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GAZIPUR 1701

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Foreword

Bangladesh Rice Research Institute, the leader of rice research in Bangladesh, has been working on rice from laboratory to farmers' fields with an objective to improve rice production. Researchers from 19 divisions and 9 regional stations of Bangladesh Rice Research Institutes engaged themselves to discover new technologies in rice production. However, generation of technology has never been low hanging fruits. Every piece of researcher's work may put at least a little firewood to cook a palatable technology for rice. Many of the findings from short term research would not have immediate utility in the field but a series of continuous thoughtful work on a definite problem usually bring a sudden wonderful solution.

Rice production in Bangladesh confronts the challenges of low soil fertility, changing climatic conditions, low and high temperature during flowering, rice marketing issue, scarcity of laborers, shortage of irrigation water, industrial pollution and so on. Given the diversity of rice related constraints down from soil to socio-economic arena, researchers keep on turning the stones to look for a piece of solution in a scientific manner. This document, in fact, compiled some important findings, which are waiting for being a shape as technology in near future.

I believe all the abstracts compiled here are important, but at least some of them are very important for future discovery. I congratulate all the scientists who were keen to accommodate their abstracts in this issue and will keep on writing for the future issues. I am grateful to the people who managed time to compile, edit and made the abstracts more readable.

Dr. Jiban Krishna Biswas
Director General
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October 01, 2015

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VARIETY DEVELOPMENT

Identification and utilization of high yielding QTLs from wild rice

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The objective of the present study was to detect yield enhancing QTLs and to enhance grain yield of elite Bangladeshi rice varieties through introgression of identified QTLs from wild rice *Oryza rufipogon*. In this study two popular modern Boro rice varieties BRRI dhan28 and BRRI dhan29 were used as recipient parents and wild rice *Oryza rufipogon* (Acc. No. 103404 and 105890) were used as donors. A total of 430 simple sequence repeat (SSR) markers were used to identify polymorphism between the parents. Among the primer tested 108, 102 and 89 primers were identified for genotyping progenies of BRRI dhan28/*Oryza rufipogon* (Acc.no.105890), BRRI dhan28/*Oryza rufipogon* (Acc.no.103404), and BRRI dhan29/*Oryza rufipogon* (Acc.no.103404) crosses, respectively. Three BC₂F₂ QTL mapping populations were developed through backcross breeding method. In total 655 individual plants of three BC₂F₂ generations (238, 209 and 208 progenies of BRRI dhan28/*Oryza rufipogon* (Acc.no.105890), BRRI dhan28/*Oryza rufipogon* (Acc.no.103404), and BRRI dhan29/*Oryza rufipogon* (Acc.no.103404), respectively) were grown in the field. Phenotypic data on yield and yield components of all the three populations was recorded. Leaves from each plant were collected for DNA extraction followed by genotyping. For genotyping, 103, 33 and 25 polymorphic SSR markers were amplified from 238, 209 and 208 progenies of BRRI dhan28/*Oryza rufipogon* (Acc.no.105890), BRRI dhan28/*Oryza rufipogon* (Acc.no.103404), and BRRI dhan29/*Oryza rufipogon* (Acc.no.103404), respectively.

Keywords: Yield enhancing QTL, DNA extraction, *Oryza rufipogon*

Anther culture for development of modern rice variety

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In vitro production of double haploid plants through anther culture provides an efficient system for rapid production of homozygous lines. Therefore, an attempt has been taken for developing suitable salt tolerant rice variety through anther culture. Boots were collected at appropriate stage from F₁ plants and pre-incubated at 8°C for 8 days. The panicles were then cut into small pieces and surface sterilized by 70% ethanol.

For callus induction, anthers were plated into two different media (KE and M10) and kept in an incubator under dark condition at 25°C. Induced calli were then transferred into regeneration medium (MS medium containing 1.0 mg/l NAA+ 1.0 mg/l Kinetin) for regeneration. Data were taken on number of anther plated, number of calli produced, number of albino and green plants regenerated. A total of 62657 hybrid anthers of 27 F₁ populations were plated in KE and M10 media for callus induction. A total of 330 calli were obtained from KE medium and 10 calli were obtained from M10 medium. The highest numbers (73) of calli were obtained from hybrid anthers from BRRI dhan29×MR219 cross in KE medium. However, nine green plants were regenerated from hybrid anther from BRRI dhan29×FL478 cross and three plants from MR219×IRBB60 cross, respectively. After hardening, green plants were transferred into the earthen pots and seeds were harvested at maturity. Harvested seeds will be used for further evaluation and screened for tolerance to salinity.

Keywords: Callus induction, Plant regeneration, Indica rice.

Preliminary yield trial of anther culture derived doubled haploid lines from the cross between Niamat and BR802-78-2-1-1

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Anther culture is an important method for developing rice variety within shorter period of time by reducing the breeding cycle. During Boro 2013-14 season, a Preliminary Yield Trial (PYT) was conducted to evaluate the initial yield of seven anther culture derived doubled haploid lines developed from the cross between Niamat and BR802-78-2-1-1 with a standard check, BRRI dhan28. The experiment was conducted following randomized complete block design (RCBD) with three replications. Each entry was grown in a 5.4m × 8 rows having 25 cm × 15 cm spacing using single seedling/hill. Urea, TSP, MoP, zypsum and zinc fertilizer were applied at the rate of 261, 95, 120, 111 and 11 Kg/ha respectively. Data on plant height (cm), days to maturity, tillers per plant, panicles per plant, amylose content (%), protein content (%) and grain yield (t/ha) were recorded and analyzed by SAS program. Significant variation for growth duration was observed between the lines BR8072-AC₁-2-3-2-1-1, BR8072-AC₄-2-1-2-2-1, BR8072-AC₅-4-2-1-2-1 (137 days) and BRRI dhan28 (143 days). These doubled haploid lines were 6 days earlier than the check variety BRRI dhan28. The lines BR8072-AC₇-4-1-2-2-4 and BR8072-AC₉-1-1-2-1-1 gave the similar yield to that of BRRI dhan28. Plant

height of BRRi dhan28 was significantly higher than all the tested lines. The lines BR8072-AC₅-4-2-1-2-1, BR8072-AC₇-4-1-2-2-4 and BR8072-AC₈-1-1-3-1-1 contained 26%, 23.2%, and 25% amylose, respectively. On the other hand, these lines contained 9.5%, 9.8% and 9.2% protein, respectively which were higher than the check variety BRRi dhan28. On the basis of growth duration, yield and physico-chemical properties BR8072-AC₅-4-2-1-2-1, BR8072-AC₇-4-1-2-2-4 and BR8072-AC₈-1-1-3-1-1 lines were selected for further evaluation.

Keywords: Preliminary yield trial, Amylose, Protein

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

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BRRi dhan44 is one of the popular varieties in the tidal areas of Bangladesh due to its tall stature and bold grain shape. However, the variety has no submergence tolerance in tidal flood prone area. To address this problem, marker assisted backcrossing was done using BRRi dhan52 as the donor parent for *SUB1* QTL and the BRRi dhan44 as the recurrent parent. Both parent were crossed to generate F₁ population and then backcrossed. Primer survey was done between parents for selecting the polymorphic markers which are distributed throughout the rice genome. Foreground selection was done in the BC₁F₁, BC₂F₁ and BC₃F₁ population for selecting the plants possessing the target QTL. Seventy five polymorphic markers were used in BC₃F₁ and BC₄F₁ generation for background selection of BRRi dhan44. Five homozygous plants of BC₄F₁ were selected for backcrossing. Foreground selection was done in BC₅F₁ generation to confirm the plants having *SUB1* QTL and heterozygous plants were selected with SUB1C173 primer. In BC₅F₂ plants, foreground selection was done again with SUB1C173 primer to confirm homozygous plants for *SUB1* QTL in BRRi dhan44. Twenty-six homozygous plants for *SUB1* QTL were grown as observational trial during Boro 2013-14 season. Among them 13 lines were selected for further evaluation as preliminary yield trial (PYT) and screened under submergence condition. These line with submergence tolerance might be selected as a variety for the southern part of Bangladesh. .

Keywords: *SUB1* QTL, submergence tolerance, marker assisted backcross breeding

Development of transgenic salt tolerant rice by over expressing *GlyI* and

***GlyII* genes**

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Soil salinity is an important threat for rice production in the coastal region of Bangladesh. Therefore, it is important to develop salt tolerance transgenic rice varieties with high yield potential that enable to cultivate in the coastal region of Bangladesh for sustainable agriculture. In this study, two genes that encode for Glyoxalase I and Glyoxalase II, previously isolated from a *Brassica juncea* and *Oryza sativa* L cv IRBB10, respectively were selected to be overexpressed together in rice for developing salt tolerant transgenic rice varieties. These genes were reported to be involved in salt tolerance mechanism through glutathione-based detoxification of methylglyoxal in plant. In this experiment, mature embryo derived calli of BRRI dhan29 were used as explants and *Agrobacterium*-mediated transformation technique was followed. Dehusked sterilized seeds were placed on callus induction medium to produce embryogenic calli. Calli were then sub-cultured for actively growing calli. After that calli were infected with *Agrobacterium* containing *GlyI* and *GlyII* gene and co-cultivated on co-cultivation media for 48 hrs at 25°C in dark. Then infected calli were washed with sterile distilled water containing cefotaxime. The washed calli were placed on selection media containing hygromycin and cefotaxime for 15 days for first selection. This step was repeated two more times to get true transformants. Survived micro-calli were then transferred to the regeneration media followed by rooting media for rooting. After hardening plantlets were shifted to earthen pot and kept there until seed set. Putative transformants were confirmed by GUS test and PCR. These selected plants will be used for further analysis.

Keywords: Salt, Rice, Over expression, *GlyI* and *GlyII*

BRRI Dhan68: A rice variety for favorable boro environment

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A proposed variety trial was carried out in the farmer's field at Mymensingh, Faridpur, Barisal, Habiganj, Satkhira, Rangpur Rajshahi and at BRRI, Gazipur to evaluate yield performance of BR7830-16-1-5-3 against standard check BRRI dhan28 during Boro season 2013-14. The experiment was conducted following randomized complete block designed (RCBD) with three replications. Data were taken on plant height, days to maturity and grain yield. The plant height of BR7830-16-1-5-3 ranged from 118-120 cm which was slightly higher than standard check BRRI dhan28 (115-116). This line matured after 5 days later than BRRI dhan28 in proposed trial. On an average BR7830-16-1-5-3 gave 7.3 t/ha grain yield compared to , 6.4 t/ha BRRI dhan28 . BR7830-16-1-5-3 gave the highest yield in Rangpur (9.2 t/ha) followed by Mymensingh (8.0 t/ha) and Sonagazi (8.0 t/ha). In Gazipur it yielded 7.0 t/ha which is 0.9 t/ha higher than BRRI dhan28. The variety has green leaf, long and wider flag leaf and golden colored medium slender grain with amylase content of 24.0%. This breeding line has been approved and released by the national seed board as BRI dhan68 for commercial cultivation in the farmer's field.

Keywords: Favorable Boro, Irrigated Rice, BRRI dhan68

BRRI dhan63 is a premium quality rice variety like balam

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A set of experiments were conducted in the farmers' field of Gazipur, Mymensingh, Comilla, Feni, Habigonj, Rajshahi, Rangpur, Kustia, Barisal and Bhanga of Bangladesh to evaluate the performance of BR7358-30-3-1 against standard check BRRI dhan50 during Boro 2012-14 season as Proposed Variety Trial. The experiments were conducted following by randomized complete block design (RCBD) with three replications. The data on plant height, days to maturity, grain yield and productivity were taken in the trial. The plant height of BR7358-30-3-1 (86 cm) was similar to standard check BRRI dhan50 (83 cm). Lowest growth duration was found in Comilla (142 days) and highest growth duration was found in Rangpur (157 days) with an average of 149 days which was lower than standard check BRRI dhan50 (155 days). BR7358-30-3-1 gave 7.35 t/ha grain yield where as BRRI dhan50 gave 6.54 t/ha on an average. BR7358-30-3-1 gave highest yield in Rangpur (8.59 t/ha) followed by Mymensingh (8.37 t/ha), Habiganj

(8.04 t/ha), Bhanga (7.72 t/ha) and Rajshahi (7.44 t/ha). In all locations BR7358-30-3-1 gave higher yield than BRRi dhan50 in Proposed Variety Trial. BR7358-30-3-1 gave highest productivity in Mymensingh (58.53 kg/ha/day) followed by Rangpur (54.71 kg/ha/day), Habiganj (54.32 kg/ha/day), Bhanga (50.12 kg/ha/day) and Comilla (47.88 kg/ha/day). BR7358-30-3-1 gave approximately 0.5-1.0 t/ha higher yield with 4-6 days lower growth duration than BRRi dhan50 in Regional Yield Trial during Boro 2011-12. In Advanced Line Adaptive Research Trial during Boro 2011-12, BR7358-30-3-1 was also evaluated in farmers' field in 10 locations of Bangladesh and gave 0.50 t/ha higher yield than BRRi dhan50. BR7358-30-3-1 has deep green leaf and golden colored extra long slender grain comparable to Balam with amylose content 24.0%. National Seed Board approved BR7358-30-3-1 as a premium quality rice variety named BRRi dhan63 in 2014 for irrigated ecosystem of Bangladesh. BRRi dhan63 may become popular for its grain quality and market prize. Therefore, BRRi should take initiative for quick dissemination of BRRi dhan63 in irrigated ecosystem of Bangladesh.

Keywords: Premium Quality Rice, Irrigated ecosystem, Boro, Yield and BRRi dhan63.

Development of disease resistant rice varieties

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Out of 31 diseases of rice recorded in Bangladesh, bacterial blight (BB), rice tungro virus (RTV) and blast caused by fungus are the most serious ones and Transplanted Aman (T. Aman) and Boro crops are vulnerable to these diseases. Therefore, efforts were made for developing varieties resistant to bacterial leaf blight, rice tungro virus and blast diseases during T. Aman, 2012 and Boro, 2012-13 seasons. Ten crosses for BB and six crosses for Blast in T. Aman and six crosses for BB and four crosses for Blast in Boro season were made. Nine crosses for BB and two for blast during T. Aman were confirmed as true F₁. Sixty four resistant progenies for BB, 103 for blast and 40 for RTV were selected in T. Aman, while 26 resistant progenies for BB were selected in Boro season from F₂ population. Two hundred sixty-six superior progenies from three F₄ – F₆ generations comprised of 12 crosses were selected for BB, 37 for Blast from F₃ generation composed of 4 crosses and 7 for RTV from F₅ generation comprising a single cross were selected in T. Aman season. Whereas 260 superior progenies from F₃ – F₆ generations comprised of 5 crosses were selected for BB during Boro season. Twelve fixed lines were isolated from F₆ and F₇ generations for BB during Boro season. A total of 15 uniform lines for BB, 7 for Blast in T. Aman, while 8 for BB during Boro season showing better agronomic performance over the check varieties were selected from

observational trial (OT). Two genotypes, IR71676-34-1-1 and BR8216-6-2 yielded significantly higher coupled with almost similar growth duration and three genotypes with significantly higher yield but about 10 days long growth duration than checks varieties BRRI dhan33 and BRRI dhan39 were selected for BB; 6 genotypes for Blast and 9 genotypes for RTV were selected from preliminary yield trial (PYT) during T. Aman season. Two breeding lines in T. Aman and 5 lines in Boro seasons were selected for BB from secondary yield trial (SYT). Two genotypes namely BRC245-4-19-2-1 and BRC250-1-3-1-1 were selected for BB from regional yield trial (RYT) for higher grain yield and almost similar growth duration than the check varieties BR11, BRRI dhan39 and BRRI dhan49 during T. Aman season. These two lines might be advanced for advance line adaptive research trial (ALART) as well as could be screened for bacterial leaf blight under artificial inoculation condition.

BR18 and Hbj. B.VI: Potential indica donors for QTLs/genes conferring seedling stage cold tolerance in rice

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Cold injury during early establishment of boro rice crop is an emerging problem in Bangladesh. Due to climatic imbalance, boro rice in more than 2 million hectares in the northern areas of Bangladesh is affected by sporadic cold injury during winter season. Sometimes seedling mortality goes up to 90% causing increased cost of cultivation and low yield. To resolve this issue, a study was undertaken in collaboration with Korea International Cooperation Agency (KOICA) to screen BRRI varieties and genebank accessions in 2012. This study identified BR18, which was released for cultivation in haor areas of Bangladesh, as the potential cold tolerant donor. BR18 showed an average leaf discoloration score of 2.3 ± 0.7 under artificial cold water treatment of 10°C for 6 days at 3-leaf stage. This study also identified Hbj. B.VI as the highly tolerant indica rice to cold stress at seedling stage. However, Hbj. B.VI was reported earlier as reproductive stage cold tolerant rice variety by many other researchers.

Keywords: Cold injury, leaf discoloration, seedling mortality and rice

Association mapping of agronomic, grain characteristics, yield components and yield traits using an elite breeding panel

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Trait evaluation of 431 rice elite breeding lines using 19 agronomic traits was done in field experiments in two seasons using a randomized complete block design at the International Rice Research Institute at Los Banos, Philippines. The research aimed to determine the extent of trait variation within rice lines, the relationship between yield and other traits to identify some traits that could serve as predictors to improve rice yield for breeding purposes. Genome-wide association studies (GWAS) based on linkage disequilibrium (LD) provide a promising tool for the detection of quantitative trait loci (QTL) underlying complex agronomic traits. A total of 28 QTLs were located within the vicinity of previously identified QTLs for all traits using mixed linear model analysis in the irrigated elite breeding lines in dry season, and 45 QTLs in wet season. The highest association was for *QHd3a* conferring days to flowering ($P < 10^{-16}$) followed by known QTL for grain length breadth ratio ($P < 10^{-7}$ and *qgy10.1* QTL for grain yield per plot ($P < 10^{-6}$). Most QTLs had small effects which is typical of most quantitative traits. Most of the QTLs identified are season specific. Some other novel QTL alleles were also identified in this study that may be useful for increasing the yield potential in rice. These potential QTLs for selected traits are of interest to breeder and need to be further validated. Elite breeding populations proved to be interesting material for identifying regions involved in the variation of important traits in rice. This was the first study in rice in which an elite breeding panel was used. Previously for AM in rice, panels have consisted of land races and traditional varieties. We confirmed some regions already observed to be involved in the genetic control of plant height, days to flowering, length breadth ratio, 1000 grain-weight, yield per plant, filled grains per plant and grain yield per plot variation. Moreover, we discovered new QTLs for traits investigated. However the experimental design needs to be more powerful to improve the detection accuracy and reduce the genotype x environment interaction. This experiment will also allow testing several models of genomic selection with one or two training populations and one or two validation populations. Association mapping offers great potential to enhance the genetic improvement of rice. The use of high throughput and cost effective sequencing techniques that may enable GWA studies to become a popular and routine approach in rice. Accounting for population structure remains a big limitation for association studies that requires careful choice of germplasm and the development of advanced statistical approaches.

