 3.17 t/ha which was higher than BRRI dhan65 (2.76 t/ha) and lowest yielded genotype was BR8821-5-22-5-1 (1.65 t/ha).

**Observational yield trial (OYT, BLB, Boro 2016-17, TRB)**

A total of 23 fixed lines with the BLB resistant check IRBB60 and IRBB65 and susceptible check BRRI dhan28 and BRRI dhan29 were evaluated in this trial. Plant height was ranged from 81.2 to 99.6 cm. Growth duration was ranged from 143 to 161 days. Yield under this trial was ranged from 4.95-7.93 t/ha (BR9650-22-1-2) where check variety BRRI dhan29 gives 6.42 t/ha.

**Preliminary yield trial (PYT#1, 2, BLB, Boro 2016-17, TRB)**

A total of six genotypes for each of PYT#1 and PYT#2 along with the BLB resistant check IRBB60 and the susceptible checks BRRI dhan28 and BRRI dhan29 were evaluated in this trial.

**PYT#1.** Plant height was ranged from 70.4 to 96.8 cm. Growth duration ranged from 138 to159 days. The highest yield was found in BR9647-30-2-1 (6.45 t/ha) followed by BR9647-8-1-5 (6.18 t/ha) where lowest in BR9649-9-1-3 (3.66 t/ha).

**PYT#2.** Plant height was ranged from 84 to 109 cm. Growth duration ranged from 106 to 160 days. The highest yielder genotype was BR9943-2-1 (7.63 t/ha) followed by BR8938-30-2-4-2-1 (7.40 t/ha) where check variety BRRI dhan29 yielded 5.04 t/ha.

**Development of cold tolerant rice**

**Observational yield trial (OYT, cold tolerant rice, Boro 2016-17, TRB).** A total of 200 cold tolerant rice genotypes were evaluated along with standard check BRRI dhan28, BRRI dhan29, BRRI dhan58 and BRRI dhan36. Plant height was ranged from 76.6 to 137.4 cm. Growth duration ranged from 144 to 172 days. The highest yield was found in BR8244-8-2-2-2-1-CS1-3-CS2-5-9-1 (8.33 t/ha) and while the lowest in BR8565-3-1-3-3-CS1-4-CS2-1-6-1 (2.27 t/ha).

**Preliminary yield trial (PYT, cold tolerant rice, Boro 2016-17, TRB)**

A total of eight cold tolerant genotypes along with four standard check varieties viz. BRR dhan28, BRRI dhan29, BRRI dhna58 and BRRI dhan60 were evaluated in this trial. Plant height was highest in BR9989-26-1-1 (97 cm) and lowest in BR8562-11-2-6-1-1-2 (70 cm). Growth duration ranged from 146 to 164 days. The highest yield was observed in BRRI dhan29 (6.65 t/ha) followed by BR8562-11-2-6-2-5-2 (6.47 t/ha) where lowest in BR8562-11-2-6-1-1-2 (4.02 t/ha).

## CROP-SOIL-WATER MANAGEMENT

**Effect of nutrient management after de-submergence and application pattern on newly developed *Sub1* genotypes**

Two *Sub1* genotypes along with one tolerant check and one susceptible check variety were evaluated in the control submergence tank (submerged for 16 days) at BRRI-Rangpur. Fertilizer treatments ($T_1$= Modified dose (100 kg ha$^{-1}$ urea + 23 kg ha$^{-1}$ MoP), $T_2$= Modified dose + 75 kg ha$^{-1}$ urea + 60 kg ha$^{-1}$ MoP and $T_3$= Modified dose + 60 kg ha$^{-1}$ MoP) were used in main plot and genotypes ($V_1$= BR9159-8-5-40-13-52 (BRRI dhan49-Sub1), $V_2$= BR9159-8-5-40-14-57 (BRRI dhan49-Sub1), $V_3$= BRRI dhan52 (Res. ck) and $V_4$= BRRI dhan49 (Sus. ck) were used in sub plot.

Nutrient after de-submergence, significantly influenced survival. The highest survival (87.6%) was found in $T_2V_2$ combination while the lowest (69.3%) in $T_1V_3$. The interaction effect of nutrient and genotypes on grain yield was significant. The highest grain yield (6.41tha$^{-1}$) was found in $T_2V_3$ and the lowest (4.78 tha$^{-1}$) in $T_1V_1$. The result indicated that all the genotypes showed the best performance of all parameters for $T_2$ treatment.

**Effect of time of submergence on survival, recovery and yield of submergence tolerance genotypes**

The trial was conducted in the submergence tank at BRRI RS, Rangpur in T. Aman 2016. Submergence tolerant high yielding variety BRRI dhan52 was evaluated in this trial. Treatments were for time of submergence at $T_1$ = 0 Days after transplanting (DAT), $T_2$ = 5 DAT, $T_3$ = 10 DAT, $T_4$ = 15 DAT and $T_5$ = 20 DAT. Time of submergence significantly influenced on survival. The highest survival (82.6%) was found in $T_5$ (20 days later submergence) while the lowest (18.1%) was found in $T_1$ (just transplanting day). $T_5$ (20 DAT) also showed the highest yield (4.70 tha$^{-1}$) among the treatments. Survivability of submergence tolerant rice increased if submergence occurred in few days later after transplanting.

**Performance evaluation of swarna varieties under different fertilizer combination**

Three swarna varieties along with two standard check varieties were evaluated under different fertilizer doses at BRRI-Rangpur. Varieties ($V_1$=Gooty Swarna, $V_2$=Lal Gooty Swarna, $V_3$=Swarna-5, $V_4$=BR11 and $V_5$=BRRI dhan52) were used in main plot and fertilizer treatments ($T_1$: Research practice: Urea-TSP-MP-Gyp-Zn @ 180-70-90-70-10 kg/ha and $T_2$: Fermers practice: Urea-TSP-MP @ 220-60-70 kg/ha) were used in sub plot. Higher yield was found in $T_1$ (5.42 t/ha) than $T_2$ (5.27 t/ha) at treatment effect. Among the varieties, $V_2$ gave the highest yield (5.68 t/ha) followed by $V_3$ (5.41 t/ha) and the lowest in $V_5$ (5.02 t/ha). It was observed that Swarna varieties had lower sterility percentage than check varieties.

## RICE FARMING SYSTEMS

**Evaluation of BRRI dhan48 as early Aus rice in Potato-Boro-T. Aman cropping system in medium highland irrigated ecosystem**

The experiment was conducted in T. Aman 2016 in the BRRI RS farm to find out the suitability of BRRI dhan48 harvest as early Aus and to find out the appropriate seedling age of rice after potato harvest in Potato-Boro-T. Aman cropping system in medium highland irrigated ecosystem. The treatments were, Factor A: Transplanting date ($T_1$= 20 February, $T_2$= 02 March and $T_3$= 12 March), Factor B: Variety and Factor C: Seedling age ($V_1S_1$=BRRI dhan28 with 40-day and $V_1S_2$= BRRI dhan28 with 30-day-old seedling ,$V_2S_1$= BRRI dhan48 with 30 days and $V_2S_2$= BRRI dhan48 with 20-day-old seedling). The results showed that plant height, panicle $m^{-2}$, panicle length, grains panicle$^{-1}$,1000 grains weight and grain yield varied significantly due to the interaction effect of variety and variable planting with different seedling age. The highest grain yield (5.56 t $ha^{-1}$) was recorded from $T_1V_1S_1$ and the lowest in $T_3V_1S_1$ (4.60 t $ha^{-1}$). BRRI dhan28 with 40-day or 30-day-old seedling gave higher yield at 20 February planting but produced statistically similar yield up to 2 March planting. BRRI dhan48 with 30-day or 20-day-old seedling gave statistically similar yield from 2 March to 12 March planting.

TECHNOLOGY TRANSFER

**Seed production and dissemination in 2016-17**

A total of 1147 kg TLS and 1200 kg of BRRI dhan48 was produced in T. Aus season in BRRI RS, Rangpur RS. A total of 4,530 kg TLS (BR11, BR22, BRRI dhan34, BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan75 and 1600 kg (BRRI dhan66, BRRI dhan71) Breeder seed were produced during T. Aman and 2,162 kg (BR16, BRRI dhan28, BRRI dhan29, BRRI dhan50, BRRI dhan55, BRRI dhan58, BRRI dhan63, BRRI dhan74) TLS and 6,454 kg (BRRI dhan50, BRRI dhan58) Breeder seed was produced during Boro season.

# BRRI RS, Satkhira

SUMMARY

A total of 710 and 864 progenies were selected from 113 and 98 crossing populations from $F_2$ to $F_7$ in Aman and Boro season, respectively. Fifteen and 49 lines were selected from 30 and 49 entries in OT against salinity in Aman season. On the other hand, 13 and 16 genotypes were selected from 56 entries in Assasuni and Koyra, respectively during Boro 2016-17 based on their saline tolerance ability and yield. BR9534-15-23-17 and IR77674-3B-8-1-3-10-3-AJY2 performed better from 12 entries and four check varieties in all the three locations of Assasuni, Koyra and Kaliganj in PYT during Aman 2016. IR89330-14-3-1-2-2-3 yielded higher than the three checks and 12 tested entries in PYT2 during Boro 2016-17 at Koyra. BR8747-B-3-3-5, BR8727-B-2-1-1, IR89609-8-2-B and BR8743-B-1-2-2 showed good yielder among the eight lines and four check varieties in SYT during Aman 2016 at Assasuni, Koyra and Kaliganj. BR8980-4-6-5 yielded (6.48 t $ha^{-1}$) higher than all of the three checks and 13 entries in SYT at Assasuni during Boro 2016-17. From RYT in Aman season; BR(Bio)8019-AC5-1-2-1 and BR(Bio)8032-AC4-1-2-2 yielded higher against the check variety BRRI for favourable T. Aman. IR11F190, BR8189-10-2-3-1-5, BR8189-10-2-3-1-6, BR8208-5-3-16, BR8208-5-3-19, BR8492-9-5-3-2 and BR8492-9-5-2-3 could be promising genotypes for rainfed lowland rice. BR8850-20-3-5-1, BR8493-16-5-1 (Com), BR8522-53-1-3, BR8522-16-5-3-1-HR2 (Com), BR8297-1-1-2- HR1 (Com), BR9051-33-1-2-5, BR8512-3-1-1, BR8514-17-1-5 and BR8512-9-1-6 were better yielder compared to the checks and could be promising lines for premium quality rice. BR8626-19-5-1-2, BR8626-10-5-1 and BR8109-29-2-2-3 yielded better than the checks (BRRI dhan28 and BRRI dhan68) in RYT for FBR with more or less similar growth duration. IR58443-6B-10-3, BR8940-B-17-4-7 and BR8982-5 exceeds the yield of all the checks (BRRI dha28, BRRI dhan67, Binadhan-10 at Assasuni in AYT during Boro 2016-17. Among the nine entries; IR8768-2-AJY1-B, IR78761-B-SATB1-52-1, BRRI dhan54 and IR78761-B-SATB1-68-6 ranked first whereas IR78761-B-SATB1-52-1, BR8715-10-7-23, BR8715-10-7-23 and BRRI dhan73 ranked second in PVS at Chiledanga (Assasuni), Kushudanga (Koyra), Kulia (Debhata) and Tarali (Kaliganj), respectively in Aman 2016. Sat-1 and BRRI dhan67 were chosen as 1st and 2nd in two locations, whereas IR 87870-6-1-1-1-1-B and Binadhan-10 were chosen as 1st and 2nd, respectively in one location in PVS during Boro 2016-17. In PVT for FBR, the tested line BR7358-5-3-2-1-HR2 yielded better than the check of BRRI dhan28 in both the locations and this line has already been suggested as a new upcoming variety of BRRI dhan81. The proposed line has BR7831-59-1-1-4-5-1-9-P1 for MER, BR(Bio)8072-AC5-4-2-1-2-1 and BR(Bio)8072-AC8-1-1-3-1-1 for SD yielded better than the check of BRRI dhan28 in PVT during Boro 2016-17. Based on the result of missing element trial, balanced fertilizer application is needed for higher yield in saline and non-saline *gher* where N is the most critical nutrient element. BRRI dhan33 and BRRI dhan75 produced significantly higher yield in stability analysis in Aman 2016 where BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan5, BRRI dhan58, BRRI dhan59, BR16 and BRRI dhan69 gave higher yield in Boro 2015-17. A total of 25 tons of breeder seed and 10 tons of TLS was produced during the reporting period. In total of 195 SPDP of different varieties, eight field days and 15 farmer's training programmes were conducted during the reporting year.

## VARIETY DEVELOPMENT

**Selection from pedigree nursery ($F_2$-$F_7$)**

In Aman season, 710 progenies were selected from 113 crossing populations where 260, 219, 144, 16, 67 and 4 progenies/lines were selected from 18$F_2$, 19$F_3$, 23$F_4$, 12$F_5$, 39$F_6$ and 2$F_7$ crosses, respectively. On the other hand, 374, 191, 211, 25 and 63 progenies/lines were selected from 21$F_2$, 25$F_3$, 30$F_4$, 7$F_5$ and 25$F_6$ crosses, respectively during Boro 2016-17.

**Observational trial (OT)**

Fifteen lines were selected from 30 genotypes in saline area of Assasuni, Satkhira during Aman 2016. From 49 STBN entries, 19 genotypes were selected in Aman season where 13 were selected at Koyra and 16 at Assasuni in Boro season. Thirteen and eight genotypes were selected from 56 entries in Assasuni and Koyra, respectively during Boro 2016-17 based on their saline tolerance ability and yield.

**Preliminary yield trial (PYT)**

Twelve salinity tolerant lines were evaluated against BR11, BRRI dhan54, BRRI dhan67 and BRRI dhan73 at Assasuni and Kaliganj of Satkhira and Koyra of Khulna district (Table 1). Overall, BR9534-15-23-17 and IR77674-3B-8-1-3-10-3-AJY2 performed better in all the three locations. In Assasuni, BR8729-B-7-3-2, BR9072-B-4-2-5, BR9079-B-3-1-3 and BR9072-B-4-1-1 yielded better than the checks but no line out yielded the checks in Koyra and Kaliganj.