Keywords: Association mapping, elite breeding lines, rice (*Oryza sativa*)

Analysis of genotype-environment interaction for advance lines of rice using GGE biplot

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Rice is an important cereal crop which receives the most attention of specialists in plant breeding and production. However, its production is limited by the adverse environmental conditions. Therefore, multi-environment trials (MET) were conducted to evaluate yield stability performance of genetic materials under different environmental conditions. GGE biplot method is useful to identify the specific location and suitable lines for group of location and also compare of performance of lines at different locations. To evaluate genotype-environment controlling adaptation in rice, six rice advanced genotypes of Green Super rice such as IR83140-B-11-B(G1), SAGC06,(G2) ZHONGZU14(G3), Weed tolerant rice(G4), HUA565(G5) and BRRI dhan28(G6) were studied during 2012-13 Boro season under six different environmental conditions - Rajshahi(E1) Comilla(E2),Bhanga(E3), Hobiganj(E4),Barisal(E5) and Kushtia(E6) in Bangladesh. The genotypes were sown in a randomized complete block design with three replications and 25×15 cm² plant spacing. The combined ANOVA analysis for grain yield data indicated that the differences among all sources of variation were highly significant ($P < 0.01$). Environment (E), Genotype (G) and G x E interaction effects accounted for 23.60, 16.27 and 24.89% of the total sum of squares, respectively. From the polygon view of biplot analysis of MET data, the genotypes fell in three section and test environments fell in two section. The first section contains all most test environments E6, E3, E1, E5 and E2 with G2 and G4 as the best yielder. And the second section contains only one environment E4 with G3 as the poorest yielder. In this study, the highest yield had genotypes G2, G4, G5, G1 and the lowers had G3 and G6 .On the other hand the greatest stability in the high yielding group had genotypes G4, G5 and G1, while the most stable of all was G4. According to the ideal-genotype biplot, genotype G4 was the better genotype demonstrating high mean yield and high stability of performance across test locations. In other word, the lower yielding genotypes (G3 and G6) were unfavorable because they are far from the ideal genotype. In view of evaluation of environments, E1and E3 are most representative whereas E6 and E4 least representative. Comparison between two genotypes, G2 and G4 had higher yield in all environments except E4.Thus the difference between G2 and G4 was relatively large in E6 but very small in all other environments. Therefore, it is concluded that Weed tolerant rice (G4) is stable for a wide range of environments of Bangladesh.

Keywords: GGE, Biplot, Stability, Rice

BR7611-5-3-2 is a promising breeding line: An alternative of BR11 mega variety

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Proposed variety trials were carried out in the farmers' field of Gazipur, Mymensingh, Comilla, Feni, Habigonj, Rajshahi, Rangpur, Kustia, Barisal and Thakurgaon of Bangladesh to evaluate the performance of BR7611-5-3-2 against standard check BR11 during T. Aman 2013-14 season. The experiments were conducted following randomized complete block design (RCBD) with three replications. The data were taken on plant height, days to maturity, grain yield and productivity. The proposed variety BR7611-31-5-3-2 was taller (120 cm) than standard check BR11 (105 cm). The growth duration of proposed variety (138 days) was similar to standard check BR11 (137 days). Mean over the locations, BR7611-5-3-2 gave 5.05 t/ha grain yield compared to 5.31 t/ha in BR11. BR7611-5-3-2 gave highest yield in Feni (6.0 t/ha) followed by Rangpur (5.87 t/ha), Thakurgaon (5.71 t/ha), Habiganj (5.36 t/ha) and Rajshahi (5.24 t/ha). BR7611-5-3-2 gave highest productivity in Rangpur (41.93 kg/ha/day) followed by Thakurgaon (41.38 kg/ha/day), Feni (41.10 kg/ha/day), Habiganj (40.00 kg/ha/day) and Rajshahi (38.25 kg/ha/day). In all the locations productivity of BR11 was higher than BR7611-31-5-3-2 except Feni, Comilla and Gazipur. BR7611-5-3-2 (4.55 t/ha) and BR11 (4.67 t/ha) produced similar yield in Regional Yield Trial during T. Aman 2012-13. In Advanced Line Adaptive Research Trial during T. Aman 2012-13 the proposed variety was also evaluated in farmers field in 10 locations of Bangladesh and gave 0.23 t/ha higher yield (5.04 t/ha) than BR11 (4.81 t/ha) with similar growth duration. BR7611-5-3-2 has deep green leaf, erect and long flag leaf and golden colored medium bold grain with amylose content 25.7%. BR7611-5-3-2 has a special character having tolerant to medium stagnant water (30 cm). So National Technical Committee of National Seed Board recommended for re-trial of BR7611-5-3-2 in T. Aman 2015-16.

Keywords: Rainfed Lowland Rice, Stagnant water tolerance, T. Aman, BR7611-5-3-2

Development of short duration submergence tolerant rice varieties through marker assisted breeding

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An effort was undertaken in order to introgress *SUB1* QTL into the genetic background of the short duration rainfed lowland rice variety BRRI dhan33 utilizing marker assisted selection technique. BRRI dhan33 does not possess the flash flooding tolerant QTL-*SUB1*, and hence susceptible against flash flooding submergence. For introgressing submergence tolerant genes, BRRI dhan52 was used as donor and BRRI dhan33 as recipient parent. Marker-Assisted Backcrossing (MABC) approach was finished by BC₄F₃ generation. Selection for target QTL *SUB1* was carried out by gene-based marker Sub1C173, an STS marker specific to the putative Sub1C gene. A cross was made between BRRI dhan33 and BRRI dhan52 at Plant Breeding Division of Bangladesh Rice Research Institute (BRRI), Gazipur for developing elite breeding lines with broad-spectrum tolerance to flash flood. Eighty-four foreground and background markers were utilized in this MABC scheme. Finally, fifteen best lines were selected where the percentage of recipient genome recovery ranged from 90.7 to 95.2%. In observational trial under rainfed condition, the grain yield (ton/ha), plant height (cm) and growth duration of the 15 introgression lines were found similar to the standard check variety cum recipient parent BRRI dhan33. In a replicated trial under rainfed condition, the introgression lines showed similar performance with respect to grain yield and yield contributing parameters indicating successful recovery of recipient genome. Some phenotypic deviation found in the introgression lines compared to the recipient parent BRRI dhan33 might be produced due to environmental interactions. In replicated trial under controlled submerged condition (15 days submergence), the grain yield and survival percentage of the three introgression lines were found significantly higher than the recurrent parent BRRI dhan33 indicating satisfactory agronomic performance and successful submergence tolerance of the newly introgressed lines. In this condition, the grain yields of the introgression lines were found 1.24 to 1.71 ton/ha higher than the recipient parent. Submergence screening was again done over 15 BRRI dhan33-Sub1 lines and 03 genotypes viz. BR9157-12-2-37-13-71-41, BR9157-12-2-37-13-15-30, BR9157-12-2-37-13-15-40 demonstrated good survivability and very good recovery; the genotypes were obviously non-elongating type. The selected Sub1-lines are being used for participatory variety selection trial as well as molecular and physiological characterization for developing future durable and short duration submergence tolerant

variety. Finally the size of the donor introgression in the BRRI dhan33-Sub1 lines was measured to be 36.0 cM. This study illustrates the success of marker-assisted breeding program to introgress the flash flooding tolerant QTLs into the rice varieties of Bangladesh.

Keywords: Short duration submergence tolerant variety, Marker Assisted Breeding

BRRI dhan47: A potential donor for arsenic phytotoxicity tolerance in rice

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Arsenic contamination in ground water is a severe public health problem in Bangladesh. BRRI dhan47, a salt tolerant rice variety was first identified to give considerably stable yield at varying level of soil arsenic in 1999. Then a detailed study was undertaken to validate this result. This study showed that BRRI dhan47 yielded relatively higher in up to 51 ppm soil arsenic under natural and artificial soil arsenic conditions. This variety showed relatively stable performance in all growth and yield related traits over the varying levels of soil and water arsenic condition in selected arsenic prone sites of Aliabad, Gerda, Posra and BJRI farm in Faridpur district. Pot experiments with different levels of soil arsenic (0 to 60 ppm) in 2011 and 2012 also confirmed this finding. BRRI dhan47 was also found highly tolerant to phyto-toxicity at early seedling stage in a hydroponic culture with up to 5 ppm arsenic. A group of other researchers have also found BRRI dhan47 to retain relatively low proportion of arsenic in the polished rice grain.

Keywords: Arsenic, phyto-toxicity, rice

Confined field trial of provitamin A enriched 'Golden Rice' event GR2-R introgressed lines of BRRI dhan29

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A confined field trial of 22 provitamin A enriched BRRI dhan29 Golden Rice (event GR2-R) introgressed lines was conducted during Boro 2013-14 in Gazipur. The genotypes showed wide range of variations in yield and yield contributing traits. The grain yield ranged from 3.4 t/ha to 6.5 t/ha with an average value of 5.4 t/ha. Growth duration differed from 138 days to 149 days. In terms of days to flowering, plant height, panicles/hill, spikelet/panicle, filled grain/panicle, spikelet fertility, the test entries differed from 109 to 128 days, 81.8 to 131.5 cm, 12.6 to 15.4, 126.4 to 172, and 77.1 to

91.5%, respectively. Seven lines were selected considering similar or higher yield than the non-transgenic control, BRRI dhan29. These lines showed up to 12 % yield advantage over BRRI dhan29. Total carotenoid (TC) levels analyzed at three months of storage after harvest in brown paper bags varied from 8.1 to 15.5 ug/g in the selected lines. However, original Golden Rice event GR2-R had average TC value of 13.7ug/g. Based on per capita consumption, bio-conversion and retention rate after milling and cooking, the carotenoids level in the selected lines could meet at least 50% of the daily requirement for vitamin A for an adult in Bangladesh.

Keywords: Golden Rice, provitamin A and carotenoids

BRRI dhan62 and BRRI dhan64: Potential food based alternatives for alleviation zinc deficiency

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Poor people in countries like Bangladesh are dependent on rice for majority of their nutritional requirements. Rice is a popular and filling food but a poor source of vitamins and minerals. To enhance nutritional quality particularly, zinc content of white rice, we have been working since 2001 in collaboration with many international and national partners. Our recent successes are the development and release of BRRI dhan62 and BRRI dhan64. The former one is the first official release of zinc enriched rice variety in the world. This variety matures at an average of 100 days and yield more than 5.0 t/ha in T. Aman season under optimum management condition. Recent reports shows that this variety yielded more than 6.0 t/ha in farmers field condition. Due to the shortest ever growth duration, this variety might be the best fit in the areas where farmers wish to grow early potato and vegetables to increase total productivity of their land. On the other hand, BRRI dhan64, a boro rice variety can yield more than 6.0 t/ha in 150 days. However, it can yield up to 7.5 t/ha under optimum management condition. Zinc content of this variety is more than 24 mg/kg, which is 5 and 8 mg/kg higher than that in BRRI dhan62 and commonly used conventional white rice, respectively. Micronutrient malnutrition due to deficiency of zinc in the pre-school aged children and pregnant women can be reduced substantially upon regular consumption of rice of these varieties.

Keywords: Micronutrient, malnutrition, zinc, rice

BRRRI dhan66: a new drought tolerant variety for drought prone area of Bangladesh

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The proposed variety trials were carried out in the farmers' field of drought prone environments at Godagari and Tanore in Rajshahi, Porsha and Neamatpur in Naogaon, Chapai Nawabganj, Rangpur, Nilphamari, Dinajpur and Kustia along with one control trial at BRRRI, Gazipur of Bangladesh to evaluate the performance of IR82635-B-B-75-2 against standard check BRRRI dhan56 during T. Aman 2013-14 season. The experiments were conducted following randomized complete block design (RCBD) with three replications. The Data were taken on plant height, days to maturity, grain yield and productivity. The plant height of IR82635-B-B-75-2 was ranged from 118-120 cm which is slightly higher than standard check BRRRI dhan56 (115-116 cm). The proposed variety IR82635-B-B-75-2 was matured 3 days after BRRRI dhan56. On an average IR82635-B-B-75-2 gave 4.02 t/ha grain yield compared to 3.23 t/ha in BRRRI dhan56. IR82635-B-B-75-2 gave the highest yield in Lalmonirhat (4.94 t/ha) followed by Rangpur (4.82 t/ha), Tanore (4.73 t/ha) and Nilphamari (4.31 t/ha). In Gazipur it yielded 4.17 t/ha and BRRRI dhan56 yielded 3.46 t/ha in the control trial. IR82635-B-B-75-2 gave highest productivity in Lalmonirhat (43.33 kg/ha/day) followed by Rangpur (42.28 kg/ha/day), Tanore, Rajshahi (41.49 kg/ha/day), Nilphamari (38.14 kg/ha/day) and Kustia (37.96 kg/ha/day). In all locations productivity of IR82635-B-B-75-2 (35.58 kg/ha/day) was higher than BRRRI dhan56 (29.36 kg/ha/day). In Advanced Line Adaptive Research Trial during T. Aman 2012-13, the proposed variety BR82635-B-B-75-2 was also evaluated in drought prone environments of farmers field in 8 locations of Bangladesh and gave 0.51 t/ha higher yield than BRRRI dhan56. The proposed variety has deep green leaf, long and wider flag leaf and golden colored medium slender grain with amylose content of 23.0%. We hope that the proposed variety BR82635-B-B-75-2 may be suitable for cultivation in drought prone rainfed T. Aman rice cultivated area of Bangladesh. National Seed Board of Bangladesh approved IR82635-B-B-75-2 as a drought tolerant variety named BRRRI dhan66 in 2014.

Keywords: T. Aman, Rainfed Lowland Rice, Drought tolerance, BRRRI dhan66

Progress of salt tolerant rice variety development for the coastal regions of Bangladesh

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Salinity, an important abiotic stress, has been affecting rice production in coastal regions. Rice is sensitive to salt stress at seedling and reproductive stages. Several experiments were conducted during T. Aman and Boro 2013-14 at BRRI Gazipur and BRRI Satkhira in order to develop salt tolerant rice variety suitable for saline prone areas of Bangladesh. Sixty-seven crosses for T. Aman and 48 crosses for Boro were made. A total of 28 for T. Aman and 38 F₁'s for Boro were confirmed and selected. One hundred and forty-nine progenies from 15 crosses in T. Aman and 242 progenies from 7 crosses in Boro were selected from F₂ populations; 796 progenies and 29 genetically fixed lines were selected from T. Aman while 815 progenies and 59 fixed lines were selected from pedigree nurseries of Boro. Eleven from T. Aman and 20 advanced lines from Boro were selected from OT, 18 for T. Aman and 9 entries for Boro were selected from PYTs. Nine genotypes for T. Aman and 8 for Boro were selected from SYTs. Two genotypes - IR78761-B-SATB1-28-3-24 and IR78761-B-SATB1-28-3-26 were selected from ALART and recommended for Proposed Variety Trial. Moreover, genotypes BR7100-R-6-6 and IR78794-B-Sat29-1 were evaluated by National Seed Board team and approved BR7100-R-6-6 to release as BRRI dhan67 for salt tolerant Boro variety. Four genotypes (IR78761-B-SATB2-17-1, IR73055-8-1-1-3-1, IR78761-B-SATB1-68-6 and IR83440-4-B-11-2-1-1-AJY1-B) in T. Aman and four genotypes (IR83484-3-B-7-1-1-1, IR86385-117-3-1-B, IR86385-117-1-1-B and IR84649-308-7-1-B-AJY1-B) in Boro were preferred and selected through Participatory Varietal Selection (PVS) by the farmers which showed consistency with yield performances. Varietal trials conducted during Aus, T. Aman and Boro at Polder 43/F/2 (low saline), T. Aman and Boro at Polder 30 (medium saline), and T. Aman at Polder 3 (high saline). Farmers did not cultivate modern rice varieties in these areas for many years and introduction of adaptable modern varieties like BRRI dhan52, BRRI dhan53 and BRRI dhan54 in polder 43/2/F was the first adoption of HYVs in this area. BRRI dhan47, BINA dhan8 and BRRI dhan61 with medium duration was suitable at polder 30 in Boro season, and farmers also preferred BRRI dhan47 and BR7100-R-6-6 due to its higher yield and good grain quality through PVS. Participatory Varietal Selection and validation trials were conducted under IAPP (breeding-salinity) at three upazilas viz. Amtoli, Borguna, Sadar and Kalapara, Patuakhali during Aus, T. Aman and Boro seasons. Farmers in coastal region preferred Mala (an unidentified HYV),

BRRRI dhan28 BRRRI dhan47 and BRRRI dhan55 in Aus; BRRRI dhan52, BRRRI dhna41, BRRRI dhan53, BR11-Saltol and BRRRI dhan54 in T. Aman; and BRRRI dhan58, BR7100-R-6-6, BRRRI dhan29, BINA dhan10, BRRRI dhan47 and BRRRI dhan61 in Boro, respectively. Information generated through PVS about varietal performance and acceptability would be helpful for rapid varietal diffusion and popularization.

Keywords: Salinity, Coastal regions, Proposed Variety Trial, Participatory Variety Selection

Genetic diversity of some BBRI developed rice varieties using SSR markers

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SSRs are frequently utilized in rice for studying genetic diversity, polymorphisms, evolutionary analyses, prediction of hybrid performance, marker assisted selection and analyses and tagging of valuable quantitative trait loci (QTL) and genes. The objectives of the present study were (1) to estimate the genetic diversity, (2) to evaluate of the degree of polymorphism among seven modern Arsenic susceptible and tolerant rice varieties, and (3) to identify SSR markers which would be useful in QTL mapping for Arsenic (As) tolerance rice breeding. Genomic DNA was isolated from young leaves of 30-day-old seedlings following modified Miniscale standard method. PCR amplification was performed at G-storm DNA Thermal Cycler. The genetic distance was calculated using the Nei distance. The allele frequency data from Power Marker version 3.25 was used for analysis with Numerical Taxonomy and Multivariate Analysis System (NTSYS-pc) and similarity matrix was calculated with the Simqual subprogram using the Dice coefficient. Cluster analysis was done by unweighted pair group method for arithmetic mean (UPGMA) and a dendrogram was generated using the programme NTSYS-pc. A total of 299 SSR markers were used covering the whole rice genome equally where 135 SSRs showed monomorphism and 165 showed polymorphism. A total of 405 alleles were detected at 165 polymorphic SSR loci and the number of alleles per marker ranged from 2 to 5, averaging of 2.45 alleles per locus. The band size for a given microsatellite locus varied between 73 bp (RM9) to 335 bp (RM539). Polymorphism information content (PIC) values ranged from 0.21 to 0.70, with an average of 0.36. Total 43 markers were found as highly informative marker. Among them, RM437 showed the highest polymorphism followed by RM9, RM472, RM85, RM548, RM334, RM336, RM464, RM222 and RM229 which might be effectively used for

genetic diversity and relationships study of rice. Comparatively higher genetic distance was observed between BRRI dhan47 and BRRI dhan50 than the other combinations. Seven rice varieties were constellated into three groups in the dendrogram, where cluster 1 contained only the most As tolerant variety BRRI dhan47, cluster 2 represents three varieties having moderate As tolerance ability (BRRI dhan50, BRRI dhan54 and BRRI dhan55) and cluster 3 contains three As susceptible varieties (BRRI dhan28, BRRI dhan29 and BRRI dhan45). The markers used here were of value for DNA fingerprinting of rice varieties, for selection of the parents for utilizing in the rice breeding program and constructing a database for breeding programs, especially in background selections during backcross breeding. In addition, the data could be used for As tolerant QTL identification.