Two PYTs were conducted at Assasuni and Koyra compared with BRRI dhan28, BRRI dhan67 and Binadhan-10 during Boro 2016-17. In PYT1, twelve lines were evaluated and no entry could beat the yield over the checks. Among ten lines in PYT 2, IR89330-14-3-1-2-2-3 yielded (6.54 t $ha^{-1}$) higher than the checks in Koyra and no entry yielded higher than the checks in Assasuni (Tables 2 and 3).

**Secondary yield trial (SYT)**

Eight lines were evaluated in SYT comparing with BR11, BRRI dhan54, BRRI dhan67 and BRRI dhan73 during Aman 2016. Among the tested entries BR8747-B-3-3-5, BR8727-B-2-1-1, IR89609-8-2-B and BR8743-B-1-2-2 gave higher yield in two or more locations where BRRI dhan73 (check) yielded more than 5.0 t $ha^{-1}$ in all the three locations (Table 4).

**Table 1. Performance of PYT entries during Aman 2016.**

| Entry/variety | Growth duration (day) | | | Yield (t $ha^{-1}$) | | |
|---|---|---|---|---|---|---|
| | Assasuni | Kaliganj | Koyra | Assasuni | Kaliganj | Koyra |
| IR77674-3B-8-1-3-10-3-AJY2 | 119 | 121 | 121 | 5.55 | 4.12 | 4.72 |
| BR8729-B-7-3-2 | 125 | 121 | 128 | 6.32 | 2.83 | 5.48 |
| BR9779-1-1 | 114 | 115 | 119 | 5.35 | 3.92 | 5.14 |
| BR9538-3-1-2 | 121 | 118 | 122 | 5.44 | 3.65 | 5.18 |
| BR9534-15-23-17 | 119 | 120 | 125 | 5.33 | 4.26 | 5.64 |
| BR9072-B-4-1-1 | 124 | 121 | 126 | 5.84 | 1.42 | 5.29 |
| BR9072-B-4-1-3 | 124 | * | 129 | 5.25 | * | 5.75 |
| BR9072-B-4-2-5 | 124 | * | 129 | 5.97 | * | 5.42 |
| BR9073-B-1-3-3 | 121 | 123 | 121 | 5.08 | 1.90 | 5.40 |
| BR9079-B-3-1-3 | 119 | 121 | 125 | 5.88 | 1.55 | 5.38 |
| BR9080-B-10-8-8 | 123 | 123 | 126 | 5.43 | 3.48 | 5.16 |
| BR9080-B-10-8-9 | 114 | 113 | 119 | 5.46 | 3.69 | 4.96 |
| BRRI dhan54 (ck) | 131 | 130 | 133 | 4.92 | 4.42 | 4.65 |
| BRRI dhan73 (ck) | 124 | 125 | 126 | 5.52 | 4.98 | 6.05 |
| BR11 (S. ck) | 138 | 141 | 139 | 5.11 | 4.71 | 5.57 |
| BRRI dhan67 (ck) | 135 | 140 | 139 | 4.85 | 4.06 | 4.59 |
| $LSD_{(0.05)}$ | 0.37 | 0.72 | 2.69 | 0.58 | 1.32 | 0.75 |

*Damaged due to lodging.

**Table 2. Performance of different entries of PYT1 during Boro 2016-17.**

| Entry/Variety | Growth duration (day) | | Yield (t $ha^{-1}$) | |
|---|---|---|---|---|
| | Assasuni | Koyra | Assasuni | Koyra |
| BR9154-2-7-1-2 | 150 | 150 | 4.83 | 5.97 |
| BR9156-4-3-2-22 | 146 | 150 | 4.89 | 4.81 |
| BR8964-3-2-3-12 | 145 | 150 | 4.19 | 4.87 |
| BR8967-2-1-3-6 | 142 | 144 | 4.89 | 3.61 |
| BR9144-4-3-2-17 | 143 | 145 | 4.83 | 5.26 |
| BR9144-2-3-1-18 | 144 | 147 | 4.93 | 5.98 |
| BR9145-5-2-7 | 140 | 143 | 4.51 | 3.68 |
| BR9152-B-2-3-1 | * | 151 | * | 4.53 |
| BR9152-1-3-1-8 | * | 144 | * | 4.91 |
| BR9154-3-2-4-7** | | | | |
| BR9156-4-1-7-9 | 140 | 156 | 4.91 | 4.43 |

**Table 2. Continued.**

| Entry/Variety | Growth duration (day) | | Yield (t ha$^{-1}$) | |
|---|---|---|---|---|
| | Assasuni | Koyra | Assasuni | Koyra |
| BR9156-5-3-4-15 | 149 | 152 | 5.01 | 4.11 |
| BRRI dhan28 (S. ck) | 138 | 143 | 3.36 | 3.11 |
| BRRI dhan67 (ck) | 143 | 147 | 4.76 | 5.54 |
| Binadhan-10 (ck) | 143 | 149 | 5.31 | 6.52 |

*Damaged by blast attack. **Germination failed

**Table 3. Performance of PYT2 entries in Boro 2016-17.**

| Entry/Variety | Growth duration (day) | | Yield (t ha$^{-1}$) | |
|---|---|---|---|---|
| | Assasuni | Koyra | Assasuni | Koyra |
| IR89330-14-3-1-2-2-3 | 147 | 149 | 4.36 | 6.54 |
| IR89331-32-3-1-3-2-2 | 140 | 143 | 4.43 | 4.99 |
| IR91715-8-1-1-1 | 140 | 142 | 4.95 | 4.56 |
| IR91715-8-1-1-AJY1 | 138 | 141 | 4.90 | 4.81 |
| IR91820-25-BAY2-3 | 142 | 144 | 4.44 | 4.08 |
| IR92860-33-CMU1-1-CMU2-AJYB | 143 | 146 | 3.94 | 5.22 |
| IR93915-82-CMU2-2-CMU3-AJYB | 140 | 142 | 4.86 | 5.86 |
| IR12T198 | 140 | 143 | 4.11 | 4.47 |
| IR12T136 | 140 | 143 | 3.72 | 4.31 |
| IR11T182 | 145<br>148 | 5.09 | | 5.09 |
| IR11T219 | 142 | 145 | 5.12 | 4.56 |
| IR11T220 | 145 | 149 | 4.65 | 4.03 |
| BRRI dhan28 (S. ck) | 140 | 143 | 4.74 | 4.08 |
| BRRI dhan67 (ck) | 140 | 145 | 5.07 | 5.84 |
| Binadhan-10 (ck) | 143 | 149 | 5.54 | 6.27 |

**Table 4. Performance of SYT entries in Aman 2016.**

| Entry/Variety | Growth duration (day) | | | Yield (t ha$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | Assasuni | Kaliganj | Koyra | Assasuni | Kaliganj | Koyra |
| BR8718-B-2-2-1 | 122 | 125 | 126 | 4.75 | 3.98 | 4.89 |
| BR8727-B-2-1-1 | 121 | 122 | 129 | 4.72 | 4.16 | 5.80 |
| BR8743-B-1-2-2 | 116 | 115 | 121 | 5.46 | 1.66 | 5.52 |
| BR8747-B-3-3-5 | 122 | 125 | 128 | 4.95 | 4.96 | 5.89 |
| IR11T174 | 122 | 125 | 122 | 5.33 | 4.35 | 4.46 |
| IR12T246 | 131 | 128 | 133 | 5.33 | 3.44 | 5.12 |
| IR89609-8-2-B | 122 | 125 | 126 | 5.59 | 3.79 | 5.20 |
| IR58443-6B-10-3 | 119 | * | 120 | 5.33 | * | 5.71 |
| BRRI dhan54 (R. ck) | 129 | 131 | 131 | 4.77 | 4.35 | 4.76 |
| BRRI dhan73 (R. ck) | 122 | 125 | 126 | 5.09 | 5.39 | 5.33 |
| BR11 (S. ck) | 139 | 139 | 139 | 4.87 | 4.81 | 5.24 |
| BRRI dhan67 (R. ck) | 137 | 140 | 140 | 4.84 | 4.14 | 4.86 |
| $LSD_{(0.05)}$ | 1.04 | 0.47 | 1.53 | 0.59 | 1.66 | 0.55 |

*Germination failed.

Thirteen entries were evaluated in SYT against BRRI dhan28, BRRI dhan67 and Binadhan-10 at Assasuni and Koyra during Boro 2015-16. BR8980-4-6-5 yielded (6.48 t ha$^{-1}$) higher than all checks in Assasuni but in Koyra no entry yielded better than the checks (Table 5).

**Regional yield trial (RYT)**

Twelve RYTs comprises of one for favourable Aman, seven for rainfed lowland rice (RLR), three for premium quality rice (PQR) and one for micronutrient enriched rice (MER) were conducted at BRRI RS, Satkhira during T. Aman 2016 (Table 6). BR(Bio)8019-AC5-1-2-1 (4.90 t ha$^{-1}$) yielded the highest followed by BR(Bio)8032-AC4-1-2-2 (4.35 t ha$^{-1}$) and both the entries yielded more than 4.0 ton, which could be selected for next varietal development programme. IR11F190, BR8189-10-2-3-1-5, BR8189-10-2-3-1-6, BR8208-5-3-16, BR8208-5-3-19, BR8492-9-5-3-2 and BR8492-9-5-2-3 could be promising genotypes for rainfed lowland rice. BR8850-20-3-5-1, BR8493-16-5-1 (Com), BR8522-53-1-3, BR8522-16-5-3-1-HR2 (Com), BR8297-1-1-2- HR1 (Com), BR9051-33-1-2-5, BR8512-3-1-1, BR8514-17-1-5 and BR8512-9-1-6 were higher yielder that the checks and could be promising lines for premium quality rice. No line could exceed the yield of checks in RYT for MER.

Eight RYTs consisting of one for short duration (SD), one for bacterial blight resistant (long duration), one for favourable Boro rice (FBR), two for micronutrient enriched rice (MER), two for premium quality rice (PQR) and one for disease resistant rice (DR) were conducted with respective check varieties at BRRI RS, Satkhira farm during Boro 2016-17 following RCB design with three replications. All cultural practices were done as per recommendation. Table 7 presents the results. Three entries showed very similar yield compared to BRRI dhan28 whereas one entry was low yielder in RYT-SD. In RYT-LD, all the entries yielded (7.10 - 7.58 t ha$^{-1}$) significantly higher than BRRI dhan28 (6.07 t ha$^{-1}$). Three entries yielded better than the checks in RYT for FBR with more or less similar growth duration. No entry could yield better than the checks in both the RYTs for MER and RYTs for PQR. All the three tested entries yielded very similar compared to BRRI dhan63 but higher than BRRI dhan50 in RYT for DR.

**Table 5. Performance of SYT entries in Boro 2016-17.**

| Entry/Variety | Growth duration (day) | | Yield (t ha$^{-1}$) | |
|---|---|---|---|---|
| | Assasuni | Koyra | Assasuni | Koyra |
| IR 87870-6-1-1-1-1-B | 149 | 150 | 4.62 | 3.62 |
| IR 87872-7-1-1-2-1-B | 146 | 147 | 5.24 | 5.59 |
| IR58443-6B-10-3 | 152 | 153 | 4.22 | 4.08 |
| IR12T254 | | | * | |
| IR12T133 | 146 | 147 | 4.12 | 2.95 |
| BR8980-4-6-5 | 141 | 144 | 6.48 | 4.87 |
| BR8981-1-6-3-14 | 150 | 151 | 4.33 | 3.81 |
| BR8987-2-4-6 | 149 | 151 | 5.39 | 1.99 |
| BR8992-3-4-10 | 145 | 148 | 5.70 | 4.67 |
| BR8980-B-1-1-1 | 142 | 146 | 5.49 | 5.19 |
| BR8980-B-1-3-5 | 142 | 146 | 5.38 | 5.22 |
| BR8992-B-18-2-26 | 140 | 145 | 5.38 | 5.19 |
| BR8980-3-4-1-3 | 140 | * | 5.18 | * |
| BRRI dhan28 (S. ck) | 140 | 146 | 4.73 | 4.36 |
| BRRI dhan67 (ck) | 143 | 148 | 5.76 | 4.69 |
| Binadhan-10 (ck) | 145 | 148 | 5.88 | 5.75 |

*Germination failed

**Table 6. Performance of different entries under RYT during Aman 2016, BRRI RS, Satkhira.**

| Designation | Plant height (cm) | Growth duration (day) | Yield (t $ha^{-1}$) |
|---|---|---|---|
| | *RYT (Biotechnology)* | | |
| BR(Bio)8019-AC4-1-1-3 | 101 | 129 | 3.48 |
| BR(Bio)8019-AC5-1-2-1 | 107 | 135 | 4.90 |
| BR(Bio)8019-AC8-1-2-2 | 99 | 130 | 4.00 |
| BR(Bio)8019-AC9-3-3-1 | 101 | 129 | 4.00 |
| BR(Bio)8032-AC3-4-1-3 | 106 | 130 | 3.97 |
| BR(Bio)8032-AC4-1-2-2 | 102 | 133 | 4.35 |
| BRRI dhan39 (ck) | 106 | 134 | 3.33 |
| $LSD_{0.05}$ | 2.57 | 1.36 | 0.85 |
| | *RYT-1 for RLR* | | |
| BR7358-56-2-2-1-HR7 (COM) | 104 | 131 | 5.35 |
| Nizersail (ck) | 133 | 139 | 3.75 |
| BR22 (ck) | 119 | 141 | 5.44 |
| BRRI dhan54 (ck) | 111 | 130 | 5.37 |
| $LSD_{0.05}$ | 2.59 | 2.13 | 0.68 |
| | *RYT-2 for RLR* | | |
| BR8204-5-3-2-5-2 | 111 | 129 | 3.75 |
| BR8192-10-1-2-3-4 | 111 | 126 | 3.76 |
| IR08L181 | 109 | 122 | 4.72 |
| BRRI dhan39 (ck) | 106 | 129 | 4.45 |
| BR8490-5-1-4-4 | 100 | 133 | 4.66 |
| IR11F190 | 128 | 130 | 5.91 |
| BR8526-9-2-3-5 | | Damaged by rat | |
| BRRI dhan32 (ck) | 121 | 135 | 4.64 |
| $LSD_{0.05}$ | 5.27 | 1.8 | 0.81 |
| | *RYT-3 for RLR* | | |
| BR8189-10-2-3-1-5 | 115 | 131 | 6.24 |
| BR8189-10-2-3-1-6 | 116 | 129 | 5.88 |
| BR8208-5-3-19 | 128 | 138 | 5.65 |
| BR8208-5-3-16 | 134 | 135 | 5.77 |
| BR8526-1-2-3 | Damaged by rat | | |
| BR8226-13-1-2 | 101 | 132 | 4.96 |
| BR11 (ck) | 120 | 142 | 5.13 |
| $LSD_{0.05}$ | 3.41 | 1.03 | 0.98 |
| | *RYT-4 for RLR* | | |
| IR11L465 | | Damaged by rat | |
| IR88886-7-2-1-4 | | Damaged by rat | |
| BRRI dhan66 (ck) | | Damaged by rat | |
| BR8521-30-3-1 | 122 | 134 | 6.84 |
| BR8526-38-2-1 | 107 | 133 | 6.55 |
| BRRI dhan49 (ck) | 101 | 135 | 6.61 |
| $LSD_{0.05}$ | 5.87 | 2.45 | 1.28 |
| | *RYT-5 for RLR* | | |
| BR8493-4-2-1-1 | 120 | 140 | 4.19 |
| BR8829-14-7-1 | 94 | 140 | 4.73 |
| BR8492-9-5-3-1 | 113 | 139 | 5.95 |
| BR8492-9-5-2-3 | 117 | 141 | 6.21 |
| BR8492-9-5-3-2 | 119 | 139 | 6.51 |
| BRRI dhan49 | 100 | 140 | 5.90 |
| Swarna (ck) | 120 | 140 | 4.19 |
| $LSD_{0.05}$ | 6.56 | 1.61 | 1.24 |
| | *RYT-6 for RLR* | | |
| Suman Swarna (Rajshahi) | 117 | 139 | 5.80 |
| Ranjit Swarna (Rajshahi) | 118 | 140 | 6.13 |
| Nepali Swarna (Rangpur) | 115 | 138 | 6.09 |
| Swarna-5 (Rangpur) | 119 | 141 | 5.87 |
| Guti Swarna | 115 | 140 | 6.14 |

**Table 6. Continued.**

| Designation | Plant height (cm) | Growth duration (day) | Yield (t $ha^{-1}$) |
|---|---|---|---|
| BR11 (ck) | 116 | 144 | 6.60 |
| BRRI dhan49 (ck) | 99 | 137 | 5.53 |
| LSD | 4.79 | 2.05 | 0.58 |
| | *RYT-7 for RLR* | | |
| BR9392-6-2-1B | 124 | 142 | 6.06 |
| BR10247-14-18 | 124 | 142 | 6.20 |
| BR10238-5-1 | 122 | 141 | 5.76 |
| IR12N177 | 109 | 132 | 5.75 |
| IR05N412 | 102 | 130 | 5.38 |
| BRRI dhan49 (ck) | 102 | 140 | 6.79 |
| $LSD_{0.05}$ | 6.56 | 1.93 | 0.72 |
| | *RYT-1 for PQR* | | |
| BR8493 -12-7-4 (Com) | 118 | 138 | 3.48 |
| BR8515-28-1-1-3-HR3 (Com) | 131 | 139 | 3.10 |
| BR8493-16-5-1 (Com) | 131 | 133 | 4.00 |
| BR8850-10-8-3-3 | 104 | 128 | 2.95 |
| BR8850-20-3-5-1 | 125 | 134 | 4.42 |
| BR8515-23-6-3 | 124 | 138 | 3.52 |
| BRRI dhan34 (ck) | 122 | 135 | 3.88 |
| Binadhan-13 (ck) | 134 | 137 | 3.21 |
| Kalizira (Local ck) | 138 | 137 | 1.69 |
| Tulsimala (Local ck) | 150 | 138 | 1.94 |
| $LSD_{0.05}$ | 5.14 | 1.49 | 0.52 |
| | *RYT-2 for PQR* | | |
| BR8535-2-1-2 | 108 | 131 | 3.13 |
| BR8522-53-1-3 | 119 | 134 | 5.19 |
| BR8522-16-5-3-1-HR2 (Com) | 128 | 139 | 5.16 |
| BR8536-27-2-1-1 | 107 | 133 | 3.38 |
| BR8536-27-4-3-6 | 107 | 132 | 3.99 |
| BR8536-6-2-1-1 | 103 | 135 | 4.48 |
| BR8536-27-2-1-2 | 111 | 136 | 4.76 |
| BR8536-27-4-3-5 | 110 | 134 | 4.04 |
| BR8526- 2-1-1-4 (Com) | 127 | 136 | 4.97 |
| BR8297-1-1-2- HR1 (Com) | 113 | 137 | 5.50 |
| BRRI dhan34 (ck) | 128 | 135 | 3.27 |
| $LSD_{0.05}$ | 3.91 | 0.49 | 0.35 |
| | *RYT-3 for PQR* | | |
| BR8512-9-1-6 | 118 | 139 | 5.22 |
| BR8234-1-3-7-1-3-HR21(Com) | 126 | 138 | 4.57 |
| BR9051-33-1-2-5 | 114 | 139 | 5.60 |
| BR8846-108-2-1-1 | 118 | 132 | 3.46 |
| BR8514-17-1-5 | 114 | 134 | 5.23 |
| BR8512-3-1-1 | 118 | 142 | 5.24 |
| BRRI dhan38 (ck) | 128 | 143 | 2.77 |
| BRRI dhan70 (ck) | 132 | 135 | 5.04 |
| Kataribhog (ck) | 135 | 132 | 1.66 |
| $LSD_{0.05}$ | 3.19 | 1.12 | 0.51 |
| | *MER* | | |
| BR7528-2R-HR16-2-24-1 | 110 | 124 | 5.40 |
| BR8410-16-4-17-9-1 | 109 | 134 | 5.28 |
| BR8442-9-5-2-3-B1 | 124 | 141 | 4.53 |
| BR7528-2R-HR16-3-98-1 | 111 | 128 | 4.88 |
| BRRI dhan39 (ck) | 123 | 136 | 5.46 |
| BRRI dhan32 (ck) | 120 | 129 | 5.86 |
| $LSD_{0.05}$ | 3.33 | 2.07 | 0.54 |

**Table 7. Performances of RYT entries in Boro 2016-17, BRRI RS, Satkhira.**

| Designation | Plant height (cm) | Growth duration (day) | Yield (t $ha^{-1}$) |
|---|---|---|---|
| | *RYT-SD* | | |
| BR(Bio)9785-BC2-6-2-2 | 90 | 136 | 6.04 |
| BR(Bio)9785-BC2-19-3-1 | 89 | 136 | 6.24 |
| BR(Bio)9785-BC2-20-1-3 | 91 | 135 | 6.47 |
| BR(Bio)9785-BC2-19-3-5 | 84 | 134 | 5.76 |
| BRRI dhan28 (ck) | 87 | 135 | 6.19 |
| $LSD_{0.05}$ | 4.56 | 1.39 | 0.55 |
| | *RYT-bacterial blight resistant (LD)* | | |
| BR(Bio)8333-BC5-1-1 | 102 | 148 | 7.10 |
| BR(Bio)8333-BC5-1-20 | 104 | 146 | 7.50 |
| BR(Bio)8333-BC5-2-16 | 102 | 145 | 7.58 |
| BR(Bio)8333-BC5-2-22 | 106 | 148 | 7.48 |
| BR(Bio)8333-BC5-3-10 | 111 | 148 | 7.45 |
| BRRI dhan28 (ck) | 88 | 136 | 6.07 |
| $LSD_{0.05}$ | 5.26 | 1.22 | 0.47 |
| | *RYT for FBR* | | |
| BR7671-37-2-2-37-3-P3 | 103 | 140 | 5.41 |
| BR8626-19-5-1-2 | 99 | 139 | 7.10 |
| BR8626-10-5-1 | 89 | 141 | 7.06 |
| BR8109-29-2-2-3 | 105 | 140 | 7.18 |
| BRRI dhan28 (ck) | 102 | 136 | 5.83 |
| BRRI dhan58 (ck) | 102 | 141 | 6.66 |
| $LSD_{0.05}$ | 3.30 | 1.13 | 0.49 |
| | *RYT-1 for MER* | | |
| BR8631-12-3-5-P2 | 112 | 138 | 6.01 |
| BR8631-12-3-6-P3 | 103 | 138 | 5.99 |
| BR7831-59-1-1-4-5 | 99 | 138 | 5.44 |
| BR8253-9-3-3-1 | 103 | 142 | 5.65 |
| BR8609-2-B-9-1-B5 | 95 | 142 | 6.45 |
| BR7815-18-1-3-2-1 | 123 | 140 | 6.46 |
| BRRI dhan28 (ck) | 95 | 139 | 5.38 |
| BRRI dhan74 (ck) | 95 | 141 | 6.63 |
| $LSD_{0.05}$ | 4.87 | 1.05 | 0.40 |
| | *RYT-2 for MER* | | |
| BR7671-37-2-2-3-7-3-P10 | 102 | 146 | 4.77 |
| BR7671-37-2-2-3-7-3-P11 | 101 | 145 | 5.00 |
| BRRI dhan28 (ck) | 95 | 138 | 5.58 |
| BRRI dhan58 (ck) | 103 | 140 | 6.18 |
| $LSD_{0.05}$ | 3.19 | 1.20 | 0.44 |
| | *RYT-1 for PQR* | | |
| BR8079-19-1-5-1 | 87 | 141 | 5.44 |
| BR8590-5-2-5-2-2 | 105 | 140 | 5.67 |
| BR8590-5-3-3-4-2 | 100 | 138 | 6.12 |
| BR8608-39-2-1 | 107 | 141 | 4.95 |
| BRRI dhan50 (ck) | 83 | 144 | 5.67 |
| BRRI dhan63 (ck) | 82 | 144 | 6.48 |
| $LSD_{0.05}$ | 2.17 | 1.13 | 0.41 |
| | *RYT-2 for PQR* | | |
| BRC266-5-1-1-1 | 105 | 138 | 6.50 |
| BRC266-5-1-2-1 | 96 | 139 | 6.40 |
| BR8523-36-2-2-6 | 116 | 132 | 5.19 |
| BR16 (ck) | 92 | 143 | 6.56 |
| $LSD_{0.05}$ | 4.80 | 1.48 | 0.58 |
| | *RYT-DR* | | |
| BR8079-52-2-2-2 | 113 | 136 | 6.26 |
| BR8076-1-2-2-3 | 114 | 142 | 6.24 |
| BR7372-18-2-1HR1-HR6 (Com) | 89 | 142 | 6.28 |
| BRRI dhan50 (ck) | 91 | 136 | 5.64 |
| BRRI dhan63 (ck) | 103 | 143 | 6.24 |
| $LSD_{0.05}$ | 9.94 | 0.97 | 0.34 |

## Advanced yield trial (AYT)

Twelve salinity tolerant entries were evaluated in an AYT against BRRI dhan28, BRRI dhan67 and Binadhan-10 at Assasuni and Koyra during Boro 2016-17 (Table 8). IR58443-6B-10-3 yielded (7.06 t $ha^{-1}$) the highest followed by BR8940-B-17-4-7 (6.54 t $ha^{-1}$), BR8982-5 (6.53 t $ha^{-1}$) and BR8943-B-1-2-7 (6.36 t $ha^{-1}$) exceeded the yield of checks in Assasuni whereas no entry could yielded higher than the checks in Koyra.

## Participatory varietal selection (PVS)

Nine entries were evaluated comparing with BR11, BRRI dhan54 and BRRI dhan73 in a PVS during Aman 2016. PVS preference analysis was done by a team consisting of 20 male and 10 female farmers along with two plant breeders. IR8768-2-AJY1-B, IR78761-B-SATB1-52-1, BRRI dhan54 and IR78761-B-SATB1-68-6 ranked first choice whereas IR78761-B-SATB1-52-1, BR8715-10-7-23, BR8715-10-7-23 and BRRI dhan73 ranked second in PVS at Chiledanga (Assasuni), Kushudanga (Koyra), Kulia (Debhata) and Tarali (Kaliganj), respectively in Aman 2016 (Table 9).

Eleven entries were evaluated comparing with BRRI dhan28, BRRI dhan67 and Binadhan-10 and SAT-1 in a PVS during Boro 2016-17. PVS preference analysis was done by a team consisting of 20 male and 10 female farmers along with two plant breeders. Sat-1 and BRRI dhan67 was chosen in two locations and IR87870-6-1-1-1-1-B was selected in Koyra (Table 10).

**Table 8. Performance of AYT entries in Boro 2016-17.**

| Entry/Variety | Growth duration (day) | | Yield (t $ha^{-1}$) | |
|---|---|---|---|---|
| | Assasuni | Koyra | Assasuni | Koyra |
| IR58443-6B-10-3 | 138 | 140 | 7.06 | 4.21 |
| A69-1 | 150 | 152 | 5.58 | 5.53 |
| IR 87870-6-1-1-1-1-B | 146 | 146 | 6.09 | 4.18 |
| BR8943-B-1-2-7 | 140 | * | 6.36 | * |
| BR8943-B-4-3-9 | 142 | 143 | 4.61 | 4.36 |
| BR8943-B-5-5-14 | 140 | 142 | 5.63 | 3.01 |
| BR8982-5 | 145 | 145 | 6.53 | 5.81 |
| BR8982-9 | 138 | 139 | 5.62 | 4.16 |
| BR8987-6 | 139 | 140 | 5.99 | 4.19 |
| BR8992-10 | 144 | 145 | 5.82 | 3.26 |
| BR8940-B-17-4-7 | 144 | 146 | 6.54 | 2.31 |
| BR8943-B-1-1-2 | 140 | 143 | 6.09 | 4.21 |
| BRRI dhan28 (S. ck) | 140 | 144 | 2.62 | 2.99 |
| BRRI dhan67 (ck) | 144 | 148 | 5.58 | 5.23 |
| Binadhan-10 (ck) | 141 | 149 | 6.19 | 6.26 |

*Germination failed.