Keywords: Genetic polymorphism, Cluster analysis, SSR markers, Rice

Progress on the development of drought tolerant rice varieties in rain fed lowland rice ecosystem in Bangladesh

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A participatory varietal selection (PVS) trial was conducted to identify suitable drought-tolerant genotypes through farmers' preference analysis. Results from the PVS trial indicated that the drought tolerant breeding lines IR74371-70-1-1 and the early-maturing, terminal drought-escaping line BR7873-5*(NIL)-51-HR6 were preferred by a majority of the farmers. Considering farmers' choices and researchers' points of view, these breeding lines were finally evaluated by the National Seed Board of Bangladesh (NSB) and released as BRRI dhan56 and BRRI dhan57 in 2010 for drought prone areas under the rainfed lowland ecosystem. In 2012, NSB evaluated another drought tolerant line, IR82635-B-B-75-2 (IR08L251) and compared it with BRRI dhan56. In 2014 breeding line IR82635-B-B-75-2 (IR08L251) appeared as a new variety BRRI dhan66. In 2013 Advanced line Adaptive Research Trial (ALART) were also conducted. Three IRRI lines viz. IR83377-B-B-93-3, IR82589-B-B-84-3 and IR83383-B-B-129-4 gave satisfactory yield (4.0-4.5 t/ha) with 114-116 days growth duration. These three lines were recommended for proposed variety trial (PVT). Some drought tolerant donors we characterized morphologically in the field condition. These donors have been used in breeding program to generate drought tolerant progenies (F₂-F₆ generations). Molecular breeding

efforts are underway to develop a drought tolerant version of the submergence tolerant variety BRRI dhan52.

Keywords: Drought tolerance, Rainfed Lowland Rice, BRRI dhan56, BRRRI dhan57, BRRI dhan66

Introgression of *SUB1* QTL into BRRI dhan49 Using Marker Assisted Backcross Technique

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BRRI dhan49 is an early transplanted Aman variety having 135 days growth duration. The variety does not possess the flash flooding tolerant QTL-*SUB1*. Molecular markers tightly linked to submergence tolerant QTL (*SUB1*) was utilized in a marker assisted selection program to develop elite breeding lines with broad-spectrum tolerance to flash flood. Sequence tagged site (STS) and simple sequence repeat (SSR) markers were used to detect the submergence tolerant genes. A cross was made between BRRI dhan49 and BRRI dhan52 (containing submergence tolerant *SUB1* QTL). High-volume backcrossing techniques were followed to produce large numbers of backcross seeds from the selected plants of different backcross generation. At each backcross generation, phenotypic selection and markers closely linked to *SUB1* QTL were used to select plants possessing the tolerant genes (foreground selection). In BC₄F₁ generation, microsatellite markers are polymorphic between donor and recurrent parents were used to select plants that have maximum contribution from the recurrent parent genome (background selection). In BC₄F₁ generation, 3 best plants were selected from previously selected ten heterozygous plants. The percentage of recipient genome recovery in the best plant 42, 47 and 49 were 86.84 %, 85.13 % and 85.0% respectively. This research work illustrates the successful application of marker-aided breeding to introgress the flash flooding tolerant QTLs into a rice variety of Bangladesh.

Keywords: *SUB1* = Submergence1, QTL= Quantitative Trait Locus, STS= Sequence tagged site

Correlation and path analysis of some promising hybrid rice

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Path coefficient along with correlation coefficient analysis gives relatively detailed information on the relations among traits. An experiment was conducted to study the correlation coefficient and path coefficient analysis of promising hybrid rice for yield and yield contributing characters. The study involved eight promising hybrids along with three checks grown in RCBD design with three replications at the Bangladesh Rice Research Institute farm in T. Aman 2014. The genotypes exhibited significant difference in agronomic characters as well as grain yield. The results indicated that grain yield strongly correlated with effective tillers per meter square (0.643*), number of spikelet per panicle (0.690*) and percent of spikelet fertility (0.847**). Path analysis revealed that percent spikelet fertility had high positive direct effect on grain yield which was followed by number of spikelet per panicle. On the other hand effective tiller per meter square had positive indirect effect on grain yield. Thus, the results suggested that effective number of tillers per meter square, number of spikelet per panicle and percent spikelet fertility should be used as reliable criteria for selection of promising hybrids.

Keywords: Correlation, path analysis, hybrid rice

Interaction effect between GA₃ and row ratio of restorer and CMS lines on different characters and F₁ seed production of BRRI hybrid dhan

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Recently developed hybrid rice at Bangladesh increased hybrid seed growers' interest in the country. Poor exertion of panicle represents a major problem in WA based CMS lines, and application of GA₃ effectively overcome the constraint. However, appropriate rates of GA₃ and row ratio of restorer and CMS lines for hybrid seed production in locally developed hybrid rice has not been reported. We conducted an experiment aiming to determine the appropriate rates of GA₃ and the proper row ratio of restorer and CMS lines for F₁ seed production for BRRI hybrid dhan2. Experiment was conducted during November to May 2012-13 involving four levels of GA₃ 0 - 350 g ha⁻¹ and five row ratios (R:A) viz. (i) 2:8, (ii) 2:10, (iii) 2:12, (iv) 2:14 and (v) 2:16. The experiment was laid out in a RCBD with three replications. Thirty-day-old seedlings of

R and A lines were transplanted @ 3-4 seedlings and 2 seedlings per hill, respectively. The row spacing maintained for R-R, R-A and A-A lines were 40, 30 and 15 cm, respectively. Urea, TSP, MP, Gypsum, zinc, borax and cowdung were applied @ 370, 250, 370, 150, 20, 7 Kg/ha and 15 t/ha respectively as mentioned in Chinese Production Technical handout. Interaction effect of different levels of GA₃ and row ratios of restorer and CMS lines significantly influenced the growth and yield components of rice except 1000 grain weight. The highest number of effective tillers hill⁻¹ (14.03) and the highest panicle exertion rate (98.08%) was found when level of GA₃ was applied @ 250 g ha⁻¹ to the row ratio of restorer and CMS lines of 2:14. The maximum number of grains per panicle (66.40) was found with 250 g ha⁻¹ at row ratio of 2:12. This treatment combination produced the highest seed yield (2.90 t ha⁻¹). Our data suggests that the row ratio of 2:12 for restorer and CMS lines and the application of GA₃ at the rate of 250 g ha⁻¹ should be appropriate for BRRI dhan2 seed production.

Keywords: GA₃, Row ratio, out crossing rate and hybrid seed production

Inheritance of fertility restoration involving wild abortive cytoplasmic male sterility system in rice (*Oryza sativa* L.)

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Precise understanding of genetics of fertility restoration is useful in planning a sound breeding strategy for development of superior restorers in a hybrid breeding program. It may also help in the efficient transfer of restorer genes into other agronomical desirable genotypes. Fertility-restorer genes are important in the production of hybrid rice. With this view, the present study was undertaken to determine the genetic control of fertility restoration of WA-CMS system. A year-round experiment was conducted starting with raising F₁ plants following selfing and backcrossing them with their respective female parents to generate F₂ and BC₁ populations in the second season. In the third season we evaluated pollen and spikelet fertility of each plant in the F₂ and BC₁ populations. From each plant, five anthers from different spikelets were collected and their pollen grains were stained in 1% Iodine Potassium Iodide (IKI) solution. Plants were classified on the basis of pollen fertility analysis as fertile (61-100% pollen stained), partially fertile (31-60%), partially sterile (1-30%) and sterile (<1%) based on their shape and extend of staining under an optical microscope. One panicle from each plant was bagged before flowering for spikelet fertility analysis and spikelet fertility of bagged panicle was counted at maturity stage. The bagged panicle was examined for seed set and classified as fertile (81-100% seed set), partially fertile (31-80%), partially sterile (1-30%) and sterile (<1%). The parental lines, F₁ progenies, 250 F₂ plants for each segregating population were grown and

evaluated in the same conditions for phenotypic and pollen fertility rate was used as the main criteria for the evaluation of fertile and sterile plants. F₁'s contained two rows, F₂ seven rows, BC₁ five rows with 37 plants/row and non replicated. For inheritance analysis plants with less than 1% stained pollen were categorized into the sterile class, and all others were regarded as fertile. Chi-square analysis was used to estimate the distribution pattern of *Rf* alleles with WA type source of CMS lines. Inheritance of fertility restoration was studied in crosses involving ten elite restorer lines of rice viz. BR6839-41-5-1R, BR7013-62-1-1R, BR7011-37-1-2R, BRR10R, BRR11R, BRR12R, BRR13R, BRR14R, BRR15R and BRR16R and one male sterile line Jin23A with WA sources of cytoplasmic male sterility. The segregation pattern for pollen fertility of F₂ and BC₁ populations of crosses involving Jin23A indicated the presence of two independent dominant fertility restoring genes. The mode of action of the two genes varied in different crosses revealing three types of interaction, i.e. epistasis with dominant gene action, epistasis with recessive gene action, and epistasis with incomplete dominance. Our findings proved that the fertility restoration system with WA sources of CMS line Jin23A is controlled by a pair of independent dominant fertility restoring genes.

Keywords: Cytoplasmic male sterility, fertility restoration, inheritance, *Oryza sativa*

Genotype by environment interaction and stability analysis of grain yield and its related traits in brr1 developed promising hybrid rice genotypes

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Hybrid rice technology has attracted the attention of researchers and policy makers in all over the world as a viable option to overcome the yield ceilings of presently available modern rice varieties. The study was performed to analyze the genotype-by-environment (G×E) interaction for thirteen (13) promising rice hybrids over 5 locations (Barisal, Comilla, Gazipur, Rangpur and Satkhira) during Boro 2012-13 seasons in Bangladesh. The purpose of this study was to evaluate the magnitude of stability and adaptability of the genotypes in different regions of the country in different environmental status. Multivariate analysis (MANOVA) technique was used for grain yield, days to 50% flowering and number of panicles per m² where two genotypes were used as local check. The AMMI (Additive Main effects and Multiplicative Interaction) model was used to assess the interaction and to select better performing ones having higher yield and other potential attributes. Considering the mean, regression coefficient (bi) and deviation from regression (S²di), all the genotypes showed different responses of adaptability under different environmental conditions. Analysis of variance

(ANOVA) showed significant G×E for grain yield, days to 50% flowering and number of panicle per m². Among the hybrids BRR10A/BRR12R, BRR1 9A/BRR15R, BRR1 hybrid dhan2, BRR1 dhan28 and BRR1 dhan29 found highly stable across the environments. BRR10A/BRR12R, BRR1 9A/BRR15R, II32A/BRR15R, II32A/BRR10R and BRR1 hybrid dhan3 were highly stable as well as high yielder. BRR1 hybrid dhan2 was the highest yielder and stable across environment. Comilla and Satkhira showed high mean with high negative interaction. Gazipur had moderate yielder with high positive interaction and Barisal given negligible interaction and found highly suitable region in Bangladesh for hybrid rice cultivation.

Key words: AMMI Model, Environment, Genotypes and Interaction.

Identification of novel QTL for salinity tolerance in rice from a Bangladeshi landrace Ashfal

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Salinity is one of the major abiotic stresses which increase the thirst to develop salt tolerant rice variety in rice growing areas worldwide to feed half of the world's population. Genotyping of 94 extreme F₂ progenies of Bangladeshi landrace Ashfal and the mid-sensitive parent IR64 and phenotyping of the 300 F_{2:3} populations were carried out to identify salinity tolerant QTLs in rice for salinity tolerance at seedling stage. After two weeks of salinization at an EC of 12 dS m⁻¹, the F_{2:3} lines has been characterized for several physiological traits associated with salinity tolerance. A genetic linkage map has been constructed using 120 SNPs markers polymorphic between the two parents. The map covers 1768.5 cM with an average distance of 14.74 cM between loci. A total of 94 QTLs were identified using Composite Interval Mapping with the software QGene 4.3.10 for the phenotypic traits; 82 of them were significant at 1% level of significance. Among them 24 large effect QTLs with a range of phenotypic variance of 30% -45% were identified on chromosome 1 for SES scores at one week after treatment (WAT) (*qSES-1WAT1.1*), SES scores at three week after treatment (WAT) (*qSES-3WAT1.1*), root K⁺ concentration (*qRKC1.1*), shoot Na⁺ concentration (*qSNaC1.1*), root Na⁺/K⁺ ratio (*qRNaKR1.1*), shoot Na⁺/K⁺ ratio (*qSNaKR1.1*), Chlorophyll A (*qCha1.1*), Chlorophyll B (*qChb1.1*), Chlorophyll A&B (*qChab1.1*); on chromosome 3 for SES scores at three Week after treatment (WAT) (*qSES-3WAT3.1*), root length (*qRL3.2*), shoot Na⁺ concentration (*qSNaC3.1*), shoot K⁺ concentration (*qSKC3.1*), shoot Na⁺/K⁺ ratio (*qSNaKR3.1*),

Chlorophyll A (*qCha3.1*), Chlorophyll B (*qChb3.1*), Chlorophyll A&B (*qChab3.1*); on chromosome 4 for root length (*qRL4.1*), Chlorophyll A (*qCha4.1*), Chlorophyll B (*qChb4.1*), Chlorophyll A&B (*qChab4.1*); on chromosome 5 for root length (*qRL5.1*); on chromosome 10 for root length (*qRL10.1*) and on chromosome 11 for root length (*qRL11.1*); Additional QTLs with phenotypic variances in the range of 16% to 29% were also identified. The positive QTL alleles for all QTLs were contributed by the tolerant parent. Some of these QTLs will be important for marker assisted improvement of salt susceptible varieties in future.

Keywords: QTL, Salinity tolerance, SNPs.

Characterization of important rice (*Oryza sativa* L.) genetic resources of Bangladesh

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A coordinated subproject entitled on characterization of important plant genetic resources implemented through National Agricultural Research System (NARS) and universities funded by NATP: Phase I of PIU, BARC. As a part of the project Bangladesh Rice Research Institute (BRRI) was involved with the activities of rice genetic resources with the objectives to analyze the genetic diversity and population structure of Bangladeshi rice germplasm; characterize important local germplasm both at morphological and molecular levels; and establish Intellectual Property Rights (IPR) of important local rice germplasm to protect from any biopiracy. To achieve the objectives several experiments were carried out both in field and laboratory to characterize rice germplasm in morpho-agronomic and at molecular levels in order to establish varietal rights through DNA fingerprinting and diversity analysis. The experiments were conducted at BRRI farm, Gazipur and laboratory during Aus 2012, T. Aman 2012, Boro 2012-13 and Aus 2013. In the field, 246 germplasm accessions were characterized in Aus, T. Aman and Boro seasons using standard rice germplasm descriptor and evaluation form. Besides, 20 Geographical Indication (GI) rice genotypes were also characterized using 53 morpho-agronomic traits. It revealed from the morpho-agronomic characters that most of the test germplasm are different from each other showing their identical nature. Out of 266 germplasm, 260 genotypes were characterized in molecular level using 100 SSR markers. For GI rice, 65 primers were

used to find out the polymorphism and 30 primers were found polymorphic. In Aus season, 48 Aus landraces were characterized with 30 primers of which 14 found polymorphic. Similarly, in T. Aman season, 96 germplasm were characterized using 22 primers and eight were found polymorphic. In Boro season 96 landraces were characterized using 25 primers and 12 were found polymorphic. The germplasm were analyzed for diversity using the polymorphic markers and six to seven clusters were formed in different season. Among these, 96 T. Aman rice were grouped into six clusters, 48 Aus rice genotypes grouped into six clusters, 96 Boro rice genotypes grouped into seven clusters and 20 GI rice grouped into six clusters. It was also observed from the molecular characterization that RM180 was the best primer to identify GI rice genotypes. Similarly, RM519 for Aus, RM163 for T. Aman and RM283 for Boro were the best marker in respective seasons. It was apparent that diversity prevailed in the germplasm both in morpho-agromonic and at molecular levels. Based on the habitats of rice germplasm and data generated through morphological and molecular characterization through this project would be helpful to establish IPR of Bangladeshi rice germplasm.

Keywords: Characterization, Rice (*Oryza Sativa* L.), genetic diversity, microsatellite markers

Nucleus seed production of BRRI developed rice varieties

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A total of 60 varieties of which 33 (all BRRI developed and released T. Aman varieties and BR21, BR24, BRRI dhan27, BRRI dhan42, BRRI dhan43, BRRI dhan48) in T. Aman and 27 (all BRRI developed and released Boro varieties and BR26) in Boro seasons, respectively were grown for maintaining as nucleus stock of BRRI developed rice varieties and sources of breeder seed for maintaining their genetic purity and homogeneity of morphological characteristics during 2013-14. 'Panicle to row' method was used for maintaining nucleus stocks. According to panicle to row method, intact panicles were sown instead of threshed seeds and seedlings from a panicle were then transplanted in to a single line for easy observation and identification of off-type. In this method required number of healthy panicles, representing a typical variety was selected and checked individually for panicle and grain characteristics. Seedlings were transplanted into panicle to row method in the main field for variety maintenance as well as breeder seed production. All the varieties were transplanted following 20x20

cm² spacing in T.Aman and Boro seasons, respectively. Fertilizers were applied @ 80:15:60 kg NPK/ha in T.Aman and @ 140:20:80 kg NPK/ha in Boro seasons. All P, K and 100 kg gypsum per ha were applied at the time of final land preparation. All protection measures were carefully taken against diseases, insect pests infestation and weed from sowing to harvesting. Urea was applied as top dress in two-three splits usually 7-10 days after transplanting, 20-30 days after transplanting and 40-50 days after transplanting depending on the crop conditions and growth duration. Individual row was carefully observed throughout the growing season for varietal characteristics. Off-type plants and rows were identified and rogued out at least three different growth stages. However, roguing was done as and when necessary. Healthy intact panicles from typical true to type plants of all the varieties were selected and harvested from nucleus stock maintenance plots and kept separately for growing nucleus stock in the following year for variety maintenance. It was revealed from the result that the extent of roguing was varied from 0 to 0.01% for maximum cases and in little case it was up to 0.05%. The nature of off-types of the newly released varieties was mainly segregating type population. But, in few cases ratoon rice varieties were also found as off-type, mainly in plots where in previous season rice was cultivated. The major agromorphological characters that reasoning for causing or making off-type plants were seedling height, plant height, days to flowering, grain size, grain shape, grain color and awning. Finally it can be concluded that newly released varieties need to be rogued vigorously and carefully to avoid segregating population and proper maintenance of the types. Secondly Nucleus seed need to be cultivated in plots, where rice-fallow-rice cropping pattern is followed.