**Table 9. Performance of different entries in PVS in Aman 2016.**

| Entry/Variety | Assasuni | | Koyra | | Debhata | | Kaligonj | |
|---|---|---|---|---|---|---|---|---|
| | Yield | Rank | Yield | Rank | Yield | Rank | Yield | Rank |
| BR8715-10-7-23 | 4.46 | 2nd-ve | 5.76 | 2nd+ve | 2.84 | 2nd+ve | 3.38 | |
| IR8768-2-AJY1-B | 5.93 | 1st+ve | 5.66 | | 3.59 | | 3.08 | |
| IR85926-11-3-1-AJY1-B | 5.51 | | 5.66 | 2nd-ve | 2.69 | 2nd-ve | 4.44 | |
| IR84095-AJY-301-SDO4-B | 5.38 | | 5.03 | | 4.20 | | 3.72 | |
| IR78761-B-SATB1-52-1 | 6.43 | 2nd+ve | 5.03 | 1st+ve | 2.76 | | 4.76 | |
| IR10T116 | 4.64 | 2nd-ve | 5.32 | | 2.34 | | 2.77 | |
| IR83484-3-B-7-1-1-1 | 5.82 | 1st-ve | 5.03 | 1st-ve | 3.20 | | 2.94 | 1st-ve |
| IR78761-B-SATB1-68-6 | 5.98 | | 5.37 | | 3.89 | | 5.04 | 1st+ve |
| BR8371-18-20-52-55 | 3.07 | | | | 2.24 | 1st-ve | 3.05 | 2nd-ve |
| BR11 (ck) | 4.43 | | 5.45 | | 3.99 | | 4.57 | |
| BRRI dhan54 (ck) | 5.59 | | 4.57 | | 3.91 | 1st+ve | 3.87 | |
| BRRI dhan73 (ck) | 6.11 | | 5.51 | | 4.70 | | 5.24 | 2nd+ve |
| $LSD_{0.05}$ | 0.67 | | 0.40 | | 1.03 | | | |

**Table 10. Performance of different entries in PVS in Boro 2016-17.**

| Entry/Variety | Assasuni | | Koyra | | Debhata | |
|---|---|---|---|---|---|---|
| | Yield | Rank | Yield | Rank | Yield | Rank |
| BR8940-B-17-4-7 | 6.15 | | 4.89 | | 5.06 | |
| BR8943-B-20-9-22 | 5.74 | | 4.41 | 1st -ve | 4.51 | |
| IR86385-85-2-1-B | 5.67 | 1st -ve | 5.58 | | 5.69 | |
| IR83484-3-B-7-1-1-1 | 5.61 | | 3.59 | 2nd -ve | 3.75 | |
| IR 87872-7-1-1-2-1-B | 5.14 | | 4.68 | | 4.74 | |
| IR86385-117-1-1-B | 4.99 | 2nd -ve | 4.79 | | 4.88 | 2nd -ve |
| IR 87870-6-1-1-1-1-B | 6.37 | | 6.34 | 1st +ve | 6.38 | |
| BR8980-4-6-5 | 5.54 | | 4.81 | | 4.89 | |
| BR8980-B-1-3-5 | 5.59 | | 5.52 | | 5.57 | |
| BR8992-B-18-2-26 | 5.86 | | 5.74 | | 5.77 | 1st -ve |
| BRRI dhan28 (S. ck) | 5.56 | | 5.74 | | 5.25 | |
| BRRI dhan67 (ck) | 6.34 | 1st +ve | 5.64 | 2nd +ve | 6.43 | |
| Binadhan-10 (ck) | 6.46 | | 5.66 | | 6.41 | 2nd +ve |
| SAT-1 | 6.42 | 2nd +ve | | | 5.33 | 1st +ve |

**Proposed variety trial (PVT)**

One PVT for rainfed lowland rice (RLR) was conducted in Stakhira during T. Aman 2016 (Table 11). The tested line yielded a little bit higher than the check BRRI dhan39 with one week growth duration advantage, low disease infestation and short plant type.

In total five PVTs were conducted in Jessore, Satkhira and Khulna during Boro 2016-17. Among them four were evaluated by PVT evaluation committee. In PVT for MER, the proposed line BR7831-59-1-1-4-5-1-9-P1 yielded (8.86 t $ha^{-1}$) better than the check BRRI dhan28 (8.46 t $ha^{-1}$). In PVT for FBR the tested line BR7358-5-3-2-1-HR2 yielded better than the check BRRI dhan28 in both the locations (Manirampur, Jessore and Kolaroa, Satkhira). In short duration entries, both the tested lines yielded better than the check BRRI dhan28 (Table 12).

**Table 11. Performance of proposed variety trial in Aman 2016 in Satkhira.**

| Varity/Line | Plant height (cm) | Growth duration (day) | PACP | Lodging score | Disease infestation | Yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|
| WAS 161-B-4-B-1-TGR 51 (NERICA-L-32) | 102 | 115 | 5 | 5% | Brown Spot (Severity-2) | 5.40 |
| BRRI dhan39 (ck) | 113 | 122 | 5 | 75% | Brown spot (Severity-3) | 5.36 |

DS: 19 Jul 2016 DT: 20 Aug 2016.

**Table 12. Performance of PVT entries in Boro 2016-17.**

| PVT type | Location | Varity/Line | Plant height (cm) | Growth duration (day) | Yield (t $ha^{-1}$) |
|---|---|---|---|---|---|
| MER | Monirampur, Jessore | BR7831-59-1-1-4-5-1-9-P1 | 121 | 136 | 8.86 |
| | | BR7831-59-1-1-4-9-1-2-P3 | 120 | 136 | 6.37 |
| | | BRRI dhan28 (ck) | 113 | 136 | 8.46 |
| FBR | Monirampur, Jessore | BR7358-5-3-2-1-HR2 | 113 | 141 | 8.98 |
| | | BRRI dhan28 (ck) | 112 | 141 | 8.28 |
| FBR | Kolaroa, Satkhira | BR7358-5-3-2-1-HR2 | 116 | 137 | 7.40 |
| | | BRRI dhan28 (ck) | 114 | 137 | 7.07 |
| Short Duration | Kolaroa, Satkhira | BR(Bio)8072-AC5-4-2-1-2-1 | 110 | 137 | 7.17 |
| | | BR(Bio)8072-AC8-1-1-3-1-1 | 109 | 136 | 7.12 |
| | | BRRI dhan28 (ck) | 107 | 136 | 6.53 |
| Long Duration | Dumuria, Khulna | BR(BE)6158RWBC2-1-2-1-1 | 117 | 150 | 6.39 |
| | | BRRI dhan28 (ck) | 103 | 136 | 5.93 |

CROP-SOIL-WATER MANAGEMENT

**Determination of nutrient requirements for Boro rice in saline *gher***

A missing element trial was set using six treatments in RCB design with three replications at Benerpota. NPKSZn was applied at a rate of 100-15-60-10-1 kg $ha^{-1}$, respectively. Recommended establishment methods and management practices were followed. About 63% lower grain yield was found in N omitted plot (3.09 t $ha^{-1}$). And N is the most limiting factor followed by K, S, Zn and P (Table 13).

SOCIO-ECONOMIC

**Stability analysis of BRRI varieties at BRRI RS, Satkhira in Aman and Boro season during 2016-17**

Thirty-seven of BRRI developed modern T. Aman and Boro varieties were tested at BRRI RS farm, Satkhira during 2016-17 following RCB design with three replications. All the management practices were followed as per BRRI recommendation. The highest grain yield was found in BRRI dhan33 (6.14 t $ha^{-1}$), which was statistically similar with BRRI dhan75 (6.05 t $ha^{-1}$) but significantly higher than the other varieties. BR11, BR25, BRRI dhan49, BRRI dhan53 and BRRI dhan73 yielded more than 5.50 t $ha^{-1}$ in Aman season. BRRI hybrid dhan2 produced the highest yield of 8.12 t $ha^{-1}$ followed by BRRI hybrid dhan3 (7.71 t $ha^{-1}$), BRRI hybrid dhan5 (7.69 t $ha^{-1}$), BRRI dhan58 (7.42 t $ha^{-1}$), BRRI dhan59 (7.39 t $ha^{-1}$), BR16 (7.31 t $ha^{-1}$) and BRRI dhan69 (7.29 t $ha^{-1}$) in Boro season.

TECHNOLOGY TRANSFER

**Breeder seed and truthfully labeled seed (TLS) production**

A total of 9.73 tons and 15.50 tons of breeder seed were produced in Aman and Boro season, respectively during 2016-17. Four tons and six tons of TLS were produced in Aman and Boro season, respectively during the reporting year.

**Activity seed production and dissemination programme (SPDP)**

In total 195 SPDPs were conducted in the farmer's field of different upazila in Satkhira, Jessore, Bagerhat and Khulna districts. In T. Aman 111 demonstrations were conducted. The average grain yield of the varieties (BRRI dhan30, BRRI dhan49, BRRI dhan62, BRRI dhan70, BRRI dhan72, BRRI dhan73 and BRRI dhan75) varied from 3.91-6.35 t $ha^{-1}$ with an average yield of 5.25 t $ha^{-1}$. Another 84 demonstrations were conducted during Boro 2016-17. Average yield of BRRI dhan50, BRRI dhan58, BRRI dhan63, BRRI dhan64, BRRI dhan67 and BRRI dhan69 ranged from 5.55-6.47 t $ha^{-1}$.

**Training, field day and fair**

Fifteen farmer's training on rice production technology was conducted to train up 460 farmers of Satkhira, Khulna, Bagerhat and Jessore districts. A total of eight field day was arranged during the reporting year. BRRI RS, Satkhira participaed in three different agricultural and development fairs.

**Table 13. Effect of missing nutrients on yield at saline and non-saline *gher* in Boro 2016-17.**

| Treatment | Yield at saline *gher* (t $ha^{-1}$) | Yield at nonsaline *gher* (t $ha^{-1}$) | Grain yield decreased (%) due to missing nutrient | |
|---|---|---|---|---|
| | | | Saline *gher* | Non saline *gher* |
| PKSZn (-N) | 2.32 | 6.52 | 2.22 | 1.20 |
| NKSZn (-P) | 4.45 | 6.93 | 0.09 | 0.79 |
| NPSZn (-K) | 4.41 | 7.40 | 0.13 | 0.32 |
| NPKZn (-S) | 4.10 | 7.32 | 0.53 | 0.40 |
| NPKS (-Zn) | 4.40 | 7.29 | 0.14 | 0.43 |
| NPKSZn | 4.54 | 7.72 | | |
| $LSD_{0.05}$ | 0.89 | 0.43 | | |

# BRRI RS, Sonagazi

SUMMARY

A total of 100 breeding lines were tested under regional yield trial (RYT) in Aus, T. Aman and Boro seasons during the reporting period. Breeding lines were supplied from Plant Breeding and Biotechnology Divisions. Five lines along with standard checks BRRI dhan43 and BRRI dhan65 were tested during broadcast Aus from which the advanced lines BR7698-2B-1-9-2 and BR7383-2B-23 were recommended for further process. In T. Aman season seven rainfed lowland rice (RLR), three premium quality rice (PQR), one micronutrient enriched rice (MER) were evaluated under on-station condition, which were supplied from Plant Breeding Division. The RLR lines BR8204-5-3-2-5-2, BR8192-10-1-2-3-4, Ranjit Swarna (Rajshahi), BR7528-2R-HR16-2-24-1 and BR8410-16-4-17-9-1 were selected for further trial. On the basis of growth duration, yield and yield contributing characters the PQR advanced lines BR8493-12-7-4(Com), BR8493-16-5-1(Com), BR8850-20-3-5-1, BR8522-16-5-3-1-HR2(Com), BR8536-6-2-1-1, BR8297-1-1-2-HR1(Com) and BR8234-1-3-7-1-3-R21(Com) were found better than the check variety and were selected for further trial. Four micronutrient enriched advanced breeding lines were also evaluated in T. Aman and only one advanced line BR7528-2R-HR16-3-98-1 was recommended for further process. In the same season six breeding lines with one check were supplied from Biotechnology Division for evaluation under RYT. The advanced lines BR(Bio)8019-AC5-1-2-1, BR(Bio)8019-AC8-1-2-2, BR(Bio)8019-AC9-3-3-1, BR(Bio)8013-AC3-4-1-3 and BR(Bio)8013-AC4-1-2-2 were recommended for further process. In Boro season, the advanced lines BR8626-19-5-1-2 and BR8109-29-2-2-3 produced 6.04 t/ha and 6.87 t/ha yield respectively under favourable Boro rice (RYT) and were recommended for further trial.

Under PQR trial in Boro season advanced line BRC266-5-1-2-1 gave 4.91 t/ha yield and selected for further trial. Two disease resistance lines BR8938-19-4-3-1-1 and BR833-15-3-2-2 were recommended for further process in Boro season. One short duration line and three bacterial blight resistant lines were also selected for further trial. In the reporting period, the station produced 20 tons of breeder seed and 40 tons of TLS. The breeder seed was sent to the Genetic Resources and Seed Division. The TLS were sold among the farmers and public organizations. Nearly 1.35 tons of seeds were given in free of cost to DAE as seed support. The station also arranged 24 trainings and 15 field days during Aus, T. Aman and Boro seasons.