Keywords: Nucleus seed, rice variety, BRRI.

Molecular characterization and genetic diversity in geographical indication (GI) rice (*Oryza sativa* L.) landraces of Bangladesh using SSR markers

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Genetic diversity of 20 geographical indication (GI) rice genotypes of Bangladesh was analyzed to characterize and discriminate the varieties as well as to establish the sovereignty of Bangladeshi rice gene pool. Seeds were germinated in germination chamber and then sown in pots. DNA was extracted from 3 weeks old young leaves

following a simple and modified protocol of Zheng *et al* 1995 to isolate total genomic DNA for polymerase chain reaction (PCR) analysis. Thirty SSR markers with known amplifications distributed in 12 chromosomes were used for diversity analysis of the varieties. Molecular weight for each amplified allele was measured in base pair (bp) using Alpha-Ease 5.0 software. The allele frequency data from Powermarker version 3.25 was used to export the data in binary format (allele presence="1" and allele absence = "0") for analysis with NTSYS-pc version 2.2. A similarity matrix was calculated with the Simqual subprogram using the Dice coefficient, followed by cluster analysis with the SAHN subprogram using the UPGMA clustering method as implemented in NTSYS-pc was used to construct a dendrogram showing relationship among the genotypes. The number of alleles per locus ranged from 5 alleles (RM275) to 15 alleles (RM180), with an average of 9.7 alleles across the 30 loci obtained in the study. The polymorphism information content (PIC) values ranged from 0.59 (RM275) to 0.90 (RM180), were identified. RM180 was found the best marker for identification of GI rice genotypes as revealed by PIC values. The frequency of the most common allele at each locus ranged from 15% (RM85 and RM180) to 55% (RM275, RM277). Molecular clustering of GI rice in dendrogram revealed six clusters at 14% coefficient of similarity level. The results from this study provided some useful implications for establishment of sovereignty of Bangladeshi rice gene pool especially on GI rice. The evaluation of genetic similarity and cluster analysis provides some useful guides for assisting plant breeders in selecting suitable genetically diverse parents for the crossing program.

Keywords: Landrace, Rice (*Oryza Sativa* L.), genetic diversity, microsatellite markers

Assessment of genetic variability of aromatic and fine rice genotypes through multivariate analysis

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Variability was assessed in 113 aromatic and fine rice genotypes for identifying parental genotypes having distant relationship for hybridization. This experiment was conducted at the experimental plot of Bangladesh Rice Research Institute (BRRI), Gazipur during T. Aman season 2011. One hundred thirteen (113) aromatic and fine rice genotypes were studied following RCBD design with three replications. All of the traits were significant and highly significant among the accessions. The genotypes were grouped into ten clusters. The inter- cluster distances were higher than intra-cluster

distances indicating wider genetic diversity among the genotypes of different clusters. The cluster I contained the highest number of genotypes (19) and the cluster VI contained the lowest (3) genotypes. Regarding the inter-cluster distance, the highest value was found between cluster V and X (16.116) followed by the cluster II and X (15.791) and so on. On the other hand, the lowest inter-cluster distance was observed between clusters I and III (3.710) followed by the clusters III and IX (3.775) indicating that genotypes of these clusters were genetically closed. The above result indicated that the genotype comprises in the cluster V and X were more diverse than the genotypes occupied in the cluster I and III. Therefore, parent's selection for hybridization from the cluster III and X may give the desirable heterosis for heterotic rice hybrids. Seedling height, flag leaf area, culm diameter and grain breadth had maximum contribution towards genetic divergence. High heritability coupled with high genetic advance as percent of mean i.e. flag leaf area, secondary branches per panicle, filled grains per panicle, grain length, grain breadth, length-breadth ratio and 1000 grain weight should be given top priority during selection of genetically diverse parents in breeding program.

Key words: Genetic variability, D² analysis, cluster analysis, aromatic rice (*Oryza sativa* L)

Effect of different degrees of milling on the retention of Iron and Zinc in some rice varieties

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Zinc deficiency is a major public health problem in Bangladesh, where 44.6 percent of young children and 57.3 percent of women are affected. Rice usually contains more Zn at the surface of endosperm and polishing of the grain reduce these important minerals. The present study aimed to determine the varietal difference and degree of polishing on Zn content in rice. We parboiled the rough rice and determined the effect of the degree of milling on the zinc content of 10 Bangladeshi rice varieties. The varieties tested were BRRI dhan28, BR11, BRRI dhan47, BRRI dhan49, BRRI dhan29, BRRI dhan52, BRRI dhan55, BR16, BRRI Hybrid dhan3 and Swarna. The zinc content in the tested rice varieties were determined at 0 (brown), 2, 4, 6, 8, and 10% degree of milling. Reducing the degree of milling from 10% to 4% resulted in a mean increase in zinc content of 27% and 47%, respectively. Based on the findings of the Laboratory Milling Experiment it may be concluded that milling up to 6-8% degree of polishing retained about 60% iron and zinc and the organoleptic quality is expected to be accepted by the consumers.

Keywords: Bangladesh, degree of milling, parboiling, rice, zinc

Development of salt tolerant BR11 and BRRI dhan28 through marker-assisted introgression of *Saltol* QTL for seedling stage salinity tolerance of rice

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Salinity is the most widespread problems in the world of agriculture. One-third of rice growing areas of the world are affected by excess salt accumulation due to irrational management, climate change and natural hazards. In Bangladesh, saline area has been increased more than 20% during past three decades and the total affected area now >1.02 Mha. Molecular breeding approaches like Marker-assisted selection (MAS) and Marker-assisted backcrossing (MABC) are now frequently used to introgress favorable alleles and major effect QTLs (Quantitative Trait Loci) in to mega varieties and elite genotypes for the improvement of different complex abiotic and biotic stress tolerance traits. *Saltol*, a major QTL identified from Pokkali in chromosome 1, accounts for 43-65% phenotypic variation for seedling stage salinity tolerance. Bangladeshi mega rice variety BR11 (*transplated Aman* season) and BRRI dhan28 (*Boro* season) was targeted to improve seedling stage salinity tolerance through introgressing *Saltol* QTL. FL378, a tolerant F₈ Recombinant Inbred Line (RIL) developed from IR29/Pokkali B was used as donor to introgress *Saltol* QTL in to BR11 and BRRI dhan28 by MABC. Three backcrosses and two selfing generations were carried out to transfer positive alleles of *Saltol* from FL378 into a clean and/or minimum background donor introgression of BR11 and BRRI dhan28. In BR11 *Saltol* introgression work, two Near Isogenic Line (NIL) at BC₃F₃ stage were selected through markers with 1.3 Mb introgression at the *Saltol* region and 97 to 99% recurrent genome recovery at the background. Four different sized segments i.e. 1.3, 2.4, 3.3 and 3.7 Mb were introgressed in to BRRI dhan28. Six NILs at BC₃F₃ stage were identified with 99% recovery of the recurrent genomes. Single Nucleotide Polymorphism (SNP) markers were used to further check any potential background introgression of the selected 8 NILs from both works. SNP markers show similar recovery and background introgression as of SSR markers used for selection during MABC. SNP assay identified single SNP for smaller segment at the *Saltol* region while 2 SNP for the largest segment i.e. 3.7 Mb. Two NILs (NIL52 and NIL1) with 1.3 Mb introgression in to BR11 background showed statistically insignificant improvement

for seedling stage tolerances. Six NILs (NIL412, 434, 607, 618, 657, 683) with largest introgression (3.7 Mb) at BRRI dhan28 background showed better tolerances at seedling stage. But all have very similar phenotype such as duration and most of the agronomic traits with greater yielding ability than recipient mega variety BRRI dhan28. All *Saltol*-NILs are now under trials in the actual saline conditions of Satkhira and Khulna for testing tolerance gains due to *Saltol* QTL and yield potential at saline condition for their eventual release as high-yielding salt tolerant rice.

Keywords: Salt tolerance, *Saltol* QTL, Marker-assisted Backcrossing,

Investigation of new sources of submergence tolerance from diverse Bangladeshi rice germplasms

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Flash flood submergence, stagnation and tidal submergence cause huge loss in rice production frequently. Experiments were conducted to identify new sources of tolerance for developing durable submergence tolerant rice variety. Three hundred rice genotypes were characterized in the *Transplanted Aman* season (June-August) in 3 consecutive years from 2011-2013. All germplasms were tested in comparison with the tolerance and susceptibility of FR13A and BR5 along with few *Sub1* introgression lines. Seedlings of 14 days of age were transplanted to the puddled soils in rows with 20 by 20 cm spacing in a concrete submergence tank. Plants were completely submerged in 75 cm flood water after 14 days of establishment with proper care and maintenance. An artificial turbid condition was maintained throughout the submergence period. The submergence duration was maintained up to 14 days with proper monitoring of water temperature and light transmission towards the crop canopy by a thermometer and under-water quantum sensor, respectively. Survivability and recovery scoring was carried out at 5 and 30 days after de-submergence, respectively. Two Bangladeshi germplasm *Sada Dangar Boro* and *Pathor Nuti* demonstrated similar elongation rate, survivability, and recovery efficiency as the tolerant check FR13A. Three *Sub1* introgression lines (BR9377-9-14-7, IR72046-B-14-8-3-1 and IR77092-B-2R-B-10) were also identified as tolerant to 14 days of complete submergence having good survivability, excellent recovery and obviously non-elongating type. Molecular and physiological characterization of the identified germplasms are necessary to understand the mechanisms for tolerance and could serve as additional sources of tolerance for developing future durable submergence tolerant variety.

Keywords: Submergence tolerance, rice germplasm, survivability.

Screening for heat tolerant rice genotype

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In general, high temperature affects at all the growth phases of rice plant but detrimental at reproductive phase particularly reduction division and heading stage. For overcoming the high temperature problem, identification of new donors for future heat tolerant breeding is necessary for the development of new high temperature tolerant variety. An experiment was conducted to identify new heat tolerant donor from 51 genotypes. Out of 51 genotypes 12 were BRRI germplasm, 25 were BRRI released Boro and Aus variety, 12 were exotic or indigenous cultivar and BRRI dhan56 and BRRI dhan57. Twenty- day- old seedlings of all genotypes were transplanted in earthen pot in the natural condition of Plant Physiology Division, BRRI, Gazipur. All pots were kept in natural condition until heading with recommended management practices. During heading triplicate pots of each variety were transferred to high temperature ($38\pm 2^{\circ}\text{C}$) and high humidity ($75\pm 5\%$) in controlled glass house and one set were kept in natural condition. After 7 days of heat treatment and completion of flowering the pots were moved back to the natural condition. Spikelet fertility at maturity was used for evaluating the heat tolerance of each genotype. Temperature and humidity were maintained by thermohygrograph set in glass house chamber. Among the BRRI germplasms only three genotypes – Acc. No. 97, 102 and 133 showed 41-60% fertility under heat stress treatment and got scored 5. None of the BRRI released HYV showed spikelet fertility more than 40%; 22 varieties scored 9 and 5 varieties scored 7 under heat stress condition. The exotic cultivar Apo scored 5 and the indigenous cultivar Kasalath scored 3. Environmental temperature extremes coinciding with the critical stage of plant development reduced the spikelet fertility of BRRI released varieties in natural condition. Acc. Nos. 97, 103, and 133 and Kasalath may be recommended to use as donor parent to develop heat tolerant variety.

Keywords: heat tolerance, rice genotypes, reproductive stage

Studies on the cold tolerance of two advance rice genotypes (IR7749-31-2-1-3-1, IR2266-42-6-2) for whole growth periods under natural condition

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Cold injury of Boro rice is a common problem for many areas in Bangladesh. Low night temperature (5-13°C) might be a limiting factor for growth of rice plant, especially at seedling and reproductive phases. Early planting of short duration rice varieties usually suffer from low temperature shock at reproductive phase. We have a variety BRRI dhan36 which is cold tolerant only at seedling stage. This study was conducted to find out the tolerance level of two advance breeding lines to low temperature at different growth stages. Two selected advanced rice genotypes (IR7749-31-2-1-3-1, IR2266-42-6-2) were evaluated using BRRI dhan28 and BRRI dhan36 as check at BRRI farm Gazipur during boro 2013-14 season. To ensure cold spell both at seedling and reproductive stages the plants were seeded on 10 October, 20 October, 30 October and 15 November. The experiment was laid out in split plot design with three replications. Both the advance rice genotypes (IR7749-31-2-1-3-1, IR2266-42-6-2) showed cold tolerant at seedling stages and their vegetative vigor were significantly higher than standard check BRRI dhan36 and susceptible check BRRI dhan28. Both the advance breeding lines showed similar cold tolerance at seedling stage. However, the advanced breeding lines as well as the check varieties showed a little tolerance to cold injury at reproductive phase. However, last internode length and panicle emergence of both advance rice genotypes were significantly higher than BRRI dhan36 but comparable to BRRI dhan28 in 10 October seeded plants. When seeds were sown in November, significantly the highest grain yield was recorded from IR7749-31-2-1-3-1 followed by IR2266-42-6-2, BRRI dhan28 and BRRI dhan36. Both the advance breeding lines produced significantly higher grain yield than check due to higher number of panicle per unit area and grains per panicle. Advance rice genotypes IR7749-31-2-1-3-1 and IR2266-42-6-2 have tolerance to cold at seedling stage and their growth duration is like our existing cold tolerant variety BRRI dhan36. They might be useful during boro season in cold prone Northern parts of Bangladesh and can be further evaluated in those areas.

Key words: Rice, growth, cold, tolerance

Screening of BRRI germplasm for high zinc and iron enriched cultivar

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Zinc deficiency is a major public health problem in Bangladesh, where 44.6 percent of young children and 57.3 percent of women are affected. To address micronutrient malnutrition especially of zinc, enriching the nutrient content of rice, the primary staple food in Bangladesh, is preferable. Some of the land races of Bangladesh contain high amount of zinc and iron. By using XRF machine, rice germplasms in BRRI Germplasm bank were evaluated for their Zn and Fe content. A total of 2500 land races and local cultivars from BRRI Germplasm bank were tested. About 10-15g of paddy was collected from BRRI Germplasm bank. Two-thirds of seeds were dehulled with Satake dehuller

and one- third of paddy from each sample was kept as references. The dehulled brown rice was used for X-ray fluorescence (XRF) analysis. The XRF machines were primarily calibrated and standardized for measuring Zn and iron in the rice grain. Total 651 germplasm contained fairly higher (>40 mg/kg) Zn in the grain. But the variation in iron content not was not so high (>17 mg/kg). Zn and Fe content in the grain showed very poor coorelation ($r = 0.14$). Land cultivar Nirin, Shor shori, Panpiaz, Madab sail, Malbhog contained relatively higher amount of zinc and Shoni, Moishor, Matichak, Moiral contained high amount of iron. Shita, Sada saita, Porangi and Botweswor had content of both zinc and iron. Local germplasm or local cultivar may be used as potential donor for high Zn and Fe in rice breeding program to increase the micronutrient level of rice.

Key word: Rice genotype, Zinc, Iron

CROP-SOIL-WATER MANAGEMENT

Impacts of different competition period of *Echinochloa crusgalli* on plant characters and critical period of weed control on transplanted aman rice

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An experiment was conducted at Agronomy Research field, Bangladesh Rice Research Institute, Gazipur during the year 2012 to determine the growth behavior of transplanted aman rice under different competition durations with *Echinochloa crusgalli*. The aman season rice variety BRRI dhan56 was used as a test variety. Different durations of weed interference (20DAT, 40DAT, 60DAT and throughout) and weed free period were imposed to understand the impact of time on crop characters and yield of rice. The results revealed that all the growth characters LAI, LAD, DMA, CGR and NAR were reduced with prolonged weed competition. Panicle/m², grains/panicle, grain yield were also reduced with increasing duration of rice-weed competition. *Echinochloa crusgalli* is a severe competitor of rice even at early growth stage because all the growth parameters of the rice crop were significantly suppressed by the increasing trend of rice-weed competition durations. Therefore it is a must that *Echinochloa crusgalli* should be controlled as early as possible for good vegetative growth of rice crop. It can be concluded that in case of short duration aman variety like BRRI dhan56 weed competition can be allowed not more than 20 days after transplanting.

Deep Placement of NPK Briquette: Environment Friendly Technology for Rice Production

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Nine experiments were conducted at Bangladesh Rice Research Institute (BRRI) farm, Gazipur, BRRI regional station, Sagordi, Barisal and farmers' field, Barisal during Boro, T.Aus and T.aman season, 2012 to evaluate the NPK briquette efficacy in rice production. Experimental result revealed that deep placement method of NPK briquette in rice production saved 51 kg N ha⁻¹ in Boro and around 29 kg N ha⁻¹ in T.Aus and T.Aman season. Deep placement of nitrogen gave higher grain yield broadcast urea application. Undiscounted benefit cost ratio (BCR) was 1.44, 2.40 and 3.20 for Boro, T.Aus and T.Aman, respectively. Thus, use of NPK briquette over urea broadcast and incorporation was economically viable and efficient for rice cultivation. NPK deep placement reduced N loss through soil-water interface which plays vital role in reducing environmental pollution.

Effects of reduced rates of nutrient application on Rice

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Fertilizers play the most critical role in rice crop production with maintaining the soil health and sustainable production in agriculture of Bangladesh. The investigation aimed to find out the effects of reduced rates of nutrient application to optimize rice yield. An experiment was conducted on Sonatala silt loam soil at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during Boro, 2014. The experiment involved a randomized complete block design (RCBD) with three replications. Seven treatments, control (T₁), recommended Fertilizer Dose, RFD (T₂), 60% of RFD (T₃), 70% of RFD (T₄), 80% of RFD (T₅), 90% of RFD (T₆) and = 110% of RFD (T₇) were evaluated in this study. The application of RFD included 100 kg N ha⁻¹, 15 kg P ha⁻¹, 50 kg K ha⁻¹, 15 kg S ha⁻¹ and 1.5 kg Zn ha⁻¹. Nitrogen, phosphorus, potassium, sulphur and zinc were applied as urea, TSP, MP, gypsum and zinc sulphate, respectively. The full doses of TSP, MP, gypsum and zinc sulphate were applied as basal dose during final land preparation. Urea was applied in three equal splits at 15-20 days after transplanting. Different fertilizer treatments significantly affected the grain and straw yields of BRRI dhan29. Recommended fertilizer dose (T₂) gave the highest grain yield (5.15 t ha⁻¹). The yield of T₂ was statistically similar to that of treatments T₅, T₆ and T₇. The maximum traits of nutrient content in grain and straw; nutrient uptake by grain and straw, and the sum total were also higher for the treatment T₂ albeit T₅ showed statistically similar result. The tallest plant production, effective tillers hill⁻¹, highest panicle length, filled grains panicle⁻¹, production and highest 1000-grains weight were also observed in the treatment T₂. Grain yield progressively increased with increasing nutrient uptake in BRRI dhan29. The application of 80% of RFD fertilizers significantly affected the yield contributing traits, nutrient content and nutrient uptake by grain and straw. The results further revealed that overall performance of the treatment T₅ and the treatment T₂ remained statistically similar. The results clearly indicated that 80% of RFD might be recommended instead of RFD in enhancing the yielding capacity of aforesaid cultivar in Sonatala silt loam soil of Bangladesh.

Keywords: Recommended fertilizer, Nutrient content, Nutrient uptake,

Nursery management for submergence tolerant rice variety

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Flash floods or submergence are known to be very common in Bangladesh, damaging rice crops that have little tolerance to submergence. With the recent development of the *SUB1* introgressed gene into mega rice varieties are released as BRRI dhan51 and BRRI dhan52 in Bangladesh for commercial cultivation. Farmers in flooded areas are now able to transplant and harvest rice despite the regular occurrence of flooding. Performance of these varieties can further be enhanced through adoption of appropriate management practices both in nursery and in main field so that farmers can fully be benefited from them. Robust seedlings also provide good anchorage to enable them to withstand submergence damage and show rapid yield losses caused by submergence. To help farmers in the northern part of Bangladesh, improve their crop management and rice yields, we conducted a study testing different nursery management options and their effect on survival, grain yield and yield components under control submergence conditions. The experiment was conducted at the Bangladesh Rice Research Institute (BRRI) Regional Station in Rangpur during T. Aman season 2012 and 2013. The two management factors as 1) four levels of nutrient management and 2) three levels of seedling age at transplanting were tested in 2012 and 2013. Results of this experiment revealed that raising of seedlings with the application of N-P₂O₅-K₂O @ 100-50-50 kg ha⁻¹ and transplanting them at an optimum age (35 days) produced maximum grain yield of BRRI dhan51 after submergence. These finding suggest the use of optimum seedling age and illustrate that by making a minor additional investment to raise healthy and vigorous seedlings in nursery seedbed, farmers can improve yields in their submergence prone areas.

Keywords: Rice, production, submergence tolerance, nursery management

Use of mixed rice husk and bran as tray media for raising rice seedling in boro season

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Seedling transplanting by mechanical rice transplanter is a promising technology in Bangladesh due to labor shortage during peak period of rice transplanting. Cold spell

is a major factor arresting the seedling quality in Boro season. Rice husk and bran mixed with soil may act as an insulator or mulch to preserve soil temperature. This experiment was conducted at the Agronomy Field Laboratory, Bangladesh Rice Research Institute, during December, 2013 to January, 2014 to study the effect of mixed rice husk and bran as tray media on tray seedling quality. Seedlings were raised on plastic trays using five different tray media. The tray media consisted of T₁ (100% soil), T₂ (75% soil+25% mixed rice husk and bran), T₃ (50% soil+50% mixed rice husk and bran), T₄ (25% soil+75% mixed rice husk and bran) and T₅ (100% mixed rice husk and bran). The experiment was conducted in a completely randomized design and replicated thrice. Tray media were prepared and placed on trays three days before sowing of seeds. Sprouted seed of BRRI dhan29 was used as planting materials. Seedling root and shoot length, leaf number, leaf color, dry weight were recorded from 20 seedlings per tray were randomly taken at 25 days after seeding. The effects of tray media on seedlings quality in terms of leaf number, leaf color, seedling height and dry weight were significant. The tray media containing 50% soil+50% rice husk and bran performed better in terms of leaf number (2.93), leaf color (3.36), seedling height (12.46cm) and dry matter (0.338g). The highest seedling strength (41.94mg cm⁻¹) was also obtained from 50% soil +50% rice husk and bran tray media. The 100% soil and 100% mixture of rice husk and bran both produced the lowest seedling strength. Therefore, 50% loamy soil + 50% rice husk and bran may be used as tray media to produce quality seedling for mechanical transplanting in boro season.

Keywords: Cold spell, rice transplanter, seedlings strength and seedlings quality

Nitrogen management for salt tolerant rice varieties in coastal saline region of Bangladesh

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About 53% of the coastal areas of Bangladesh are affected by various degree of salinity. Nutrient deficiencies of N and P are quite dominant in saline soils. Nitrogen (N) is the most limiting nutrient for rice in tropical Asian soil. Modern high yielding saline tolerant rice varieties may have differences in accumulating and using N from soil and applied fertilizer. An experiment was conducted in the farmer's field of Patuakhali and Satkhira for two consecutive years to evaluate saline tolerant varieties under different nitrogen fertilization management. Four saline tolerant varieties BRRI dhan40, BRRI dhan41, BRRI dhan53 and BRRI dhan54 and one sub1 variety BRRI dhan52 were grown in four nitrogen management practices. The N management treatments were

prilled urea, urea application according to LCC, USG deep placement and urea applied following rice crop manager software. At Patuakhali, during 2012 and 2013 water salinity varied from 1.39 to 2.87 and from 1.30 to 2.32 ds m⁻¹, respectively. At Satkhira water salinity varied from 0.32 to 1.32 ds m⁻¹ in the experimental plot. The interaction of N management and varieties demonstrated significant effect on grain yield and N uptake during 2013 at Patuakhali. Under the main plot of varieties at Patuakhali during 2012 grain yield of rice varied from 3.57 to 4.29 t ha⁻¹ and the yield range in the N treated plots was 3.92 – 4.22 t ha⁻¹. Tested rice varieties varied in grain N uptake (21.41-25.96 kg ha⁻¹) and straw N uptake (8.75-11.40 kg ha⁻¹). During 2013 at Patuakhali, BRRI dhan41 gave the highest grain yield (5.79 t ha⁻¹) with USG application and BRRI dhan53 produced the lowest (1.67 t ha⁻¹) grain yield when applied urea based on rice crop manager software. BRRI dhan40 uptake the highest total N (59.21 kg ha⁻¹) when applied USG. However BRRI dhan53 uptake the lowest total N (18.37 kg ha⁻¹) with N applied based on rice crop manager. At Satkhira district during 2013, grain yield of rice varieties varied from 2.82 to 5.22 t ha⁻¹ and the yield range in the N treated plots was 4.41- 4.96 t ha⁻¹. Tested rice varieties varied in total N uptake (31.41-55.96 kg ha⁻¹) and total straw N uptake (47.48-53.28 kg ha⁻¹). The study shows that, in the coastal saline areas of Patuakhali and Satkhira, all the salt tolerant varieties of T.Aman performed better with the nitrogen application from USG. Among the varieties BRRI dhan40 is the best followed by BRRI dhan41 at Patuakhali district and at Satkhira district BRRI dhan54 is the best followed by BRRI dhan40. Irrespective of varieties, nitrogen treatment from USG is the best in both the sides. In this study genotypic variation in saline tolerant varieties was reflected in N use of the applied N fertilizer. Hence, improving appropriate nitrogen fertilization is one of the measures to improve grain yield of saline tolerant rice.

Keywords: Saline tolerant varieties, Saline soil, Nitrogen management

Site specific nutrient management for irrigated rice in low ganges river floodplain of Bangladesh

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Site- specific nutrient management (SSNM) approach is an effective tool to determine optimum nutrient doses for a crop across a wide range of land type. The purpose of this research was to recognize spatial variability in soil fertility depending on response of

indigenous nutrient element and calculate the amount of fertilizer correctly for developing site specific nutrient management package for rice production. Participatory field trails were conducted for irrigated rice involving 108 farmers from Faridpur, Gopalganj and Madaripur district (Low Ganges River Floodplain, AEZ-12) during Boro season in 2012. We took four fertilizer treatments: i) Omission of N (-N), ii) Omission of P (-P), iii) Omission of K (-K) and iv) Full dose of NPK. High yielding popular Boro varieties (hybrid or inbreed) were used as test crops in different fields. We followed randomized complete block design. Results demonstrated enormous variation in the indigenous N, P, and K supply among farmers' fields across the locations. However, the full doses of fertilizer application produced the highest grain yield ($> 7.0 \text{ t ha}^{-1}$) in most fields. The plots without application of P and K containing fertilizer produced about 6.0 t ha^{-1} . Nitrogen omission plots produced the lowest grain yield ($< 5.0 \text{ t ha}^{-1}$). The response of indigenous N was mentionable and it gave similar grain yield of NPK but native P and K response was poor. For optimum grain yield in Boro season farmers can be recommended for using N, P and K @ 143, 6 and 35 kg ha^{-1} in Faridpur; 94, 5 and 20 kg ha^{-1} in Gopalganj; and 88, 3 and 11 kg ha^{-1} in Madaripur.

Keywords: Site specific nutrient management, Irrigated rice, Low Ganges River Floodplain

Nutrient management for irrigated rice based on rice crop manager in the Low Ganges River Floodplain of Bangladesh

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An easy-to-use and interactive computer-based fertilizer management decision tool has been developed called Rice Crop Manager (RCM) by the collaboration of IRRI and BRRI. The purpose of this research was to evaluate the field specific fertilizer guideline obtained from RCM and to minimize the fertilizer cost for rice production in Low Ganges River Floodplain of Bangladesh. Participatory field trail was conducted involving 72 farmers field of Gournadi, Agailjhara and Uzirpur of Barisal (Low Ganges River Floodplain AEZ-12) during Boro season 2013. The field specific fertilizer guideline evaluated obtained from RCM was compared with farmer's fertilizer practice (FP), soil test based (STB) and BRRI recommended fertilizer management (BR). Farmers grew their preferred rice varieties and applied fertilizer according to protocol of the selected treatments. The treatments were laidout in randomized complete block design. Fertilizer management based on RCM gave around 6.0 t ha^{-1} grain which was slightly

lower than that of BRRI recommended fertilizer practice. But, the amount of fertilizer required for RCM was significantly lower than of FP and BR. Fertilizer management based on RCM reduced fertilizer cost compared to farmer's fertilizer management and soil test based fertilizer management during Boro season. Rice crop manager ensure application of right amount and timing of N fertilizer, right amounts of P and K. The fertilizer dose of rice crop manager was lower and yield was comparable to BRRI recommended practice. The RCM calculated the doses of urea, TSP and MoP fertilizer but did not take gypsum and zinc sulphate under consideration. Again, it is knowledge based, required internet connection and sometimes it is difficult to collect correct information also. So, it requires further improvement.

Keywords: Site specific nutrient management, Irrigated rice, Low Ganges River Floodplain

Soil fertility management in single cropped area of the Low Ganges River Floodplain of Bangladesh

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Relatively secured rice yield in Boro season and vulnerable production of deep water rice possesses farmers to single cropped area in the greater Faridpur region of low Ganges River Floodplain. Dark grey to brown colour soils of this area are silty clay loam to clay; predominantly calcareous in nature, having neutral to slightly alkaline pH. The organic matter content is moderate in the basins and fertility level is medium with high CEC and K, Zn and B status is medium. Deficient plant nutrients for cultivating modern variety are mainly N, P, K, S and Zn fertilizers in Bangladesh Rice Research Institute farm, Bhanga, Faridpur was determined for getting the maximum grain yield. Omission plot technique was followed involving seven fertilizer management treatments 1) NPKSZn, 2) PKSZn, 3) NKSZn, 4) NPSZn, 5) NPKZn, 6) NPKS and 7) No fertilizer. The treatments were distributed followed by Randomized Complete Block design with replicated thrice. Transplanting was done in January, 2012 and 2013 using 46- and 50-day-old seedlings in 20 x 20 cm spacing. Popular long duration variety in greater Faridpur region, BRRI dhan29 was transplanted and fertilizer was applied at the rate of 114-20-60-12-13 kg/ha as NPKSZn as per treatment in the respective plots. Required amounts of N, P, K, S and Zn were applied through urea, triple super phosphate, murate of potash, gypsum, zinc sulphate, respectively. Fertilizer were applied as per treatment at the final land preparation but N was top dressed as urea at three equal

split at 12-15 days, 25-30 days and 40-45 days after transplanting. Other intercultural operations i.e. weed and water management was done as per BRRI recommendation and pesticide was applied twice to control yellow stem borer. The highest yields were obtained from NPKSZn treated plot (8.42 t/ha and 8.34 t/ha), followed by NPKS treated plot (8.34 t/ha and 8.30 t/ha) and NPKZn (8.31 t/ha and 8.19 t/ha) in 2012 and 2013, respectively. The crop yield in fertilizer emission plot was the lowest (6.46 t/ha and 6.67 t/ha) compared to other treatments in all the trial plots and the growth parameters also represented the same trend in both the years. Plant height (cm), Tiller/m², Panicle/m² and straw yield (t/ha) production were significantly higher on N application, followed by P application and Zn, S and K affect insignificantly on grain yield. The marginal benefit from investment in nutrient inputs in Agronomic N use efficiency was 0.01048 and optimum N, P, K dose were calculated was 54, 2 and 6 kg/ha, respectively followed by Driessen (1996) and BRRI (2004). However, the calculated optimum doses need to be verified.

Keywords: Balanced fertilizer, yield maximizing, single cropped area, Faridpur.

Location specific modern rice cultivation techniques affect in minimizing rice yield gap at Faridpur and Gopalganj District

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Rice yield gap between maximum attainable yield and farm level yield across different rice-ecosystem, regions, and crop seasons is very crucial to increase the efficiency of land and labor use, reduce production costs and increase food security. Rice yield between researchers and farmer's plots may be attributed to many factors, such as quality seeds and seedlings, planting time, fertilizers and other management practices. Yield gap mainly depends on the management practices of rice that might be of knowledge gap and of technology packages. An experiment was conducted in six sites of Gopalganj and Faridpur District during Boro season in 2012-13 and T.Aman, 2013 seasons. Six participatory farmers were selected from Tongipara, Kotalipara and Gopalganj Sadar of Gopalganj district and Sadarpur, Charvadrason and Bhanga in Faridpur district. BRRI dhan 29 was cultivated in Boro season and BRRI dhan33, BRRI dhan39, BRRI dhan52 was cultivated in T.Aman season, according to the farmers choice and considering the ecosystem. One bigha of land in each site received BRRI technology with the suitable existing resources (RM) and another bigha of land received farmers' management (FM). The RM plots increased grain yield over farmers' practices by 5.50%

and 23.58% in T.Aman season; and 12.67% and 15.78% in Boro season, respectively in Faridpur and Gopalganj District. Plant height, tiller m⁻², panicle m⁻², grain yield and straw yield production was significantly higher in BRRI recommended management plots. According to the farmers opinion, they got higher profit margin in T.Aman season than Boro season due to saving of irrigation cost, average sale price of paddy was 580-600 Tk./Mon and the price of straw was 17,000-18,000 Tk/ha when thrashing with power paddle thresher and 10,000-11,000 Tk/ha when thrashing by power thresher. Selection of suitable variety considering the submerged flood prone areas and favorable area, rising and transplanting of quality seedling, soil need based fertilizer application or timely application balance fertilizer, supplemental irrigation and provide farmer's training may contribute to higher grain yield of that experimental plot.

Keywords: Rice yield gap, yield maximizing, Faridpur and Gopalganj.

Fertilizer and weed management options for direct wet seeded rice in Bangladesh

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Enormous weed infestation and lack of judicious fertilizer management approach stand in the way of adapting direct seeding of rice . Considering this problem experiments were conducted during Boro season in 2010 and 2012. Wet direct seeding of rice seed was sown using drum seeder. Weed density and weed biomass were strongly influenced by weed control method and fertilizer doses. Weed density was higher in no weeding treated plot with fertilizer doses 140:36:43 NPK kg ha⁻¹ while weed free treated plot gave lower weed density irrespective of fertilizer doses. *Echinichloa crusgalli* represented as the most devastating weeds. The weed free plot following three hand weeding showed maximum weed control. The chemical based weed management showed above 80 and 70% weed control efficiency in 2010 and 2012, respectively. The grain yield showed strongly negative and linear relationship with weed density. The herbicide with one hand weeding and BRRI weeder in combination with 160:46:53 NPK kg ha⁻¹ fertilizer produced 104.45% and 98.62% higher yield in 2010 and 89.38% and 81.5% higher yield respectively in 2012 in BRRI dhan29 and BRRI dhan28, respectively. Weed free plot produced 112% higher yield with maximum fertilizer doses. Besides

herbicide with one hand weeding and BRRI weeder treated plot produced statistically similar yield irrespective of fertilizer doses. The strong positive and linear relationship was found in case of yield and yield component. Although weed free treated plot with fertilizer doses 160:46:53 NPK kg ha⁻¹ gave higher gross return herbicide with one hand weeding and fertilizer dose 120:26:33 N-P-K kg ha⁻¹ showed higher net return (1145 \$/ha). Because herbicide based weed management requires less labour and less cost was involved due to lower rate of fertilizer. The benefit cost ratio was also higher in herbicide based weed management with lower rate of fertilizer.

Keywords: Direct seeding, boro rice, weed, fertilizer

Long-term potassium fertilization effects on quantity-intensity relationships and potential potassium buffering capacity of wetland rice soil

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Potassium (K) fertilizer recommendation for rice cultivation in Bangladesh based on exchangeable K status often does not match with crop K requirement, particularly in the long run and thus gradual soil K depletion is taking place. The availability of K to plant strongly depends on K intensity (I) in the soil solution, capacity or quantity (Q) and renewal rate in the soil solution. The present research aimed to (i) understand the effect of long-term K fertilization on the Q/I parameters for K in soil and (ii) characterize the grey terrace soil for K supplying capacity under long-term continuous rice cropping and K fertilization conditions. The study involved laboratory experiments on Q/I parameters of the soils from long-term K management experimental field, which received 0-80 kg/ha/season with an interval of 20 kg/ha for 16 seasons. Soil samples from K omission (K₀) and the highest K level (K₈₀) plots were collected from 0-70 cm soil depth. The Q/I showed a linear relationship for both K omission and K fertilized soils at different depths. Omission of K decreased the equilibrium K concentration ratio (CR₀^K) compared to K applied soil and slightly decreased the labile K (K_L) and non-specifically available K (-ΔK₀) but had no effect on specifically available K (K_X). The K omission increased the potential buffering capacity (PBC^K) compared to K fertilized soil. Potassium management had little effect on equilibrium exchangeable K (EK₀), magnitude of the conversion of added K to exchangeable pool (α) and non-exchangeable pool (β). However, equilibrium solution K (CK₀) in K omission soil was

lower than K applied soil. The β was higher than α in both the K management conditions. The PBC^K for non-exchangeable pool was also higher than exchangeable pool both in K omission and K fertilized soils. Potassium management influenced critical solution K (CKr) and critical exchangeable K (EKr) but had no effect on minimum exchangeable K (Emin). The Emin was very close to EK in both the K management conditions.