VARIETY DEVELOPMENT

**Regional yield trial (RYT) in Aus 2016**

Five advanced lines BR7698-2B-1-9-2, BR7383-2B-23, BR7587-2B-3, BR6855-3B-13 and BR8235-2B-4-4 along with two checks BRRI dhan43 (ck), and BRRI dhan65 (ck) were tested. The advanced lines BR7698-2B-1-9-2 and BR7383-2B-23 gave 3.67 and 3.61 t/ha, respectively that were higher than the standard checks (Table 1). Based on the yield performance BR7698-2B-1-9-2 and BR7383-2B-23 may be recommended for further process

**Regional yield trial (RYT) in T. Aman 2016**

**Development of rainfed low land rice (RLR) in T. Aman season-RLR-1.** one advanced line BR7358-56-2-2-1-HR7(Com) with checks Nizersail BR22 and BRRI dhan54 were tested (Table 2). The advanced line did not produce higher yield than the standard checks.

**Table 1. Performance of the lines in regional yield trial development of Upland rice in Aus-2016.**

| Designation | Plant height (cm) | Growth duration (day) | Yield (t/ha) |
|---|---|---|---|
| BR7698-2B-1-9-2 | 77 | 108 | 3.67 |
| BR7383-2B-23 | 89 | 107 | 3.61 |
| BR7587-2B-3 | 105 | 107 | 3.02 |
| BR6855-3B-13 | 100 | 107 | 3.53 |
| BR8235-2B-4-4 | 89 | 107 | 2.96 |
| BRRI dhan43 (ck) | 98 | 107 | 3.51 |
| BRRI dhan65 (ck) | 88 | 107 | 3.45 |
| CV(%) | 2.23 | 1.21 | 3.98 |
| $LSD_{0.05}$ | 3.67 | 2.31 | 0.24 |

**Table 2. Performance of the lines in regional yield trial (RLR-1).**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t $ha^{-1}$) |
|---|---|---|---|
| BR7358-56-2-2-1-HR7(Com) | 128 | 107 | 3.01 |
| Nizersail (ck) | 132 | 134 | 4.12 |
| BR22 (ck) | 143 | 120 | 4.94 |
| BRRI dhan54 (ck) | 128 | 112 | 4.45 |
| CV | 2.30 | 1.65 | 1.68 |
| LSD at 0.05 | 5.42 | 4.37 | 0.14 |

**RLR-2.** Six advanced lines BR8204-5-3-2-5-2, BR8192-10-1-2-3-4, IR08L181, BR490-5-1-4-4, IR11F190, BR8526-9-2-3-5, along with two checks BRRI dhan32 and BRRI dhan39 were tested (Table 3). Advanced lines BR8204-5-3-2-5-2 and BR8192-10-1-2-3-4 performed better than the check BRRI dhan39 and were recommended for further trial.

**RLR-3.** Six advanced lines BR189-10-2-3-1-5, BR8189-10-2-3-1-6, BR8208-5-3-19, BR8208-5-3-16, BR8526-1-2-3, BR8226-13-1-2, along with one check BR11 (ck) were tested (Table 4). None of the tested lines performed better than the check BR11.

**RLR-4.** Six advanced lines IR11L465, IR88886-7-2-1-4, BR8521-30-3-1, BR8526-38-2-1, along with two checks BRRI dhan49 (ck) and BRRI dhan66 (ck) were tested and none of the tested lines performed better than the check BRRI dhan49 (Table 5).

**Table 3. Performance of the lines in regional yield trial (RLR-2).**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield ($tha^{-1}$) |
|---|---|---|---|
| BR8204-5-3-2-5-2 | 134 | 118 | 5.84 |
| BR8192-10-1-2-3-4 | 119 | 123 | 5.06 |
| IR08L181 | 118 | 107 | 4.52 |
| BR490-5-1-4-4 | 125 | 104 | 4.37 |
| IR11F190 | 144 | 105 | 4.31 |
| BR8526-9-2-3-5 | 141 | 125 | 4.79 |
| BRRI dhan32 (ck) | 127 | 109 | 3.49 |
| BRRI dhan39 (ck) | 130 | 121 | 5.10 |
| CV | 3.22 | 3.44 | 7.90 |
| LSD at 0.05 | 7.31 | 6.87 | 0.65 |

**Table 4. Performance of the lines in regional yield trial (RLR-3) (T. Aman).**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield ($tha^{-1}$) |
|---|---|---|---|
| BR189-10-2-3-1-5 | 136 | 115 | 5.47 |
| BR8189-10-2-3-1-6 | 137 | 112 | 5.35 |
| BR8208-5-3-19 | 139 | 122 | 3.92 |
| BR8208-5-3-16 | 138 | 123 | 4.08 |
| BR8526-1-2-3 | 135 | 104 | 3.01 |
| BR8226-13-1-2 | 139 | 101 | 4.38 |
| BR11 (ck) | 141 | 114 | 5.53 |
| CV | 4.79 | 1.77 | 2.08 |
| LSD at 0.05 | 1.17 | 3.56 | 0.17 |

**Table 5. Performance of the lines in regional yield trial (RLR-4).**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield ($tha^{-1}$) |
|---|---|---|---|
| IR11L465 | 111 | 103 | 3.00 |
| IR88886-7-2-1-4 | 113 | 101 | 3.09 |
| BRRI dhan66(ck) | 122 | 102 | 4.22 |
| BR8521-30-3-1 | 132 | 113 | 4.39 |
| BR8526-38-2-1 | 127 | 105 | 4.15 |
| BRRI dhan49 (ck) | 130 | 100 | 5.18 |
| CV | 1.78 | 2.17 | 2.64 |
| LSD at 0.05 | 3.96 | 4.12 | 0.193 |

**RLR-5.** Seven advanced lines BR8493-4-2-1-1, BR8829-14-7-1, BR8492-9-5-3-1, BR8492-9-5-2-3, BR8492-9-5-3-2, along with two checks BRRI dhan49 (ck), Swarna (ck) were tested (Table 6). None of the tested lines performed better statistically than the check BRRI dhan49 and Swarna.

**Table 6. Performance of the lines in regional yield trial (RLR-5).**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t/ha) |
|---|---|---|---|
| BR8493-4-2-1-1 | 135 | 108 | 3.26 |
| BR8829-14-7-1 | 131 | 103 | 4.48 |
| BR8492-9-5-3-1 | 129 | 107 | 4.16 |
| BR8492-9-5-2-3 | 131 | 106 | 4.32 |
| BR8492-9-5-3-2 | 128 | 106 | 4.16 |
| BRRI dhan49 (ck) | 131 | 97 | 4.73 |
| Swarna (ck) | 142 | 94 | 4.26 |
| CV | 1.72 | 2.18 | 5.96 |
| LSD at 0.05 | 4.06 | 3.68 | 0.451 |

**RLR-6.** Seven advanced varieties Suman Swarna (Rajshahi), Ranjit Swarna (Rajshahi), Nepali Swarna (Rangpur), Swarna-5 (Rangpur), Gutiswarna, BR9782-BC2-124-1-5 along with two checks BR11 and BRRI dhan49 were tested (Table 7). Ranjit Swarna (Rajshahi) was recommended for further process.

**RLR-7.** Five advanced lines BR9392-6-2-1B, BR10247-14-18, BR10238-5-1, IR12N177, IR05N412 along with one check were tested (Table 8). Advanced lines BR7528-2R-HR16-2-24-1 and BR8410-16-4-17-9-1 gave higher yield than the standard checks and those two lines may be recommended for further process.

**Table 7. Performance of the lines in regional yield trial (RLR-6).**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t/ha) |
|---|---|---|---|
| Suman Swarna (Rajshahi) | 148 | 103 | 4.37 |
| Ranjit Swarna (Rajshahi) | 143 | 110 | 4.87 |
| Nepali Swarna (Rangpur) | 142 | 104 | 4.44 |
| Swarna-5 (Rangpur) | 135 | 109 | 4.66 |
| Guti swarna | 137 | 106 | 4.59 |
| BR11 (ck) | 143 | 104 | 4.73 |
| BRRI dhan49 (ck) | 135 | 99 | 4.81 |
| CV | 1.60 | 2.18 | 5.39 |
| LSD at 0.05 | 3.98 | 4.07 | 0.43 |

**Table 8. Performance of the lines in regional yield trial (RLR-7).**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t/ha) |
|---|---|---|---|
| BR9392-6-2-1B | 136 | 114 | 4.28 |
| BR10247-14-18 | 137 | 114 | 3.57 |
| BR10238-5-1 | 137 | 111 | 4.29 |
| IR12N177 | 127 | 104 | 4.14 |
| IR05N412 | 125 | 103 | 4.10 |
| BRRI dhan49 (ck) | 135 | 98 | 4.67 |
| CV | 3.16 | 2.28 | 5.37 |
| LSD at 0.05 | 7.64 | 4.44 | 0.41 |

## Regional yield trial (PQR-1) (T. Aman)

**Development of premium quality rice in T. Aman, PQR-1.** Six advanced lines BR8493-12-7-4(Com), BR8515-28-1-1-3-HR3(Com), BR8493-16-5-1(Com), BR8850-10-8-3-3, BR8850-20-3-5-1 and BR8515-23-6-3 along with four checks BRRI dhan34 (ck), BINA dhan13 (ck), Kalizira (Local ck), Tulsimala (Local ck.) were tested (Table 9). Advanced lines BR8493-12-7-4 (Com), BR8493-16-5-1 (Com) and BR8850-20-3-5-1 performed better than std ck and those three lines may be recommended for further trial.

**PQR-2.** Ten advanced lines were tested from which the advanced lines BR8522-16-5-3-1-HR2(Com), BR8536-6-2-1-1& BR8297-1-1-2-HR1(Com) was recommended for further process (Table 10).

**Table 9. Performance of the lines in regional yield trial (PQR-1, Kalizira type).**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t/ha) |
|---|---|---|---|
| BR8493-12-7-4 (Com) | 138 | 101 | 2.63 |
| BR8515-28-1-1-3-HR3 (Com) | 134 | 104 | 1.61 |
| BR8493-16-5-1 (Com) | 133 | 111 | 2.70 |
| BR8850-10-8-3-3 | 132 | 102 | 2.46 |
| BR8850-20-3-5-1 | 142 | 106 | 2.92 |
| BR8515-23-6-3 | 133 | 108 | 2.24 |
| BRRI dhan34 (ck) | 133 | 120 | 2.44 |
| BINA dhan13 (ck) | 142 | 141 | 2.83 |
| Kalizira (Local ck) | 134 | 146 | 2.43 |
| Tulsimala (Local ck) | 134 | 148 | 2.44 |
| CV | 9.87 | 1.81 | 6.04 |
| LSD at 0.05 | 2.29 | 3.69 | 0.25 |

**Table 10. Performance of the lines in regional yield trial (PQR-2).**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t/ha) |
|---|---|---|---|
| BR8535-2-1-2 | 122 | 106 | 2.53 |
| BR8522-53-1-3 | 139 | 106 | 2.26 |
| BR8522-16-5-3-1-HR2 (Com) | 138 | 113 | 2.62 |
| BR8536-27-2-1-1 | 132 | 99 | 1.93 |
| BR8536-27-4-3-6 | 122 | 107 | 2.25 |
| BR8536-6-2-1-1 | 132 | 103 | 2.86 |
| BR8536-27-2-1-2 | 131 | 104 | 2.30 |
| BR8536-27-4-3-5 | 130 | 107 | 2.27 |
| BR8526-2-1-1-4 (Com) | 131 | 118 | 2.39 |
| BR8297-1-1-2-HR1 (Com) | 132 | 111 | 2.94 |
| BRRI dhan34 (ck) | 133 | 132 | 2.58 |
| CV | 1.75 | 3.93 | 8.40 |
| LSD at 0.05 | 3.90 | 7.32 | 0.52 |

**PQR-3.** Six advanced lines BR8512-9-1-6, BR8234-1-3-7-1-3-HR21(Com), BR9051-33-1-2-5, BR8846-108-2-1-1, BR8514-17-1-5 and BR8512-3-1-1 along with three checks BRRI dhan38, BRRI dhan70 and Kataribhog were tested at Sonagazi farm Feni during Aman 2016 with three replications (Table 11).

The advanced line BR8234-1-3-7-1-3-HR21(Com) performed better than standard checks and recommended for the further process.

### Development of micronutrient enriched rice (MER) in T. Aman 2016

Six advanced lines BR7528-2R-HR16-2-24-1, BR8410-16-4-17-9-1, BR8442-9-5-2-3-B1, BR7528-2R-HR16-3-98-1 along with three checks BRRI dhan39, BRRI dhan72 and BRRI dhan72 were tested (Table 12). The advanced line BR7528-2R-HR16-3-98-1 recommended for the further process.

**Table 11. Performance of the lines in regional yield trial (PQR-3).**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t/ha) |
|---|---|---|---|
| BR8512-9-1-6 | 131 | 89 | 3.22 |
| BR8234-1-3-7-1-3-HR21(Com) | 139 | 82 | 4.00 |
| BR9051-33-1-2-5 | 135 | 105 | 3.63 |
| BR8846-108-2-1-1 | 135 | 106 | 3.13 |
| BR8514-17-1-5 | 131 | 107 | 3.36 |
| BR8512-3-1-1 | 135 | 106 | 3.35 |
| BRRI dhan38 (ck) | 141 | 102 | 3.51 |
| BRRI dhan70 (ck) | 135 | 101 | 5.00 |
| Kataribhog | 135 | 104 | 3.34 |
| CV | 5.35 | 1.76 | 2.18 |
| LSD at 0.05 | 1.25 | 3.18 | 0.14 |

**Table 12. Performance of the lines in regional yield trial (MER).**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t/ha) |
|---|---|---|---|
| BR7528-2R-HR16-2-24-1 | 134 | 103 | 3.93 |
| BR8410-16-4-17-9-1 | 134 | 100 | 3.06 |
| BR8442-9-5-2-3-B1 | 140 | 102 | 3.83 |
| BR7528-2R-HR16-3-98-1 | 140 | 101 | 4.70 |
| BRRI dhan39 | 131 | 102 | 4.53 |
| BRRI dhan32 | 139 | 113 | 4.50 |
| BRRI dhan72 | 136 | 117 | 4.97 |
| CV | 6.64 | 2.53 | 2.72 |
| LSD at 0.05 | 1.49 | 4.73 | 0.21 |

### Under regional yield trial for (RYT-Biotechnology) in T. Aman 2016

Six advanced lines BR(Bio)8019-AC4-1-1-3, BR(Bio)8019-AC5-1-2-1, BR(Bio)8019-AC8-1-2-2, BR(Bio)8019-AC9-3-3-1, BR(Bio)8013-AC3-4-1-3, BR(Bio)8013-AC4-1-2-2 along with three checks BRRI dhan39 were tested (Table 13). The advanced lines BR(Bio)8019-AC5-1-2-1, BR(Bio)8019-AC8-1-2-2, BR(Bio)8019-AC9-3-3-1, BR(Bio)8013-AC3-4-1-3 and BR(Bio)8013-AC4-1-2-2 recommended for the further process.

### Regional yield trial for development of favourable Boro rice (FBR) in Boro 2016-17

Four advanced lines BR7671-37-2-2-3-7-3-P3, BR8626-19-5-1-2, BR8780-10-5-1 and BR8109-29-2-2-3 along with three checks BRRI dhan28 (ck), BRRI dhan58 (ck) and BRRI dhan29 (ck) were tested and the advanced lines BR8626-19-5-1-2 and BR8109-29-2-2-3 may be recommended for further process (Table 14).

**Table 13. Performance of the lines in regional yield trial (RYT-Bio).**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t/ha) |
|---|---|---|---|
| BR(Bio)8019-AC4-1-1-3 | 131 | 102 | 4.50 |
| BR(Bio)8019-AC5-1-2-1 | 132 | 100 | 4.69 |
| BR(Bio)8019-AC8-1-2-2 | 132 | 103 | 4.69 |
| BR(Bio)8019-AC9-3-3-1 | 129 | 98 | 4.65 |
| BR(Bio)8013-AC3-4-1-3 | 129 | 103 | 4.68 |
| BR(Bio)8013-AC4-1-2-2 | 130 | 102 | 4.61 |
| BRRI dhan39 (ck) | 130 | 104 | 4.51 |
| CV | 1.35 | 4.37 | 3.50 |
| LSD at 0.05 | 3.14 | 7.90 | 0.29 |

**Table 14. Performance of the lines in regional yield trial (FBR) Boro 2016-17.**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t/ha) |
|---|---|---|---|
| BR7671-37-2-2-3-7-3-P3 | 156 | 92 | 5.52 |
| BR8626-19-5-1-2 | 151 | 89 | 6.04 |
| BR8780-10-5-1 | 154 | 78 | 5.67 |
| BR8109-29-2-2-3 | 155 | 90 | 6.87 |
| BRRI dhan28(ck) | 141 | 87 | 5.32 |
| BRRI dhan58 (ck) | 151 | 98 | 6.53 |
| BRRI dhan29 (ck) | 160 | 94 | 6.22 |
| CV | 1.60 | 2.18 | 5.39 |
| LSD at 0.05 | 3.98 | 4.07 | 0.43 |

**Development of premium quality rice, in Boro 2016-17**

**PQR-1.** Four advanced lines BR8079-19-1-5-1, BR8590-5-2-5-2-2, BR8590-5-3-3-4-2 and BR8608-39-2-1 along with two checks BRRI dhan50 (ck) and BRRI dhan63 (ck) were tested (Table 15). No advanced lines were gave higher yield than standard checks.

**PQR-2.** Three advanced lines BRC266-5-1-1-1, BRC266-5-1-2-1 and BR8523-36-2-2-6 along with check BR16 was tested (Table 16). Advanced line BRC266-5-1-2-1 gave 4.91 t/ha yield, respectively that was higher than standard checks. Based on the yield performance BRC266-5-1-2-1 may be recommended for further process.

**Table 15. Performance of the lines in regional yield trial (PQR-1), Boro 2016-17.**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t/ha) |
|---|---|---|---|
| BR8079-19-1-5-1 | 154 | 89 | 3.87 |
| BR8590-5-2-5-2-2 | 157 | 95 | 4.63 |
| BR8590-5-3-3-4-2 | 152 | 84 | 4.94 |
| BR8608-39-2-1 | 161 | 99 | 4.59 |
| BRRI dhan50 (ck) | 153 | 82 | 5.28 |
| BRRI dhan63 (ck) | 149 | 83 | 5.76 |
| CV | 1.60 | 2.18 | 5.39 |
| LSD at 0.05 | 3.98 | 4.07 | 0.43 |

**Table 16. Performance of the lines in regional yield trial (PQR-2), Boro 2016-17.**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t/ha) |
|---|---|---|---|
| BRC266-5-1-1-1 | 155 | 93 | 4.82 |
| BRC266-5-1-2-1 | 155 | 84 | 4.91 |
| BR8523-36-2-2-6 | 150 | 106 | 4.05 |
| BR16 | 158 | 89 | 4.86 |
| CV | 1.60 | 2.18 | 5.39 |
| LSD at 0.05 | 3.98 | 4.07 | 0.43 |

**Regional yield trial for micronutrient enriched rice MER in Boro 2016-17**

**MER-1.** Six advanced lines BR8631-12-3-5-P2, BR8631-12-3-6-P3, BR7831-59-1-1-4-5, BR8253-9-3-3-1, BR8609-2-3-9-1-B5, BR7815-18-1-3-2-1 along with two checks BRRI dhan28 and BRRI dhan74 were tested (Table 17). None of them was recommended for the further process.

**MER-2.** Two advanced lines BR7671-37-2-2-3-7-3-P10, BR7671-37-2-2-3-7-3-P11 along with two checks BRRI dhan39, BRRI dhan72 (ck) and BRRI dhan72 were tested. None of these was recommended for the further process.

**Regional yield trial for the development of disease resistant rice (DRR) in Boro 2016-17**

**DRR.** Two advanced lines BR8938-19-4-3-1-1, BR833-15-3-2-2 along with three checks IRBB60 BRRI dhan28 and BRRI dhan29 were tested. The advanced lines BR8938-19-4-3-1-1 and BR833-15-3-2-2 were recommended for the further process.

**Bio-SD.** Four advanced lines BR(Bio)9785-BC2-6-2-2, BR(Bio)9785-BC2-19-3-1, BR(Bio)9785-BC2-20-1-3 and BR(Bio)9785-BC2-19-3-5 along with one check BRRI dhan28 (ck) were tested. Advanced line BR(Bio)9785-BC2-20-1-3 gave 6.76 t/ha yield, respectively that was higher than the standard checks. Based on the yield performance BR(Bio)9785-BC2-20-1-3 may be recommended for further process.

**Table 17. Performance of the lines in regional yield trial (MER-1), Boro 2016-17.**

| Designation | Growth duration (day) | Plant height (cm) | Grain yield (t/ha) |
|---|---|---|---|
| BR8631-12-3-5-P2 | 154 | 104 | 5.49 |
| BR8631-12-3-6-P3 | 144 | 88 | 5.45 |
| BR7831-59-1-1-4-5 | 144 | 89 | 5.20 |
| BR8253-9-3-3-1 | 151 | 87 | 5.03 |
| BR8609-2-3-9-1-B5 | 144 | 86 | 4.92 |
| BR7815-18-1-3-2-1 | 152 | 115 | 5.56 |
| BRRI dhan28(ck) | 141 | 90 | 5.43 |
| BRRI dhan74 (ck) | 149 | 94 | 5.93 |
| CV | 6.64 | 2.53 | 2.72 |
| LSD at 0.05 | 1.49 | 4.73 | 0.21 |

**Bio-BBR.** Five advanced lines BR(Bio)8333-BC5-1-1, BR(Bio)8333-BC5-1-20, BR(Bio)8333-BC5-2-16, BR(Bio)8333-BC5-2-22 and BR(Bio)8333-BC5-3-10 along with one check BRRI dhan29 (ck) were tested. Advanced lines BR(Bio)8333-BC5-1-1, BR(Bio)8333-BC5-1-20 and BR(Bio)8333-BC5-3-10 produced higher yield than standard checks. Based on the yield performance those three lines may be recommended for further process.

## CROP-SOIL-WATER MANAGEMENT

**Integrated nutrient management on growth and yield of Aus rice in charland**

There were the treatments such as $T_1$: Control (No fertilizer); $T_2$: BRRI Recommended dose (NPKSZn); $T_3$: PM 2.5 ton ha$^{-1}$; $T_4$: Cowdung 5 ton ha$^{-1}$; $T_5$: BRRI RD 25% NP + PM 2.5 ton ha$^{-1}$; $T_6$: BRRI RD 25% NK + PM 2.5 ton ha$^{-1}$ ; $T_7$: BRRI RD 25% PK + PM 2.5 ton ha$^{-1}$; $T_8$: BRRI RD 25% NP + CD 5 ton ha$^{-1}$; $T_9$: BRRI 25% NK + CD 5 ton ha$^{-1}$ and $T_{10}$: BRRI RD 25% PK + CD 5 ton ha$^{-1}$. The experiment was laid out in a RCB design with three replications.

There was significant difference in producing grain yield and straw yield (t/ha). The highest grain yield and straw yield (3.9 and 9.7 t/ha) was found in $T_5$ treatment and the lowest (1.7 and 2.9 t/ha) in control. It can be concluded from the results that BRRI RD 25% NP + PM 2.5 ton ha$^{-1}$ treatment performed better than the other treatments. Therefore the cultivation of BRRI dhan48 with BRRI RD 25% NP + PM 2.5 ton ha$^{-1}$ was recommended in Aus rice for saline charland ecosystem.

## PEST MANAGEMENT

**Survey and monitoring of rice diseases**

Survey and monitoring of rice disease incidence was done in Boro 2016-17 to know the status of disease incidence and how farmers' address the disease. This was done mainly at Sonagazi, Chagolnaiya and Dagonbhuiyan of Feni, Laxmipur sadar and Noakhali sadar upazilas. Farmers' were interviewed during the visit was taken to know the knowledge status regarding rice disease. The results show that blast incidence was more irrespective of variety. BRRI dhan28 and BRRI dhan61 were severely infested by neck blast. Farmers' statement indicated that they know the disease with few control measures. The results suggested the need of farmers' skill development on rice disease orientation and management through training programme.

**Monitoring of pest and natural enemy incidence by using light trap**

Rice insect pests and their natural enemies were monitored throughout the year by light traps from July 2016 to June 2017 in BRRI RS, Sonagazi. The abundance of yellow stem borer (YSB), leaf roller (LR), caseworm (CW), long horn grasshopper, mole cricket (MC), field cricket (FC), rice bug (RB), green leafhopper (GLH), grasshopper (GH) and stink bug (SB) were found in the light trap during the reporting period. Among the insect pests, yellow stem borer (YSB) populations were found the highest followed by long horn grasshopper and green leafhopper. Among the natural enemies lady bird beetle populations was found the highest followed by earwig (EW) and green mirid bug (GMB). Peak of STB and EW was observed in March and June respectively whereas, BPH showed two peak of November and May.

## TECHNOLOGY TRANSFER

**Seed production and dissemination programme (SPDP)**

SPDPs were conducted in two different locations of Hatia upazila of Noakhali district. Zinc enriched rice varities BRRI dhan62 and BRRI dhan72 were used as cultivar during T. Aman season. The total demonstration area was 2.68 hectare of land and 20 farmers were involved in this demonstration programme. The average grain yield of BRRI dhan62 was 3.7 t/ha whereas BRRI dhan72 produced mean grain yield 5.6 t/ha. Total production of those two demonstrated varieties were 12,975 kg from which interested farmers retained 3,290 kg for further use in the next year.

During Boro 2016-17, SPDPs were conducted in two upazillas of two districts (Laxmipur sadar and Dagonbhuiyan) under SPIRA project. BRRI dhan63 and BRRI dhan69 were used as cultivars in the selected upazilas. The demonstration plot size of BRRI dhan63 and BRRI dhan69 were three *bigha* for each variety in each upazila. BRRI dhan63 produced the highest mean yield (5.93 t/ha) followed by BRRI dhan69. BRRI dhan63 and BRRI dhan69 produced 4,763 kg and 4,473 kg grains respectively, which could be used as seed. As a result 9,236 kg grains were produced from all the demonstrated plots and 2,034 kg quality seeds were retained by the farmers for next year use.

**Farmers training**

Under GoB and SPIRA project 24 farmers training programme on 'Modern Rice Production Technology' were conducted in eight different districts during the reporting period. In each farmers training 30 farmers and five DAE field stuffs participated in which they were trained up with rice production technology in different ecosystem especially on tidal submergence, salinity and drought environment.

**Field day**

Field days were conducted mainly in demonstration sites in collaboration with DAE and local farmers at different locations of Bangladesh. Around 150-200 persons (farmers, researchers, extension service providers, GO personnel, administrative people, public leaders etc) are invited in a field day. Field visit followed by discussion is carried out. A total of 15 field days were arranged during Aus, T. Aman and Boro season. A total of nearly 3,000 progressive farmers, local leaders, DAE field stuff, public representatives and NGO workers participated in those occasions.

# BRRI RS, Kushtia

SUMMARY

A total of 23 regional yield trials (RYT) were conducted during T. Aus, T. Aman and Boro seasons 2016-17. Three RYTs were conducted in T. Aus. The line BR7383-2B-23 yielded the highest in RYT-upland Aus, while none of the advanced lines could outyield the standard checks in the other two RYTs.

In T. Aman, 12 RYTs were conducted. Of them seven were rainfed lowland rice (RLR), three were premium quality rice (PQR), one each of micronutrient enriched rice (MER) and Biotech. In the RYT-RLR the lines BR8204-5-3-2-5-2, BR8189-10-2-3-1-6, BR8492-9-5-3-2 and BR9392-6-2-1B outyielded the checks. On the other hand, in the rest three RYT-RLR the yield of the checks were higher than the tested lines. In case of three RYT-PQR most of the lines including BR8493-12-7-4 (Com) and, BR8297-1-1-2 HR1 (Com) outyielded the checks, while in the RYT-MER none of the lines outyielded the checks. The yields of two lines BR(Bio)8019-AC9-3-3-1 and BR(Bio)8019-AC5-1-2-1 were higher than the checks.