Keywords: Potassium, Q/I, CR_0^K , $-\Delta K_0$, PBC^K

Effect of different organic manures and fertilizer on carbon emission and its sequestration in soil under rice-rice cropping pattern

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Small changes in soil organic carbon (SOC) create great impacts on atmospheric C concentration. Rice-fallow-rice, the dominant cropping system in Bangladesh, received little attention in SOC changes through organic amendments. The present study aimed to determine the effect of organic amendments on CO₂ emission and soil C sequestration. A field experiment in five consecutive rice seasons (August 2010 – November 2012) was conducted at the research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh using cowdung (CD), poultry manure (PM), rice straw (RS) and soil test based fertilizer dose (STB) and compared with control. The rate of C applied from CD, PM and RS was 2 t C/ha/season. Carbon dioxide production from the fields was measured through NaOH absorption followed by HCl titration. After five seasons, SOC along with other properties were measured from the post-harvest soil samples. The difference in the amount of cumulative CO₂ evolution and SOC accretion between control and organic materials treatments gave the apparent C balance and C sequestration. Cowdung, PM and RS contributed for positive soil nutrient balance. The application of CD, PM and RS resulted in 47, 39 and 49% loss of applied C through CO₂ respiration. The application of organic C through RS, CD and PM accounted for 10, 30 and 49% sequestration, respectively. There were 12, 23 and 41% unaccounted C from PM, CD and RS, respectively. The unaccounted portions of added C might have lost as CO₂ through aerenchyma channel to the leaf surface or not produced at all during anaerobic decomposition. Slight C sequestration in STB treatment indicates SOC buildup in rice – rice cropping system.

Keywords: Organic manures, CO₂ emission, C sequestration, rice-rice cropping pattern

Effect of nitrogen rates on growth and yield of some newly released BRRI varieties

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Newly released BRRI varieties may have slightly different nitrogen (N) response than the existing HYVs. A field trial was conducted to evaluate the performance of BRRI dhan58, BRRI dhan59, BRRI dhan60 and BRRI dhan61 with 0, 40, 80, 120, 160 and 200 kg N/ha at BRRI farm, Comilla during Boro 2013-14 season. The experiment was laid out in a split-plot design with 3 replications. Nitrogen doses were accommodated in the main-plots and varieties in the sub-plots. Nitrogen was applied in three three splits at basal, 25 days after transplanting (DAT) and 7 days before panicle initiation stage. A blanked dose of P, K and S @ 31-40-1.4 (kg/ha), respectively were applied as soil test based (STB) during final land preparation. Applied N significantly influenced plant height, tiller/m², panicle/m², filled grain/panicle, unfilled grain/panicle, %sterility and 1000 grains weight. Among the tested varieties, BRRI dhan58 produced higher grain yield than other varieties at all N levels. All tested rice varieties gave maximum grain yield (5.03-6.06 t/ha) at 160 kg/ha N levels.

Keywords: N rates; BRRI varieties; STB; DAT;

Effect of copper on rice productivity under continuous wetland intensive cropping

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The demand for rice is increasing in Bangladesh and thus cropping intensity needs to be increased by harvesting three rice crops per year. However, its consequences on soil fertility over time are important for recuperation. This experiment was initiated in 1971 in a permanent layout with NPK fertilizer application keeping the soil perpetually wet. The treatments were control (native nutrient), reverse control (NPKSZnCu), NPK, NPKS, NPKSZn and NPKSZnCu. The varieties tested, recently, in T. Aus, T. Aman and Boro seasons were BRRI dhan48, BRRI dhan46 and BRRI dhan50, respectively. The NPK doses were 140-25-80, 60-15-80 and 60-10-60 kg/ha for Boro, T. Aman and T. Aus, respectively. Sulfur, Zn and Cu were applied at 10, 4 and 1 kg/ha in Boro season only. The annual rice production in the unfertilized plot decreased from 6.41 t/ha in 1981 to less than 2.0 t/ha in 2008. However, grain yield in control plot slightly increased (2.7-3.8 t/ha) since the last four years. Grain yield trend in NPKS treatment over the last 32

years showed a little bit increasing trend compared to 1981. Addition of NPKSZn fertilizer yielded (12.21 t/ha/yr), which was slightly higher than NPKSZnCu treatment (11.05 t/ha/yr). The results indicate that the soil has capability to produce optimum yield when it receives balanced fertilizer; however, application of Cu is not necessary, presently.

Keywords: Copper, Intensive cropping, wetland, rice

Performance of BRRI dhan43 under different fertilizer packages

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BRRI dhan43 is a promising rice variety for T. Aus season in Bangladesh. The study was conducted in the research field of Bangladesh Rice Research Institute in T. Aus, 2014 season to assess its performance under different fertilizer management practices. The treatments used were, i) 100% soil test based dose (STB), ii) 50% STB and 50% mixed manure (cow dung + ash) as integrated nutrient management (INM), iii) Farmers' practice and iv) fertilizer control. The experiment utilized randomized complete block with three replications. Nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) contents in grains and straw samples were analyzed and their subsequent uptake was calculated. Total (grain + straw) N, P, K and S uptake by BRRI dhan43 was statistically similar with 100% STB dose and 50% STB + 50% mixed manure. The application of chemical and organic fertilizer as INM supported higher grain (3.0 t/ha) and straw (3.24 t/ha) yields, although comparable to chemical fertilizer as STB indicating that INM and STB (100%) dose of chemical fertilizer could be better fertilizer management practices for growing BRRI dhan43 in T. Aus season.

Keywords: BRRI dhan43; INM; STB; nutrient uptake, yield

Pyramid method for intense cropping in coastal waterlogged soils

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Vegetable cultivation is a challenge in coastal region because of lowland conditions in wet season except homestead gardening. A new approach was introduced for vegetable cultivation with rice crop during pre-monsoon and monsoon season under waterlogged situations. A soil ridge of 1- x 1- x 0.75-m was made in dry period and placed 3- x 3-m apart from each ridge. The height of ridge depends on water depth and it was 0.30 m above of maximum water depth. Vegetables like cucumber, bitter gourd, water gourd, cowpea and sponge gourd seeds were placed on the ridge. A *macha* (thatch like

structure) above man-height was made by net for creeping vegetable crops on it and beneath it rice was grown. In pre-monsoon 2013, 320 kg paddy was harvested from 18 decimal, but it was 280 kg in 2014 indicating that there was reduction of 40 kg paddy (equivalent to Tk. 640 loss) might be due to ridge/pyramid construction. However, 130 kg bitter gourd and 190 kg cucumber was harvested from the same piece of land and gross margin was Tk. 3346 per 18 decimal. In monsoon 2014, 30 kg sponge gourd, 20 kg cowpea and 60 pieces water gourd have also been harvested from previously made ridge/pyramid. Based on the performance of vegetable cultivation with rice in waterlogged soil, framers on that locality were highly encouraged and interested to cultivate vegetables in their land.

Keywords: Lowland, rice, ridge method, vegetables

Effects of nitrogen sources and water management practices on rice yield and nitrogen use efficiency in Boro rice

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Nitrogen (N) management in rice received much attention with a view to increase its efficiency, but yet to harvest full benefit. The present investigation aimed to compare broadcast application of prilled urea (PU), deep placement of urea briquette (UDP) and NPK briquette (NPKBRIQ) for rice yield, $\text{NH}_4^+\text{-N}$ in flood water and N use efficiency (NUE). The experiment involved eight N treatments: two rates (78 and 104 kg N ha⁻¹) of UDP (UDP₇₈ and UDP₁₀₄), three rates (78, 104 and 156 kg N ha⁻¹) of PU (PU₇₈, PU₁₀₄ and PU₁₅₆) and two rates (78 and 102 kg N ha⁻¹) of NPKBRIQ (NPKBRIQ₇₈ and NPKBRIQ₁₀₂) and N control (N₀). The treatments were compared in a randomized complete block design with 3 replications under two water regimes- alternate wetting and drying (AWD) and continuous standing water (CSW) in Boro 2013 at BRRI farm, Gazipur. Prilled urea was broadcasted in 3 splits, while the briquettes were deep placed (7-10 cm below soil surface) between 4 rice hills at the alternate rows after 7 days of rice transplanting as a single application. Ammonium N concentration in flood water was measured for a week after each application of fertilizer. The N use efficiency was determined at harvest. Ammonium N concentration in PU reached peak of 15-17 ppm after 24 hour of application compared to 7-9 ppm in UDP and 3-4 ppm in NPKBRIQ. The AWD and CSW showed little difference in flood water ammonium N because of similar water depth during PU, UDP and NPKBRIQ applications. The application of N increased rice yield but increasing rates of N either from broadcast urea or deep placed

urea had insignificant effect on yield. Grain yield with UDP (78 kg N/ha) and PU (156 kg N/ha) was statistically identical. For a given source, AWD and CSW showed similar agronomic N efficiency. The UDP and NPKBRIQ at lower rate (78 kg N/ha) gave significantly higher N recovery efficiency compared to broadcast application of PU in both water management conditions. However, NPKBRIQ and urea briquettes (USG) gave comparable grain yield and N use efficiency.

Keywords: PU, UDP, $\text{NH}_4^+\text{-N}$, NUE, CSW, AWD

Effect of intermittent drainage on suppressing CH_4 emission in paddy soil during rice cultivation

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Winter cover crop cultivation and its biomass addition as a green manure is recommended to increase soil carbon (C) sequestration. However, application of biomass can significantly increase methane (CH_4) emission as well as global warming potential due to rice cultivation. Intermittent drainage of rice fields may reduce CH_4 emission. The objective of this study was to evaluate effectiveness of intermittent drainage on CH_4 emission from paddy soil using closed chamber method under different rates of cover crop biomass incorporation. The biomass was incorporated at 0, 3, 6, 12 Mg ha⁻¹ with soil one week before rice transplanting along with chemical fertilization (N-P₂O₅-K₂O at the rate of 90-45-58 kg ha⁻¹). Two types of closed chambers -transparent glass chambers for monitoring CH_4 emission and acrylic column chambers monitoring CO_2 emission were installed. The increasing rate of cover crop biomass addition significantly increased CH_4 emission under continuous flooding compared to intermittent drainage. But the effectiveness of CH_4 emission decreased significantly under intermittent drainage conditions. However, the net effluxes of CO_2 from the paddy soil were significantly higher under intermittent drainage than continuous flooding. This result suggests that the intermittent drainage can be an appropriate option to reduce CH_4 emission by 76-78% of global warming potential in high biomass amendment in paddy soil during rice cultivation.

Keywords: rice, paddy soil, CH_4 emission, CO_2 emission, water management

Arsenic uptake in rice plant at maximum tillering and flowering stage and its effect on agronomic characters of rice

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Pot experiments were conducted at the net house of soil science research field, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) to study arsenic (As) concentration in rice straw at maximum tillering and flowering stages and its consequence on rice agronomic parameters. Two rice varieties (BRRI dhan45 and BRRI dhan47 in Boro, BRRI dhan47 and BRRI dhan49 in T. Aman) in two successive growing seasons with four soil As doses (0, 20, 40 and 60 mg⁻¹kg) were grown. Two sets of rice plant were grown separately upto maximum tillering and flowering stages, respectively. Rice shoot As concentrations increased with increasing soil As levels in all tested rice varieties. Comparatively higher shoot As concentrations were found at maximum tillering stage than at flowering stage because of its translocation to panicle. Comparing the increase in shoot As content with increasing levels of soil As content, BRRI dhan47 showed tolerance and/or exclusion mechanism. The highest shoot and panicle As concentrations were found in BRRI dhan45 in Boro season and BRRI dhan49 in T. Aman season. In case of different agronomic parameters, BRRI dhan47 performs better than other varieties in both growing season.

Keywords: Arsenic, Translocation rate, Maximum tillering and flowering stage

Multistrain biofertilizer for rice production with rock phosphate and reduced chemical nitrogen

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Climate change is now global issue and threat for food security. Continuous use of chemical N and P fertilizers is one of the major causes of global warming and eutrophication. Results of several glasshouse and field study proved that biofertilizer prepared with consortium of free living N fixing (diazotrophs) and phosphate solubilizing bacteria (PSB) can reduce 30% use of chemical N and promote naturally

occurring rock phosphate as phosphorus source for rice production. Nitrogen fixing bacteria were isolated from wetland rice and phosphate solubilizing bacteria from aerobic rice rhizosphere. The bacterial strains were identified using 16S rRNA as *Burkholderia* spp. and *Bacillus* spp. The identified gene sequences were deposited in the Gene bank (accessions number JQ820251, JQ820252, JQ820253, JQ820254, JQ820255, JQ820256, JQ820257, JQ820258, JQ820259, and JQ82026). The result of the ¹⁵N field study proved that free living N fixing bacteria used in the biofertilizer were able to fix 20-52 kg/ha N per cropping season and PSB solubilized 2/3rd of the applied hardly soluble phosphate rock within one month (³²P technique) at soil-plant system. In the *in vitro* condition, the phosphate solubilizing isolates solubilized 0.034-0.083% of rock phosphate within one hour. These isolates produced indoleacetic acid (33-55 mg/l) in broth culture. The application of the biofertilizer (2-4 ton ha⁻¹) along with 30% reduced urea-N and rock phosphate resulted in 33% increased rice yield over full chemical fertilizer. Bacteria provided in the biofertilizer produced oxalic acid (72-265ppb), citric acid (13-268ppb) and malic acid (3-315ppb). The organic acids produced by the bacteria reduced Al and Fe toxicity of rice roots grown in acid sulfate soil by chelation process and improved rice yield by 60% over control. In aerobic rice, the application of biofertilizer (4 ton ha⁻¹) increased shoot length (32%), leaf chlorophyll (21%) and biomass yield (20%) over full fertilizer. The mechanisms involved for increased crop yield and plant growth promotion were due to i) increased N supply through biological N fixation, ii) increased availability of P by phosphate solubilizing bacteria, iii) Indoleacetic acid induced extensive root system for increased nutrient uptake. This multistrain biofertilizer is environmental friendly and reduced (1/3th) use of chemical N and promote natural sources of rock phosphate instead of highly soluble chemical P fertilizer for rice production.

Nitrogen requirements of some BRRI rice genotypes

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Most of the soils in Bangladesh are nitrogen (N) deficient. So, N fertilization is essential to meet the crop requirement for optimum yield. There are considerable uncertainties about N requirements because N response patterns depending on rice variety. It is necessary to know N response behavior of newly developed varieties and promising lines, which are in pipelines for future varieties. Investigation was undertaken to determine N response behavior of promising lines and BRRI modern rice varieties at BRRI farm, Gazipur during T. Aman 2013 and Boro 2013-14. In T. Aman season, 0, 40,

80 and 120 kg N/ha were tested with BR8417-2-1-2, BR7528-2R-19-HR10, and varieties BRRI dhan39 and BRRI dhan49. In Boro season, BR7830-16-1-5-3, weed tolerant rice, BR7671-37-2-2-3-7 and BR7833-11-1-1-2-1-2B5 were tested with BRRI dhan28 under 0, 60, 120 and 180 kg N/ha. The treatments were assigned in a split-plot design with N doses in the main plots and varieties in the sub-plots. Phosphorus, K, S and Zn were applied @ 12-42-10-2 kg/ha and 20-60-10-2.2 kg/ha in T. Aman and Boro seasons, respectively at final land preparation. In T. Aman season, BR7528-2R-19-HR10 gave significantly higher grain yield (4.95 t/ha) than BRRI dhan49 (4.76 t/ha) at 120 kg N/ha. In Boro, BR7830-16-1-5-3 gave significantly higher grain yield at 180 kg N/ha compared to 120 kg N/ha. Nitrogen concentration in grain and straw varied significantly with N rates and rice genotypes. Total N uptake was also significantly influenced by N doses and rice genotypes. However, 120 kg N/ha was sufficient to produce maximum grain yield for weed tolerant rice (5.87 t/ha), BR7671-37-2-2-3-7 (5.17 t/ha) and BR7833-11-1-1-2-1-2B5 (4.58 t/ha). About 15-16 kg N in T. Aman and 14-17 kg N in Boro seasons was required to produce one ton rice grains. In T. Aman season, BR7528-2R-19-HR10 showed greater N recovery efficiency (RE) (36%) than other genotypes. In Boro season, weed tolerant rice showed higher nitrogen RE (47%) than other genotypes.

Keywords: Nitrogen, Fertilizer, BRRI Varieties/Promising Lines

Delineation of nutrient status in the soils under some selected agro ecological zones of Bangladesh

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A baseline study was conducted to delineate nutrient status of soils in the unfavorable ecosystems AEZ-3: Rangpur (Submergence and Cold area); AEZ-13: Barisal (Tidal Flood Ecosystem) (AEZ-18: Sonagazi (Char and Saline area); AEZ-21: Hobigonj (Haor area); and AEZ-26: Rajshahi (Drought prone and Cold area) in 2011. Soil samples (0-20 cm depth) were collected along with GPS reading and basic information from each location. Soil samples were analyzed for texture, pH, EC, OC, total N, available P, exchangeable K, Ca, Mg, available S, available Zn. Soil pH (AEZ 18, 3 and 13) was slightly acid to neutral. But in AEZ 21, it was strongly acidic and in AEZ 26 it was neutral to slightly alkaline. In most locations, the status of soil organic matter was below critical level (1.72%) in 80 to 96% samples. Except in AEZ 21, about 100% samples had total N content below critical level (0.12%) . In AEZ 3, 60% of the sample were K deficient and 32% S deficient, respectively. In AEZ 13, 21, 100% samples were P deficient and in AEZ

26 it was 24%. In AEZ 3, 60% samples were K deficient and in AEZ 26 it was 40%. Thirty-two and 24% samples were S deficient in AEZ 3 and 26, respectively. The highest samples (84%) were Zn deficient in AEZ 18 followed by AEZ 21(48%). Nutrient status of soils was mostly low and varied among locations.