Eight RYTs were conducted in Boro 2016-17 in BRRI RS, Kushtia. Among them two were PQR, one disease resistant rice (DRR), one favourable Boro rice (FBR), two were MER and two were Biotech. The lines BR8079-19-1-5-1 and BR8590-5-2-2-5-2-2 outyielded the checks in RYT-PQR (Boro). In one of the RYTs-MER (Boro) the line BR7815-18-1-3-2-1 yielded higher than the checks, while in the other trial, the lines could not outyield the checks. The yields of the tested lines BR(Bio)0985-BC2-62-2 and BR(Bio)8333-BC5-1-20 were higher than the checks in RYT-Biotech (Boro). Similarly, the line BR8333-15-3-2-2 outyielded the checks in RYT-DRR (Boro). In case of FBR, the check variety BRRI dhan29 yielded higher than the tested lines and other checks. However, the line BR8109-29-2-2-3 outyielded the checks BRRI dhan28 and BRRI dhan58.

Proposed variety trial (PVT) were conducted both in T. Aman and Boro seasons in BRRI Kushtia. In T. Aman the proposed material WAS161-B-1TGR51(NERICA-L-32) could not outyield the check BRRI dhan39. Among the PVTs conducted in Boro, one was Short duration (SD-Biotech), one was MER and one was FBR. The proposed materials BR7831-59-1-1-4-5-1-9-P1 and BR(Bio)8072-Ac8-1-1-3-1-1 outyielded the checks in PVT-MER and PVT-SD-Biotech. In PVT-FBR, the proposed material BR7358-5-3-2-1-HR2 yielded lower than the check.

In an experiment for terminal drought mitigation through integrated approaches in T. Aman, all the varieties in supplemental irrigation plots outyielded the farmer's practice plots (rainfed condition). Thus to enhance crop yield farmers should practice levee management and apply supplemental irrigation when necessary. In another trial for the determination of suitable time for application of supplemental irrigation in T. Aman, yield loss was found to occur when water level goes 35 cm below ground level compared with standard yield.

In the stability analysis trial of BRRI varieties in T. Aus, BRRI dhan48 yielded the highest (4.80 t/ha) and the local variety-1 (Noya paizam) yielded the lowest (2.41 t/ha). Lodging tendency was not found during T. Aus season. In T. Aman, the highest yield was obtained from BRRI dhan51 (5.70 t/ha) and the lowest from BRRI dhan38 (2.75 t/ha). Among 37 varieties lodging at different magnitudes (25-40%) was observed in case of six test varieties BR5, BR25, BRRI dhan32, BRRI dhan34, BRRI dhan37 and BRRI dhan38. In Boro 2016-17, the highest yielder was BRRI hybrid dhan2 (7.87 t/ha) and the lowest was BR7 (5.56 t/ha). Lodging tendency was not found during Boro season.

Three varieties BR3, BRRI dhan28 and BRRI dhan29 were evaluated to know the effect of change in protein content in Boro 2016-17. In this case BRRI dhan29 gave highest yield (7.49 t/ha).

A total of 11 batches farmers' training and two field days were organized at different upazilas of Kushtia and Meherpur district. About 330 and 250 farmers participated in the training programme and field day. Modern rice varieties and relevant technologies were disseminated among the farmers. We also participated in an 'Agricultural Fair' arranged by DAE, Kushtia district where BRRI developed technologies were demonstrated.

## VARIETY DEVELOPMENT

**Regional yield trial (RYT-1), upland Aus 2016**

Five lines and two standard checks BRRI dhan43 and BRRI dhan65 were tested under this trial to evaluate the lines for yield potential and adaptability in Kushtia region. The line BR7383-2B-23 gave highest yield (3.71 t/ha) than both the checks varieties (Table 1).

**Regional yield trial (RYT-2 Biotech.), T. Aus 2016**

Six genotypes against one standard check BRRI dhan48 were evaluated under this trial to evaluate the lines for yield potential and adaptability in Kushtia region. None of the advance lines could outyield check variety BRRI dhan48 (5.19 t/ha) (Table 2).

**Regional yield trial (RYT-3), T. Aus 2016**

One genotype and two standard checks BR26 and BRRI dhan48 were tested under this experiment for yield potential and adaptability test under different agro-climatic conditions of Kushtia region. Both the check varieties outyielded the tested line (Table 3).

**Table 1. Performance of some RYT lines, upland Aus 2016.**

| Designation | Growth duration (day) | Plant height (cm) | Panicle/ $m^2$ | TGW (g) | Yield (t/ha) |
|---|---|---|---|---|---|
| BR7898-2B-1-9-2 | 108 | 95.8 | 189 | 23.21 | 3.05 |
| BR7383-2B-23 | 108 | 107.1 | 324 | 24.87 | 3.71 |
| BR7587-2B-3 | 107 | 126.3 | 249 | 26.19 | 2.92 |
| BR6855-2B-13 | 109 | 107.9 | 300 | 25.89 | 3.61 |
| BR8235-2B-4-4 | 112 | 125.5 | 317 | 22.54 | 2.76 |
| BRRI dhan43 (ck) | 106 | 106.3 | 298 | 21.30 | 3.35 |
| BRRI dhan65 (ck) | 106 | 86.3 | 301 | 22.53 | 3.15 |
| LSD$_{0.05}$ | | 9.98 | 108.3 | 2.53 | 0.32 |
| CV (%) | | 4.07 | 44.27 | 1.03 | 4.13 |

DS: 18 Apr 2016, 1000 grain weight = (TGW).

**Table 2. Performance of some BRRI developed RYT lines, T. Aus 2016.**

| Designation | Growth duration (day) | Plant height (cm) | Panicle/$m^2$ | TGW (g) | Yield (t/ha) |
|---|---|---|---|---|---|
| BR(Bio) 7783-AC12-3 | 130 | 118.3 | 240 | 20.47 | 3.47 |
| BR(Bio) 7783-AC13-5 | 130 | 119.3 | 259 | 21.03 | 3.63 |
| BR(Bio) 7783-AC14-5 | 130 | 119.1 | 256 | 21.76 | 3.65 |
| BR(Bio) 9785-BC2-6-2-2 | 101 | 110.9 | 259 | 21.69 | 4.09 |
| BR(Bio) 9785-BC2-8-5-4-2 | 102 | 111.4 | 270 | 22.70 | 4.24 |
| BR(Bio) 9785-BC2-120-2-1 | 102 | 107.0 | 196 | 22.74 | 4.12 |
| BRRI dhan48 (ck) | 104 | 110.1 | 260 | 24.33 | 5.19 |
| LSD$_{0.05}$ | 4.8 | 37.23 | 1.49 | 0.44 | |
| CV (%) | 2.4 | 8.4 | 3.8 | 6.1 | |

DS-21 Apr 2016, DT-15 May 2016.

**Table 3. Performance of some BRRI developed RYT lines, T. Aus 2016.**

| Designation | Growth duration (day) | Plant height (cm) | Panicle/$m^2$ | TGW (g) | Yield (t/ha) |
|---|---|---|---|---|---|
| BRRI dhan62 | 102 | 101.4 | 326 | 24.24 | 4.09 |
| BR26 (ck) | 104 | 104.8 | 278 | 20.82 | 4.51 |
| BRRI dhan48 (ck) | 107 | 108.9 | 271 | 23.93 | 5.43 |
| LSD$_{0.05}$ | 4.87 | 20.94 | 1.26 | 0.94 | |
| CV (%) | 2.0 | 3.2 | 2.4 | 4.42 | |

DS-22 Apr 2016, DT-15 May 2016.

**Proposed variety trial (PVT-1), RLR, T. Aman 2016** One genotype and one standard check BRRI dhan39 was evaluated under this trial to recommend the proposed genotype as a new variety by the NSB team. The proposed material WAS161-B-1TGR51(NERICA-L-32) gave lower yield (4.45 t/ha) than the check variety BRRI dhan39 (4.61 t/ha) (Table 4). However, the yield difference was not statistically significant.

**Regional yield trial (RYT-4), RLR, T. Aman 2016**

One genotype and three standard checks BR22, BRRI dhan54 and Nizersail were evaluated under this experiment for specific and general adaptability in Kushtia region. The tested line yielded higher (3.93 t/ha) than check variety Nizershail (2.73 t/ha) but lower than other checks (BR22 and BRRI dhan54) (Table 5).

**Regional yield trial (RYT-5) RLR, T. Aman 2016** Seven genotypes and one standard check BRRI dhan32 was tested under this experiment to evaluate specific and general adaptability of the advance breeding lines as compared to standard check in Kushtia region. The line BR8204-5-3-2-5-2 was the highest yielder (6.00 t/ha) than the check and others genotypes (Table 6).

**Table 4. Performance of proposed variety trial (PVT) lines, RLR, T. Aman 2016.**

| Designation | Growth duration (day) | Plant height (cm) | Panicle/m$^2$ | TGW (g) | Yield (t/ha) |
|---|---|---|---|---|---|
| WAS161-B-1TGR51 (NERICA-L-32) | 115 | 96.7 | 322 | 26.74 | 4.45 |
| BRRI dhan39 (ck) | 118 | 115.6 | 301 | 24.91 | 4.61 |
| $LSD_{0.05}$ | 3.54 | 96.51 | 1.35 | 1.57 | |
| CV (%) | 1.0 | 8.9 | 1.5 | 10.0 | |

DS-14 Jul 2016, DT-14 Aug 2016.

**Table 5. Performance of some rainfed low land rice (RLR) lines, T. Aman 2016**

| Designation | Growth duration (day) | Plant height (cm) | Panicle/m$^2$ | TGW (g) | Yield (t/ha) |
|---|---|---|---|---|---|
| BR7358-56-2-2-1-HR7 (Com) | 111 | 114.7 | 211 | 19.09 | 3.93 |
| Nizersail (ck) | 114 | 140.8 | 260 | 18.17 | 2.73 |
| BR22 (ck) | 118 | 118.1 | 254 | 18.70 | 4.48 |
| BRRI dhan54 (ck) | 111 | 108.9 | 181 | 24.14 | 4.10 |
| $LSD_{0.05}$ | 6.68 | 23.45 | 1.23 | 0.78 | |
| CV (%) | 2.7 | 5.2 | 3.1 | 10.3 | |

DS-6 Aug 2016, DT-29 Aug 2016.

**Table 6. Performance of some rainfed low land rice (RLR) lines, T. Aman 2016.**

| Designation | Growth duration (day) | Plant height (cm) | Panicle/m$^2$ | TGW (g) | Yield (t/ha) |
|---|---|---|---|---|---|
| BR8204-5-3-2-5-2 | 128 | 124.0 | 228 | 27.36 | 6.00 |
| BR8192-10-1-2-3-4 | 116 | 118.5 | 211 | 27.72 | 4.99 |
| IR08L181 | 116 | 117.9 | 204 | 24.66 | 4.95 |
| BRRI dhan39 (ck) | 116 | 113.1 | 226 | 25.26 | 5.43 |
| BR8490-5-1-4-4 | 129 | 104.0 | 227 | 20.74 | 4.90 |
| IR11F190 | 121 | 128.4 | 222 | 25.42 | 5.18 |
| BR8526-9-2-3-5 | 116 | 122.3 | 214 | 18.49 | 5.51 |
| BRRI dhan32 (ck) | 121 | 124.6 | 228 | 21.63 | 4.94 |
| $LSD_{0.05}$ | 4.97 | 23.88 | 0.62 | 0.64 | |
| CV (%) | 2.4 | 6.2 | 1.5 | 7.1 | |

DS-18 Jul 2016, DT-16 Aug 2016.

**Regional yield trial (RYT-6) RLR, T. Aman 2016**
Six genotypes and one standard check BR11 was evaluated under this experiment to test the lines for specific and general adaptability in Kushtia region. The line BR8189-10-2-3-1-6 yielded the highest (5.74 t/ha) among the check and the other tested genotypes (Table 7).

**Regional yield trial (RYT-7) RLR, T. Aman 2016**
Four genotypes and two standard checks BRRI dhan49 and BRRI dhan66 were tested for specific and general adaptability in Kushtia region. All the tested lines yielded lower than the check varieties BRRI dhan49 (5.47 t/ha) and BRRI dhan66 (6.41 t/ha) (Table 8).

**Regional yield trial (RYT-8) RLR, T. Aman 2016**
Five genotypes and two standard checks BRRI dhan49 and Swarna were tested for specific and general adaptability in Kushtia region. Only one line BR8492-9-5-3-2 yielded higher (5.77 t/ha) than cheek varieties BRRI dhan49 and Swarna. However, the yield difference was not statistically significant (Table 9).

**Table 7. Performance of some rainfed low land rice (RLR) lines, T. Aman 2016.**

| Designation | Growth duration (day) | Plant height (cm) | Panicle/m$^2$ | TGW (g) | Yield (t/ha) |
|---|---|---|---|---|---|
| BR8189-10-2-3-1-5 | 125 | 128.6 | 223 | 26.05 | 5.32 |
| BR8189-10-2-3-1-6 | 125 | 128.0 | 219 | 25.76 | 5.74 |
| BR8208-5-3-19 | 125 | 136.6 | 218 | 19.51 | 5.10 |
| BR8208-5-3-16 | 125 | 143.1 | 226 | 20.19 | 5.54 |
| BR8526-1-2-3 | 119 | 122.2 | 226 | 17.34 | 4.28 |
| BR8226-13-1-2 | 130 | 114.6 | 268 | 16.99 | 4.75 |
| BR11 (ck) | 133 | 133.9 | 229 | 24.57 | 5.12 |
| $LSD_{0.05}$ | 4.91 | 20.7 | 1.19 | 0.80 | |
| CV (%) | 2.1 | 4.9 | 3.1 | 8.8 | |

DS-18 Jul 2016, DT-13 Aug 2016.