Keywords: Soil, Nutrient status, Agro Ecological Zones, Bangladesh

Evaluation of fertilizer requirement for cropping patterns in different unfavorable ecosystems of Bangladesh

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The study was conducted in farmers' fields to determine fertilizer requirement of rice and rice based cropping patterns under unfavorable ecosystems (AEZ-18: Sonagazi (Char and Saline area); AEZ-21: Hobigonj (Haor area); AEZ-3: Rangpur (Submergence and Cold area); AEZ-13: Barisal (Tidal Flood Ecosystem) and AEZ-26: Rajshahi (Drought prone and Cold area) during the period of 2011-2013. Eight treatments with different rates of inorganic fertilizers were studied. In haor area (AEZ-21), rice yield ($7.35 \text{ t ha}^{-1}\text{yr}^{-1}$) was the highest in T_5 (STB rate + 25% PK), whereas in drought prone ecosystem (AEZ-26), rice yield ($10.63 \text{ t ha}^{-1}\text{yr}^{-1}$) was the highest in T_1 (STB rate). In non-saline tidal flood ecosystem (AEZ-13), the highest rice production ($8.80 \text{ t ha}^{-1}\text{yr}^{-1}$) was achieved in T_2 (STB rate + 25% N). In submergence ecosystem (AEZ-3), rice production ($13.56 \text{ t ha}^{-1}\text{yr}^{-1}$) was the highest in T_3 (STB rate + 25% NP), whereas in saline and char land ecosystem (AEZ-18), rice production ($9.35 \text{ t ha}^{-1}\text{yr}^{-1}$) was the highest in T_6 (STB rate + 25% NPK). Based on results the following fertilizer recommendations were made: (i) Boro-Fallow-T. Aman cropping pattern at Rangpur (AEZ-3): $N_{230} P_{15} K_{75} S_{15} Zn_1$ (Boro) and $N_{125} P_{10} K_{40} S_{10} Zn_1$ (T. Aman); (ii) Boro-Fallow-T. Aman cropping pattern at Rajshahi (AEZ-26): $N_{175} P_{25} K_{85} S_{20} Zn_0$ (Boro) and $N_{60} P_{10} K_{30} S_{10} Zn_0$ (T. Aman); (iii) Boro-Fallow-T. Aman cropping pattern at Barisal (AEZ-13): $N_{200} P_{10} K_{60} S_{10} Zn_0$ (Boro) and $N_{30} P_5 K_{20} S_5 Zn_0$ (T. Aman, LIV); (iv) Boro-Fallow-T. Aman cropping pattern at Sonagazi, Feni (AEZ-18): $N_{225} P_{30} K_{20} S_{15} Zn_4$ (Boro) and $T_1 = N_{120} P_{15} K_{10} S_{10} Zn_3$ (T. Aman); (v) Boro-fallow-fallow cropping pattern at Hobigonj (AEZ-21): $N_{145} P_{45} K_{10} S_5 Zn_0$

Key words: Evaluation, Fertilizer Requirement, Cropping Patterns, Unfavorable Ecosystems, Bangladesh

Assessment of existing carbon stock in soils of ten AEZs in Bangladesh

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The investigation (2010-2013) assessed soil organic carbon (SOC) stocks of 10 ten AEZs in Bangladesh, which included AEZ 1- Old Himalayan Piedmont Plain, AEZ- 2- Active Tista Flood Plain, AEZ 3- Tista Meander Flood Plain, AEZ 4- Karatoya-Bangali Floodplain, AEZ 5- Lower Atrai Basin, AEZ 6- Lower Purnabhaba Flood Plain, AEZ 7- Active Brahmaputra and Jamuna Flood Plain, AEZ 8- Young Brahmaputra and Jamuna Flood Plain, AEZ 9- Old Brahmaputra Flood Plain and AEZ 10- Active Ganges Flood Plain. Two to four land types under each AEZ viz. highland (HL), medium highland (MHL), medium lowland (MLL) and lowland (LL) were considered for SOC assessment. The SOC stock was estimated by multiplying SOC (%) with bulk density (g/cc) and soil depth (cm). Across the AEZs and land types, the SOC (%) decreased with increase in soil depth. The SOC (%) was the highest in low land (0.62-1.71%) and the lowest in high land (0.45-0.89%) soils over the AEZs. Soil bulk density increased with soil depth in every AEZ. Bulk density of medium high land varied from 1.00-1.67 g/cm³ where as in high land and low land it varied from 0.81-1.65 g/ cm³ and 0.77-1.63 g/ cm³, respectively. The SOC stock at 0-20 cm depth was higher (4.67-11.71 t/ha) in low land (except AEZ-1) compared to medium high land (3.55-8.25 t/ha) and high land (2.64-6.46 t/ha) soils irrespective of AEZs. Among 10 AEZs, the highest SOC stock (t/ha) was found in AEZ-1 irrespective of land types.

Key words: SOC stock, bulk density, agro ecological zones, land types.

Carbon accumulation and its mineralization in soils under aerobic and anaerobic conditions without Crop

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The experiment was conducted at the laboratory of Soil Science Division, BRRI on September 20, 2012 at room temperature (18°C to 34°C) for 129 days. The objective of the study was to determine CO₂ emission rate of some organic materials (OM) under moist and flooding situations. The bulk of soil samples were collected from AEZ 1. Different OM such as rice straw (RS), rice root (RR), cow dung (CD) and poultry manure (PM) (having the carbon content 42%, 25%, 20% and 20%, respectively) were incorporated in the jar @ 5 t C/ha (0.25 g C/100 g soil or without soil). During 129 days of incubation, the highest total amount of CO₂ released from PM containing pot was 1.59 g/kg in flooding condition and 1.47 g/kg in moist condition, which was significantly different

from PM mixed with soil in both the conditions. Total CO₂ emission from control treatment (100 g soil only) was 0.65 g/kg in flooding condition and 0.61 g/kg in moist conditions. The rate of CO₂ emission was higher in earlier stage of incubation irrespective of organic sources in both flooding and moist conditions. However, PM emitted more CO₂ than CD, RS and RR alone. Carbon balance varied from 3.4g/kg (soil) to (3.9-4.7g/kg (soil+residues).

Keywords: Laboratory, carbon dioxide emission, carbon balance

Carbon accumulation and its mineralization in soils under aerobic and anaerobic conditions with rice

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The experiment was conducted at the net house of Soil Science Division, Bangladesh Rice Research Institute (BRRI), Gazipur during 22 March 2011 to 28 September 2011. The objective of the study was to determine the changes of SOC under alternate wetting and drying (AWD) and continuous flooding conditions with rice crop. The bulk of soil samples were collected from AEZ 1. Different organic materials such as rice straw, rice root, cow dung and poultry manure (having the carbon content 40%, 24%, 28% and 23%, respectively) were incorporated in pot soils @ 0.0, 0.5, 1.0, 1.5 & 2.0 t C/ha. At 30 and 60 days of incubation, poultry litter was more efficient to increase soil pH level significantly than others. On the other hand, at 180 days of incubation poultry litter, cow dung and rice straw significantly increased soil pH than rice root. It was found that Soil pH increased more when carbon rate was 1.5 and 2.0 t/ha. The AWD significantly influenced soil pH at 90 days, while CSW at 30, 120 and 180 days of incubation. The SOC decreased slightly with increased crop growth duration due to increasing temperature irrespective of residues used in the experiment and carbon rates. The CSW condition favored organic carbon accumulation in soils.

Keywords: Net house, SOC, pH, CSW, AWD, rice

Carbon sequestration in soils under different tillage and rice straw management

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An experiment was conducted at the Bangladesh Rice Research Institute (BRRI) H/Q Farm, Gazipur (AEZ-28) during T. Aman 2010 to 2013. The objective of the experiment

was to determine the level of soil organic carbon (SOC), which is influenced by tillage methods, rice straw (RS) management practices and fertility levels under irrigated Rice-Rice cropping pattern and to quantify the rates of carbon dioxide (CO₂) emission from rice soils influenced by management. There was no significant effect of tillage operations, RS management practices on SOC after 5th crop. Similar trend was also found in case of available P and exchangeable K. The total amount of released CO₂ was higher in T. Aman season (4291 kg/ha/114 days) than Boro season (3490.kg/ha/112 days). The RS surface mulch released significantly higher amount (4420 kg/ha/114 days) of CO₂ over control (3969 kg/ha/114 days). The higher positive C-balance was found with RS addition. Tillage methods had no effect on grain yield indicating that the minimum tillage might be used for rice.

Keywords: Tillage, RS management, CO₂ emission and SOC

Effect of different organic manure and fertilizer management on carbon sequestration under rice-rice cropping pattern

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An experiment was conducted at the Bangladesh Rice Research Institute (BRRI) H/Q Farm, Gazipur (AEZ-28) during T. Aman 2010 to T. Aman 2013. In this study the causes of SOC change in relation to use of various organic materials (OMs) and the rates of CO₂ emission from rice soils were quantified. The treatments used were: T₁ = absolute control, T₂ = cow dung + IPNS based chemical fertilizer (CD + IPNS), T₃ = poultry manure (PM) + IPNS based chemical fertilizer (PM + IPNS), T₄ = rice straw + IPNS based chemical fertilizer (RS + IPNS) and T₅ = soil test based (STB) chemical fertilizer. The OMs were used at 2 t C/ha. Among the tested OMs, the rate of CO₂ emission was higher in PM and CD treated plots compared to RS treated plots. The total amount of released CO₂ was higher in T. Aman season than Boro season. Total CO₂ emission was the highest in PM treated plots (4943 kg/ha/114 days in T. Aman and 4315 kg/ha/112 days in Boro) and the lowest was in control (3605 kg/ha/114 days in T. Aman and 2955 kg/ha/112 days in Boro). The highest SOC (1.54%) was built in CD (2.0 t C/ha) + IPNS treated plot compared to control plot (1.13%) and the highest available P (53.05 mg/kg) was observed in PM + IPNS treatment. The higher positive C-balance was found in those treatments where OMs were applied. In general, PM + IPNS gave higher grain yield both in T. Aman (4.07 t/ha) and Boro seasons (5.44 t/ha).

Keywords: cow dung, poultry manure, rice straw, chemical fertilizer, carbon dioxide emission, SOC and rice.

Characterization of rice genotypes for salt tolerance at seedling and reproductive growth stage

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Screening or characterization of different rice genotypes at seedling and reproductive stage can play a vital role for developing salt tolerant genotypes. Aiming to find out salt tolerant genotypes, forty-seven F₂ materials, fifty-five anther cultured lines, twenty-five GSR materials, forty advanced breeding lines, forty INGER materials and one hundred and eighty-one rice germplasms were screened at seedling stage. The screening program also includes six anther-cultured lines with standard boro checks at reproductive stage during 2012-13 at Plant Physiology Division, BRRI. At seedling stage sprouted seeds were sown on nylon net fitted with styro-foam floating on Yoshida's full strength culture solution. Salinity stress @ 12 dS/m was applied at 7 days after sowing. In each tray FL478 and IR29 were used as a tolerant and susceptible check, respectively. When susceptible check IR29 died, visual score was made according to standard evaluation system (SES). At reproductive stage plants were grown in the perforated plastic pots (drilled and lined with canvas) filled with grinded soil. The soil was fertilized with NPK and S @ 50, 25, 40 and 25 mg/kg soil. The pots were placed inside a bucket serving as water bath. Salt stress was applied at maximum tillering stage maintaining 0 and 8 dS/m. Six crossing materials (47 F₂ segregating progenies), one Green Super Rice (GSR) genotype, nine anther cultured lines, seven breeding lines, seventeen INGER materials and nineteen germplasm (BRRI Gene Bank) scored 3 to 5 (tolerant to moderately tolerant) at seedling stage. The anther derived and two breeding lines were very sensitive to salinity at reproductive stage. Fifty-nine materials were found tolerant to moderately tolerant at seedling stage. These screened materials could be used for further breeding program for developing salt tolerant variety.

Keywords: Rice, salinity, seedling stage, reproductive stage.

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

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Knowledge on photoperiodism of rice variety is useful to the farmers in making decision on time of planting, inclusion to avoid drought or fit in a cropping system. The present investigation aimed to determine photoperiodism in recently BRRI released modern T. Aman varieties. The test varieties were BRRI dhan49, BRRI dhan51, BRRI

dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan56, BRRI dhan57, BRRI dhan62, including BR11 and Nizersail. Ten hour photoperiodic treatment (natural light) was imposed since seed sowing in March. One set were grown at natural day length condition. The experiment was replicated four times. Observations were made on dates of seeding and heading; basic vegetative phase (BVP), photoperiod sensitive phase (PSP) and relative photoperiod sensitivity (RPS) were calculated. The duration of BVP varied greatly among the varieties ranging from 10 to 39 days. The duration of PSP also varied among the varieties from 5 to 171 days. There were differences among the varieties for days taken to flowering. Nizersail took maximum days (215) for this character followed by BRRI dhan54 (206) under natural day length condition. The PSP of BRRI dhan62 was only 5 days. BRRI dhan62 showed a low response or a slight delay in flowering with an increase in photoperiod. The PSP of BRRI dhan56 and BRRI dhan57 were 19 and 30 days and RPS 11 and 18%, respectively. The PSP of BRRI dhan49, BRRI dhan52 and BRRI dhan53 were 58, 50 and 55 days, respectively. The PSP of BRRI dhan51 was 80 days and RPS 47%. The PSP of BRRI dhan54 was 166 days and RPS 97%. BRRI dhan54 demonstrated similar photoperiod sensitivity as Nizersail. On the basis of BVP and PSP BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan56, BRRI dhan57 are weakly photoperiod-sensitive, BRRI dhan54 was strongly photoperiod-sensitive while BRRI dhan62 was found as photoperiod insensitive variety. *Key words:* Photo-period sensitive, Basic Vegetative Phase, Photoperiod sensitive Phase.

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

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Double transplanting system is a crop establishment method for rice cultivation where farmers transplant Aman rice seedlings twice, first on a piece of high land, and then in the main field after the recession of heavy rains. It is also practiced in Boro season when main field is occupied by other crops at transplanting time. It is laborious and sometimes not economic if yield is not better than normal transplanting with same aged seedlings. So a comparative study of normal transplanting and double transplanting system on the basis of some growth parameters and yield is required. Therefore, this experiment was conducted to study the physiological growth performance and to find out the yield and yield components of some T. Aman varieties under double transplanting compare to normal transplanting system. Sprouted seed of BR22, BRRI dhan46 and BRRI dhan49 were sown in the seedbed. Thirty-day-old seedlings were

transplanted at 10×10cm spacing using 9 seedlings per hill in an intermediate field; after 30 of planting the entire hill were uprooted and planted in the main field at the rate 2-3 tillers/hill at 20 × 15 cm spacing. At the same time of re-transplanting thirty, forty-five and sixty-day old seedlings were transplanted in the main field with at 20 × 15 cm spacings. The experiment was conducted in RCB design with 3 replications. All the plots received BRRI recommended fertilizer and cultural practices. Crop establishment method demonstrated significant interaction with variety in sterility percent, days to flowering and harvest index. The highest percentage of sterility was observed in normal transplanting which was transplanted with 60- day's old seedlings and lowest in the plant which was transplanted with 45 and 30- day old seedlings. Maximum days to complete flowering was observed for BR22 at normal transplanting with 60 days aged seedlings followed by double transplanting. Minimum days to complete flowering was observed for BRRI dhan49 at normal transplanting with 30 days old seedlings. In conclusion, though the growth performance of double transplanting was good at initial stage, it dropped to maturity and yield as well as growth duration become similar with normal transplanting with same aged seedling. Double transplant and different ages of seedling produced insignificant effect on rice yield in the tested three varieties.

Key words: Rice, normal transplanting, double transplanting, yield

Performance of some NERICA genotypes in transplanted aman season

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Short duration NERICA (The New Rice for Africa) varieties have been claimed as stronger disease resistant and stress tolerant. The present investigation evaluated NERICA genotype against some BRRI varieties. Field experiments were conducted at BRRI research field in T Aman 2013. The site receives annual rainfall of about 2376 mm and annual average temperature maximum 36°C and minimum 12.7 °C. The study involved 8 (eight) NERICA genotypes and 2 (two) BRRI varieties-BRRI dhan56 and BRRI dhan49 in RCBD design with 3 replications. Thirty- day-old seedlings were transplanted at 20 × 20 cm spacing. BRRI recommended fertilizer and cultural practices were followed. The tested geotypes produced significant variations in spike fertility, grain yield and harvest index. Two NERICA genotypes NERICA-L-8 and NERICA-L-36 gave 14 and 10% greater yield than the BRRI dhan56, which produced 3.22 t/ha. Both the NERICA expressed less BLB infection than other tested NERICA genotypes. Growth duration of those two NERICA varieties were similar to BRRI dhan56. BRRI dhan49 produced 17% higher yield than the best NERICA genotypes.

Keywords: NERICA genotypes, performance, yield and yield components.

Effect of municipal wastewater on hydraulic properties of soils

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Wastewater in Bangladesh represents an alternative irrigation water source in the country, especially in city vicinity. The application of waste water may bring a change in soil hydraulic properties. We evaluated soil hydraulic properties including soil-water characteristics curves as affected by municipal wastewater (untreated). The experiment involved six agricultural soils from Mymensingh, Gazipur, Pabna, Rajshahi and Kustia. The soil samples were packed in steel soil cores at Soil and Water Engineering Laboratory, Bangladesh Agricultural University, Mymensingh. Municipal wastewater was collected from Mymensingh peri-urban area. Each of the soil cores received either fresh water or wastewater simulating with the amount of water required for producing a wheat crop for successive three years in Bangladesh. Compared to fresh water, the municipal wastewater had greater manganese content and electrical conductivity. Municipal wastewater significantly improved the soil properties and also the soil-water characteristic curves (SWCC). At high suction, slope of the SWCC increased after treating with wastewater as compared to fresh water. The application of wastewater changed van Genuchten parameters α and n and increased soil physical quality index, S . Our data suggest recommending to use municipal wastewater of Mymensingh town as irrigation water.