**Table 8. Performance of some rainfed low land rice (RLR) lines, T. Aman 2016.**

| Designation | Growth duration (day) | Plant height (cm) | Panicle/ m$^2$ | TGW (g) | Yield (t/ha) |
|---|---|---|---|---|---|
| IR11L465 | 113 | 121.3 | 206 | 28.19 | 4.87 |
| IR88886-7-2-1-4 | 110 | 120.3 | 205 | 27.22 | 4.76 |
| BRRI dhan66 (ck) | 113 | 117.0 | 229 | 24.19 | 6.41 |
| BR8521-30-3-1 | 122 | 128.8 | 261 | 16.73 | 5.43 |
| BR8526-38-2-1 | 122 | 109.1 | 273 | 17.80 | 5.28 |
| BRRI dhan49 (ck) | 123 | 107.3 | 275 | 19.39 | 5.47 |
| $LSD_{0.05}$ | 2.36 | 34.52 | 0.64 | 0.99 | |
| CV (%) | 1.1 | 7.8 | 1.6 | 10.2 | |

DS-16 Jul 2016, DT-12 Aug 2016.

**Table 9. Performance of some rainfed low land rice (RLR) lines, T. Aman 2016.**

| Designation | Growth duration (day) | Plant height (cm) | Panicle/m$^2$ | TGW (g) | Yield (t/ha) |
|---|---|---|---|---|---|
| BR8493-4-2-1-1 | 132 | 111.6 | 235 | 14.93 | 4.95 |
| BR8829-14-7-1 | 118 | 105.2 | 237 | 20.40 | 5.09 |
| BR8492-9-5-3-1 | 118 | 107.9 | 216 | 19.48 | 4.73 |
| BR8492-9-5-3-2 | 124 | 113.5 | 228 | 20.54 | 5.77 |
| BR8492-9-5-3-2 | 118 | 111.2 | 232 | 20.26 | 5.24 |
| BRRI dhan49 (ck) | 124 | 100.5 | 260 | 19.77 | 5.55 |
| Swarna (ck) | 132 | 100.7 | 261 | 20.53 | 5.47 |
| $LSD_{0.05}$ | 5.90 | 25.92 | 0.62 | 0.67 | |
| CV (%) | 3.1 | 6.1 | 1.8 | 7.2 | |

DS-16 Jul 2016, DT-11 Aug 2016.

**Regional yield trial (RYT-9) RLR, T. Aman, 2016**

Five genotypes and two standard checks BR11 and BRRI dhan49 were tested under this experiment to evaluate the lines for specific and general adaptability in Kushtia region. All the tested lines yielded higher than the check variety BRRI dhan49 (5.14 t/ha) but lower than the check BR11 (5.74 t/ha). However, the yields of all the tested genotypes were statistically similar (Table 10).

**Regional yield trial (RYT-10) RLR, T. Aman 2016**

Five genotypes and one standard check BRRI dhan49 was evaluated under this experiment to test the lines for specific and general adaptability in Kushtia region. All the genotypes yielded higher than the check except IR05N412. The highest yielder was BR9392-6-2-1B (6.35 t/ha).

**Regional yield trial (RYT-11), PQR, T. Aman 2016**

Six genotypes and three standard checks BRRI dhan34, BINA dhan13 and Tulsimala (Local) were evaluated under this trial to test the lines for specific and general adaptability in Kushtia region. All the lines yielded higher than the check varieties and among these BR8493-12-7-4(Com) gave highest yield (4.67 t/ha).

**Regional yield trial (RYT-12), PQR, T. Aman 2016**

Ten genotypes and one standard check BRRI dhan34 were evaluated for specific and general adaptability in Kushtia region. All the lines yielded higher than the check variety BRRI dhan34 and among these BR8297-1-1-2 HR1(Com) gave highest yield (4.96 t/ha).

**Regional yield trial (RYT-13), PQR, T. Aman 2016**

Six genotypes and three standard checks BRRI dhan38, BRRI dhan70 and Kataribhog were evaluated under this experiment for specific and general adaptability in Kushtia region. Most of the lines gave higher yield than the check varieties BRRI dhan38 and Kataribhog. However, BRRI dhan70 yielded the highest among all the varieties.

**Regional yield trial (RYT-14), MER, T. Aman 2016**

Four genotypes and three standard checks BRRI dhan32, BRRI dhan39 and BRRI dhan72 were evaluated for specific and general adaptability in Kushtia region. None of the lines gave higher yield than the check varieties.

**Regional yield trial (RYT-15, Biotech), T. Aman 2016**

Six genotypes and one standard check BRRI dhan39 was evaluated for specific and general adaptability in Kushtia region. Only two lines BR(Bio)8019-AC9-3-3-1 and BR(Bio)8019-AC5-1-2-1 gave higher grain yield than the check variety BRRI dhan39 and among the lines BR(Bio)8019-AC9-3-3-1 gave highest yield (5.70 t/ha).

**Table 10. Performance of some rainfed low land rice (RLR) lines, T. Aman, 2016.**

| Designation | Growth duration (day) | Plant height (cm) | Panicle/m$^2$ | TGW (g) | Yield (t/ha) |
|---|---|---|---|---|---|
| Suman Swarna (Rajshahi) | 135 | 123.2 | 220 | 20.10 | 5.52 |
| Ranjit Swarna (Rajshahi) | 135 | 124.5 | 225 | 20.58 | 5.52 |
| Nepali Swarna (Rangpur) | 135 | 123.9 | 241 | 21.27 | 5.21 |
| Swarna-5 (Rangpur) | 135 | 127.5 | 208 | 20.66 | 5.56 |
| Guti Swarna | 135 | 127.2 | 220 | 20.89 | 5.33 |
| BR11 (ck) | 129 | 118.1 | 239 | 24.30 | 5.74 |
| BRRI dhan49 (ck) | 126 | 105.1 | 240 | 19.33 | 5.14 |
| $LSD_{0.05}$ | 4.78 | 22.91 | 1.29 | 0.50 | |
| CV (%) | 2.2 | 5.7 | 3.4 | 5.2 | |

DS-16 Jul 2016, DT-13 Aug 2016.

**Regional yield trial (RYT-16), (PQR), Boro, 2016-17**

Four genotypes and two standard checks BRRI dhan50 and BRRI dhan63 were evaluated for specific and general adaptability of the genotypes in Kushtia region. Among the tested lines BR8079-19-1-5-1 and BR8590-5-2-2-5-2-2 gave higher grain yield (6.98 and 6.92 t/ha) than both the check varieties.

**Regional yield trial (RYT-17), (PQR), Boro, 2016-17**

Three genotypes were tested against standard check BR16 was evaluated under this experiment to specific and general adaptability of the genotypes in Kushtia region. None of the lines gave higher yield than the check variety.

**Regional yield trial (RYT-18), (DRR), Boro 2016-17**

Two genotypes were tested against IRBB60 (Resistant ck), BRRI dhan28 (Susceptible ck) and BRRI dhan29 (Susceptible ck) were evaluated for specific and general adaptability of the genotypes in Kushtia region. The line BR8333-15-3-2-2 gave higher grain yield (3.71 t/ha).

**Regional yield trial (RYT-19), (FBR), Boro 2016-17**

Four genotypes and three standard checks BRRI dhan28, BRRI dhan29 and BRRI dhan58 were evaluated for specific and general adaptability of the genotypes in Kushtia region. The check variety BRRI dhan29 gave higher grain yield (8.10 t/ha) than the lines and other checks but the line BR8109-29-2-2-3 outyielded the checks BRRI dhan28 and BRRI dhan58. However, it's yield was statistically similar to BRRI dhan29.

**Regional yield trial (RYT-20), (MER), Boro 2016-17**

Six genotypes and two standard checks BRRI dhan28 and BRRI dhan74 were evaluated under this experiment for specific and general adaptability of the genotypes in Kushtia region. The line BR7815-18-1-3-2-1 gave higher grain yield (8.01 t/ha) than the checks and other lines.

**Regional yield trial (RYT-21), (MER), Boro 2016-17**

Two genotypes and two standard checks BRRI dhan28 (ck) and BRRI dhan58 (ck) were evaluated for specific and general adaptability of the genotypes in Kushtia region. None of the lines could outyield the check BRRI dhan58.

**Regional yield trial (RYT-22), (Biotech), Boro 2016-17**

Four genotypes and one standard check BRRI dhan28 was evaluated for specific and general adaptability of the genotypes in Kushtia region. The line BR(Bio)0985-BC2-62-2 gave higher grain yield (7.41 t/ha) than the check and other lines.

**Regional yield trial (RYT-23), (Biotech), Boro 2016-17**

Five genotypes and one standard check BRRI dhan29 was evaluated under this experiment for specific and general adaptability of the genotypes in Kushtia region. The line BR(Bio)8333-BC5-1-20 gave higher grain yield (7.55 t/ha) than the check and other lines.

**Proposed variety trial (PVT), FBR, Boro 2016-17**

One genotype was evaluated against one standard check BRRI dhan28 was evaluated to recopmmend the proposed genotype as a new variety by the NSB team. The check variety BRRI dhan28 (6.45 t/ha) outyielded the proposed material BR7358-5-3-2-1-HR2 (6.33 t/ha).

**Proposed variety trial (PVT), MER, Boro 2016-17**

Two genotypes and one standard check BRRI dhan28 was evaluated under this trial to evaluate the proposed genotype by the NSB team for recommendation to release as a new variety. The proposed material BR7831-59-1-1-4-5-1-9-P1 gave higher yield (6.39 t/ha) than the check variety BRRI dhan28 (6.25 t/ha).

**Proposed variety trial (PVT), Biotech. (SD) Boro 2016-17**

Two proposed lines along with one check BRRI dhan28 were evaluated to observe the performance of the proposed lines releasing as variety. The proposed material BR(Bio)8072-Ac8-1-1-3-1-1 gave higher yield (7.32 t/ha) than the check variety BRRI dhan28 (7.04 t/ha) with two days shorter growth duration.

CROP-SOIL-WATER MANAGEMENT

**Terminal drought mitigation through integrated approaches in T. Aman 2016**

Drought is an unpredictable phenomenon and it reappears after 5-10 years. But we can't forecast the year of occurrence. The effect of drought is observed after some days of its beginning. Meanwhile crop is hampered and yield is reduced consequently. In T. Aman, long and short duration varieties were tested to determine the effect of drought on the yield of HYV rice in drought prone areas with two water management treatments (supplemental irrigation and levee management). Some integrated approaches were compared with farmer's practice (no supplemental irrigation; rainfed only). The approaches are 1. Variety: A long (BR11) and two short duration (BRRI dhan33 and BRRI dhan71) T. Aman, 2. Timely transplanting (22 July) for low risk drought during critical period of the crop and 3. Supplemental irrigation if necessary (35 cm) and approach 4: Levee management). The experiment was laid out in split plot design with water management in main plot and variety in subplot.

In supplemental irrigation plots all the varieties outyielded the farmer's practice plots (Rainfed condition) and yield differences between the plots were statistically significant. Hence it is observed that enhanced crop yield can be achieved if farmers practice levee management and apply supplemental irrigation when necessary.

In rainfed condition, BRRI dhan33 and BRRI dhan71 suffered comparatively less drought than BR11 due to its shorter growth duration at reproductive and ripening phase.

**Determination of suitable time for application of supplemental irrigation in T. Aman 2016**

In T. Aman 2016 the experiment was conducted to find out suitable time for application of supplemental irrigation with three treatments ($T_1$= Supplemental irrigation when water level goes 15 cm below ground surface, $T_2$= Supplemental irrigation when water level goes 25 cm below ground surface and $T_3$= Supplemental irrigation when water level goes 35 cm below ground surface). Nine, eight and five numbers of irrigation was applied when water level went down 15, 25 and 35 cm below ground surface respectively. The highest yield was found in $T_1$ (5.70 t/ha) and the lowest in $T_3$ (4.90 t/ha). Yield difference between the treatments $T_1$ and $T_2$ are statistically insignificant but yield difference between the treatments $T_1$ and $T_3$ and $T_2$ and $T_3$ are significant. So we can say that yield loss occurs when water level goes 35 cm below ground surface compared with standard yield.

SOCIOECONOMICS AND POLICY

**Stability analysis of BRRI varieties**

The experiment was conducted to maintain season, year and location-wise data base on the yield performance of BRRI varieties. The number of varieties tested in T. Aus, T. Aman and Boro 2016-17 was 10, 37 and 37 respectively.

Among the tested 10 varieties in T. Aus, the highest yield was obtained from the BRRI dhan48 (4.80 t/ha) and the lowest from the Local Variety-1 (Noya paizam) (2.41 t/ha). Lodging tendency was not found in any of the BRRI varieties during T. Aus season.

In T. Aman, 2016 the highest yield was obtained from BRRI dhan51 (5.70 t/ha) and the lowest from BRRI dhan38 (2.75 t/ha). Lodging was observed at different magnitudes (25%-40%) in case of six test varieties namely BR5, BR25, BRRI dhan32, BRRI dhan34, BRRI dhan37 and BRRI dhan38.

In Boro, 2016-17 the highest yield was obtained BRRI hybrid dhan2 (7.87 t/ha) and the lowest from BR7 (5.56 t/ha). Lodging tendency was not found in any of the varieties during Boro season.

**Grain quality and nutrition, Boro 2016-17**

Three varieties BR3, BRRI dhan28 and BRRI dhan29 were evaluated under this experiment to know the effect of changes in protein content on the yield of HYV rice in Kushtia region. In this case BRRI dhan29 gave highest yield (7.49 t/ha).

## TECHNOLOGY TRANSFER

Eleven batches of farmers' training and two field days were organized with the cooperation of the Department of Agricultural Extension (DAE) at different upazilas of Kushtia and Meherpur districts. About 330 and 250 farmers participated in the training and field day programs. Modern rice varieties and relevant technologies were disseminated among the farmers. We also participated in an 'Agricultural Fair' arranged by DAE, Kushtia district where BRRI developed technologies were demonstrated.