Keywords: van Genuchten parameters α & n , saturated hydraulic conductivity (K_s), soil-water characteristic curves (SWCC), soil physical quality index (S)

PEST MANAGEMENT

Reaction of Pro-vitamin A enriched 'Golden Rice' event GR2-R introgressed lines of BRRI dhan29 to different insect pests under confined field trial conditions

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One in every five pre-school children and 23.7 percent of pregnant women in Bangladesh are affected by vitamin A deficiency. A confined field trial of provitamin A enriched 'Golden Rice' event GR2-R introgressed lines of BRRI dhan29 was conducted during Boro 2013-14 season. Twenty-four test entries including BRRI dhan29 were evaluated at the confined field trial (CFT) site of BARI, Gazipur to observe the insect abundance and their damage severity under natural infestation. The crop was established by Plant Breeding Division following RCB design with three replications. Prophylactic measures were taken against rice insect pests as and when necessary. The insect pests were monitored in weekly basis and were reported fortnightly. Based on the fortnightly report, prophylactic application of insecticide (both granular and liquid) was applied at 15 days interval in the main field. Insecticides were applied during afternoon as per recommended dose (s). Active Barrier System (ABS) and chicken net were used to protect crops from rice field rat and bird infestation, respectively during reproductive stage. Environmental safety guidelines were followed during data collection. Insect pest, birds and rodents were monitored in main field. Among the major insects pest, leaf folder and stem borer were appeared below the economic threshold level (ETL) both in vegetative and reproductive stage of the test entries including BRRI dhan29. However, the leaf folder damage was above 50% in the event GR2-R in contrast to BRRI dhan29 at the reproductive stage. In addition to the event GR2-R, the following test entries namely BR29-GR#9-GID21, BR29-GR# 5-GID7, BR29-GR#4- GID6 and BR29-GR#M28-GID22 also infested (5-20%) by leaf folder. Among the other test entries namely, BR29-GR#3-6-GID14, BR29-GR#21-GID19, BR29-GR#PSBI7-GIDI8, BR29-GR#24-GID11 and BR29-GR#2-5-GID13 gave good performance having pest (SB & LF) tolerance at field conditions. No unknown pest was recorded during the reporting period. Besides, there was no chance to excess the vertebrate pest (rodent and birds) inside the confined field trial plots as environment-safety measures were taken properly.

Keywords: Provitamin A, Golden Rice, Prophylactic measures, GR2-R introgressed lines

Screening of Breeding Lines against Brown Planthopper

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The brown planthopper (BPH), *Nilaparvata lugens* (Stål) recently has increased their infestation to the rice crop in Asia including Bangladesh. Screening of breeding materials against the local population of BPH is, therefore, necessary to establish the existence of biotypes and to utilize resistant sources for genetic improvement. Resistant cultivars offer an easy method of insect control. The present study aimed to identify suitable BPH resistant parents for further breeding programme. This experiment was conducted in the greenhouse of Entomology Division at Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh. In Transplanted Aman 2013-14, 436 rice entries including a local resistant and a local susceptible check were sown in seed boxes (60 × 45 × 10 cm) in two replications using the Seedling Bulk Test (SBT) method having free choice for the insects. Seeds were sown in rows 2 cm apart, while plant to plant distance was one cm. Twenty plants in each entry were maintained in a row. All the seed boxes were then placed in a galvanized tin tray (225 × 90 × 10 cm) filled with water. At seven days after planting, seedlings were infested with second or third instar nymphs of BPH at 6-8 nymphs/seedling and infested seed boxes covered with a fine mesh nylon cage. Mean damage rating was done on 0-9 scale of Standard Evaluation System by IRRI, when 95% of susceptible check, BR3 seedlings were dead (IRRI 1988). The materials showing doubtful reactions were retested using "no-choice" method. In this method each entry was caged separately by a small mylar film cage (20.5×5×21.5 cm). Out of 436 entries only one entry viz. BR 8182-1-1-1-1 was graded as highly resistant (HR, score 1), 13 entries were resistant (R, score 3), 13 entries were graded as moderately resistant (MR, score 5). Out of rest 409 entries, moderately susceptible (MS, score 7) and highly susceptible (HS, score 9). The cultivar BR3 used as check showed highly susceptible reaction and T27A showed resistant reaction to the insect. The resistant sources detected in rice entries under natural condition may be considered as an important achievement. Therefore, these 13 BPH resistant rice entries can be used as potential donors in the BPH resistant breeding programme.

Keywords: Rice entry, Resistant, *Nilaparvata lugens* (Stal).

Conservation of natural enemy of rice insect pests through ecological management approach

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Improper insect pest management may results in a decrease of biodiversity and simultaneously increase in insect resurgence or emerge of other insect as major pests. Therefore, conservation of natural enemies may be one of the options to manage insect pests in rice ecosystem. An experiment was conducted to understand the impact of conservation in rice arthropods (pests and their natural enemies) at the farm of Bangladesh Rice Research Institute, Gazipur in irrigated rice field (Boro 2013-14). A 1364 m² field was divided into three (3) blocks and each block was divided into four (4) plots and BR3 rice variety was grown in all the plots. Nectar-rich flowering plant, Marigold, *Calendula officinalis* L. was planted on bunds of each four plots of the first block to provide food and shelter for different parasitoids and other natural enemies. Usual cultivation was followed in the 2nd block as control plot i.e. without any application of insecticide. Carbofuran 5G (@10.0 kg/ha) was applied as prophylactic use at 15 days interval in each of four plots of the 3rd block after 1st top dressing of urea fertilizer. Twenty complete sweeps were taken from all the blocks at 15 days interval up to flowering. Insect pests and natural enemies number of all sweeps from different blocks were counted and recorded from four different treatments i.e., T₁=One meter away from the flowering plants of rice bunds, T₂=Four meter away from the flowering plants of rice bund, T₃= Prophylactic insecticide use and T₄= Control (no insecticide and no flowering plants). Parasitism of *Trichogramma zahiri* Polaszek, an egg parasitoid of rice hispa, *Dicladispa armigera* (Oliver) was determined separately from all the plots through retrieval method. The highest number of grasshopper, green leafhopper and white leafhopper were found in T₁ (6, 2 and 2 per 20 complete sweeps respectively). However, the incidence was below the economic threshold level. Among natural enemies, highest number of spiders, damsel fly and lady bird beetles (19, 7 and 3 per 20 complete sweeps respectively) were found in treatment T₁. *T. zahiri* caused the lowest parasitism (27%) in T₃ and the highest parasitism (70%) in T₁. The plot T₃, which received four times Carbofuran 5G application yielded 6.12 t/ha compared to 6.22 and 6.13 t/ha in T₁ and T₂, respectively where no insecticide was used. However, the lowest yield 5.74 t/ha was observed in T₄ which received neither marigold boundaries nor insecticide application. Therefore, farmers can avoid the toxic and hazardous insecticides to control the insect pests by growing nectar-rich flowering plants on the bunds of surrounding rice crops.

Keywords: Flowering plants, marigold, rice hispa, parasitoid, eco-engineering.

Validation of BRRI recommended practices for insect pest management

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Integrated pest management (IPM) practices favors maintenance of biodiversity and reduce insect resurgence as well as emerge other insect as major pests. We demonstrated IPM in 8 farmers' fields in Pirganj and Taraganj upazila of Rangpur district for successful management of major rice insect pests. One portion each farmer's field was managed with three treatment combinations i.e., T₁ = Prophylactic use of insecticide, T₂ = Perching + sweeping + need based insecticide application and T₃ = Perching only. Other portion of the field was remained under the respective farmers' supervision treated as control (T₄). BRRI dhan52 and BRRI dhan58 were grown in all the fields during T. Aman and Boro season respectively. All the plots recieved same agronomic management. Each farmer's field was treated as a replication and the data was anlysed considering RCBD. The insect infestation was monitored fortnightly by 20 randomly visual hill counting and 20 complete sweeping. The insect infestation, yield and yield contributing characteristics were compared by one way analysis of variance with Tukeys' Post hoc Test. All the experimental fields had insect infestation below the economic threshold level (ETL) both in Taraganj and Priganj . Among major pests, yellow stemborer, rice leaf roller, green leafhopper, brown planthopper, white backed planthopper and gall midge were found in both locations. No significant differences were observed for insect infestation among the treatments in both the locations. Among the natural enemies, spider (SPD), ladybird beetle (LBB), dragon fly, damsel fly, carabid beetle (CBB) and staphylinid beetle (STB) was found both in Taraganj and Pirganj. In both locations, SPD and LBB population represented the highest in T₂ treatment where no insecticide was applied. However, in T. Aman 2012, LBB and STB were not found in Pirganj and also STB and CBB were not found in Taraganj where continuously insecticide was used. In Boro 2012-13, damsel fly was not found in both locations where insecticide was applied fortnightly. Routine application of insecticide (T₁), significantly reduced natural enemy populations in both the locations In T. Aman 2013, frequent insecticide application reduced CBB populations. IPM treatments produced similar grain yields that obtained with T₁, where insecticide (Carbofuran 5G@ 10.0 kg/ha) was applied five times. Therefore, it was found that continuous use of insecticide had no effect on yield of rice when insect infestations below the ETL. In conclusion, farmers could avoid indiscriminate use of insecticide which ultimately save production cost and save the environment from insecticidal pollution.

Keywords: Insect pest and natural enemy, IPM, perching, sweeping, insecticide, yield

Mass rearing of *Trichogramma zahiri* Polaszek on alternate host, *Corcyra cephalonica* (Stainton) egg and it's natural host, *Dicladispa armigera* (Olivier) egg

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An experiment was conducted at the parasitoid rearing laboratory of Bangladesh Rice Research Institute (BRRI), Gazipur to explore the feasibility of mass rearing and utilization of *T. zahiri* for the management of rice hispa. Egg parasitoid, *Trichogramma zahiri* Polaszek (Hymenoptera: Trichogrammatidae) of rice hispa was reared on alternate host, rice meal moth, *Corcyra cephalonica* (Stainton) egg and also on its natural host, rice hispa, *Dicladispa armigera* (Olivier) (Chrysomelidae: Coleoptera) egg. *T. zahiri* emerged successfully from both hosts. The parasitoid parasitized about 58% of rice meal moth eggs whereas it parasitized about 87% of natural host eggs i.e. rice hispa eggs. On an average 1.99 parasitoids emerged from a single hispa egg. However, that was only 0.40 from a single alternate host egg. This result indicated that the alternate host was found to be less suitable when compared to natural host. Developmental duration from egg to adult of *T. zahiri* was same (10 - 11 days) on both hosts with same temperature regime 25-30°C. The population of *T. zahiri* developed from its natural host (hispa egg) parasitized 86.64% of *D. armigera* eggs. Also, population of *T. zahiri* developed from the alternate host has almost similar capability (87.22%) to parasitizing host rice hispa egg in the laboratory. The parasitoid develop from the alternate host was found to be capable to parasitizing rice hispa eggs and also developing its offspring successfully. Therefore, rice meal moth egg could be used as a potential alternate host of this egg parasitoid. However, determining the performance and comparing availability of both hosts for mass rearing of *T. zahiri* on alternate host may not be required in practice as the usual host showed its superiority in all aspects.

Keywords: Rice meal moth, egg parasitoid, rice hispa

An exploratory study of false smut disease of rice in Bangladesh

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Rice false smut (RFS) caused by the pathogenic ascomycetefungus *Ustilaginoideavirens* (Cooke) Takah (teleomorph: *Villosiclavavirens*) has recently become one of the most devastating grain diseases in the majority of rice-growing areas of the world.

Bangladesh has been no exception on that and its incidence is historically experienced during in T. Aman season in this country. This study was undertaken to explore five aspects of RFS – (i) incidence on varieties, (ii) effect of time of planting, (iii) effect of plant spacing, (iv) management through fungicides, and (v) the timing of first symptom appearance on the crop. The objectives were achieved through four experiments conducted during T. Aman season of 2012 and 2013. All the experiments were carried in the experimental farm of BRRI head quarter, Gazipur. Unless otherwise mentioned, BRRI dhan49 was used as test variety and transplanted during late to early August in a density of 25 hills m⁻² using 2-3 seedling hill⁻¹ in individual plot size of 1-4 m⁻². For observing the incidence of RFS on varieties, 11 and 26 varieties of BRRI developed rice tested against naturally occurring RFS in 2012 and 2013, respectively. Results shows, only two varieties out of 11, produced RFS balls in 2012, whereas the incidence recorded in 22 out of 26 varieties in 2013. For knowing the effect of time of planting and plant spacing, 3 time of planting (transplanted on 20 July, 27 July and 04 August) and 3 spacing (15 cm × 15 cm, 15 cm × 20 cm and 20 cm × 20 cm line-to-line and hill-to-hill distances) were designated. The delayed planting resulted in significantly increased number of RFS balls per plot (8.1±1.7, 12.6±1.7 and 18.1±2.9, respectively for 20 July, 27 July and 04 August transplanting), while spacing did not show any significant effect (11.3±2.3 to 13.1±3.4 RFS balls per plot across three spacing). Under poorly infested crop, compared to control (i.e. no fungicide), the number of RFS balls reduced in the range of 59 to 100% in the plots separately treated with 7 fungicides. To know the timing of first symptom appearance on the crop 5 time of planting (transplanted on 19 July, 26 July, 02 August, 11 August and 17 August) were designated. Results further reveal that RFS symptom as balls became visible on panicles in around 12 days after flowering, with an exception that in one occasion the balls were visible about 20 days after flowering. It is concluded that (i) although BRRI dhan49 is widely regarded as the most susceptible to RFS, its incidence is visible in almost all the modern varieties of T. Aman; (ii) time of planting, not the spacing, can have an effect on incidence of the disease; and (iii) RFS symptom as balls usually become visible around two weeks after flowering. Under the circumstances of low disease pressure, as experienced in this study, the effectiveness of fungicides in controlling RFS disease could not be ascertained; a high disease pressure would require to truly assessing the effectiveness of fungicides as a management option for RFS. It is recommended that research should be directed towards a systematic epidemiological study under natural environment in order to find appropriate and effective management options for RFS disease.

Keywords: Epidemiology, rice false smut, disease management, *Ustilaginoidea virens*

Identification of existing races of *Pyricularia grisea* in rice in Bangladesh using monogenic lines of rice

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Blast caused by *Pyricularia grisea* (Cooke) Sacc is one of the major diseases of rice in Bangladesh. To study the epidemiology of blast disease, genetic variability of *P. grisea* and PCR-based screening for blast resistant genes, three experiments were conducted at BRRI during 2010-2013. Incidence and severity of blast disease of rice was recorded in ten agro-ecological zones (AEZ1, AEZ2, AEZ9, AEZ11, AEZ12, AEZ13, AEZ19, AEZ20, AEZ23 and AEZ28) of Bangladesh during Boro (irrigated) and Transplanted Aman (rainfed) seasons. Disease incidence and severity was higher in Boro (21.19%) than in rainfed ecosystem (T. Aman) (11.98%) regardless of locations (AEZs). It was as high as 68.7% in Jhalak hybrid rice followed by BRRI dhan47 (58.2%), BRRI dhan29 (39.8%), BRRI dhan28 (20.3%) during Boro and in BRRI dhan34 (59.8%) during T. Aman. Yield loss was estimated from survey data on neck blast infection. Maximum yield loss was noted in AEZ9 for both the seasons. Percent yield loss was higher in all the locations for Boro season compared to T. Aman season. In the crop sequence1 (CS-1= Crop cycle with one rice followed by fallow/other crops) disease incidence was 16.7% and in crop sequence2 (CS-2= Crop cycle with two rice followed by fallow/other crops) it was 31.9%. Most popularly adopted Boro rice was BRRI dhan28 (29.6%) followed by BRRI dhan29 (25.9%) and T. Aman rice was BRRI dhan34 (22.9%). A total of 139 isolates representing 8 AEZs of Bangladesh were characterized for their pathogenecities using 26 differential varieties (DVs) targeting 23 resistant genes namely, *Pish.*, *Pib*, *Pit*, *Pia*, *Pii*, *Pi3*, *Pi5*, *Pik-s*, *Pik-m*, *Pi1(t)*, *Pik-h*, *Pik*, *Pik-p*, *Pi7(t)*, *Pi9*, *Piz*, *Piz-5(pi-2(t))*, *Piz-t*, *Pita-2*, *Pi12(t)*, *Pita= Pi4(t)*, *Pi19* and *Pi20* including a susceptible check LTH. Isolates clarified on MLs through pathogenecity test indicated that *pi9*, *pish*, *pita* and *pita2* (80-90% resistance frequencies) were the major genes responsible for blast resistance in Bangladesh. These blast isolates were categorized into 112 races based on the reaction patterns against DVs. Twenty five isolates were found suitable with high differentiating ability of 23 resistant genes and they had good sporulation ability. All the five pathotypes viz. U, i, k, z and ta were identified in the isolates. Of them, U63, i0, i7, k177, z00, z04 and ta403 were basically dominant and commonly found in all eight AEZs. The computations from distance matrix gave hierarchical clustering among 139 blast isolates and grouped them into five distinct clusters. The inter-cluster distance was maximum between cluster I and cluster V ($D^2 = 5.51$). Minimum inter-cluster distance was

observed between cluster III and cluster IV (2.32) which indicated that the isolates of these clusters were genetically closer. On the other hand, these two clusters maintained maximum distance from cluster V. One hundred forty four plant materials were classified into 10 cultivar groups (CG) based on their reaction patterns to four distinct blast isolates, H-11-64, H-1-8, H-1-1 and H-11-67. The reaction patterns of plant materials to these four standard blast isolates indicated presence of *Pish*, *Pi9*, *Pita-2* and *Pita* genes and their combination in the genetic background of tested plant materials. Gene specific primer 195R-1/195F-1, Pita440 (YL153)/Pita440 (YL154), OSM89 and AOL45/AOL48 were used to identify *Pi9*, *Pita*, *Pita-2* and *Pish* genes, respectively through PCR-based assay. Plant materials, H13, H23, H25, H35, H47, H49, H136, H138 harbored all three genes, *pita*, *pita2* and *pish* in their genetic background. The *pi9* gene together with *Pita-2* was detected in local rice cultivar H100 and H129 which was confirmed by DNA analysis in PCR assay. These materials could be used in gene pyramiding in promising high yielding cultivar for durable blast resistance.

Keywords: Rice, differential variety, blast resistance, gene pyramiding.

A LysR family transcriptional regulator XOO2767 involved in the positive regulation of *hrp* gene expression in *Xanthomonas oryzae* pv. *oryzae*

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The rice bacterial leaf blight pathogen *Xanthomonas oryzae* pv. *oryzae* (*Xoo*) exploits the type III secretion system (T3SS) encoded by hypersensitive response and pathogenicity (*hrp*) genes to deliver effector proteins during infection in plants. To identify novel *hrp*-regulatory genes in *Xoo*, a transposon EZ::TN<Km> was randomly introduced into the strain 74RΔXrvB/hpa1::lux, which is the bioluminescent mutant harboring the *lux* operon controlled by the *hpa1* (one of *hrp* genes regulated by HrpX) promoter and deficient in XrvB. By transposon mutagenesis and *hrp* gene expression analysis, we found that a novel *hrp* regulatory gene XOO2767 encoding a LysR family transcriptional regulator positively regulates *hrp* gene expression in the xylose-containing *hrp*-inducing condition by inducing a key *hrp* regulatory gene *hrpG* independently on the XrvB-mediated cascade in *Xoo*. Electrophoretic mobility shift assay using His-tagged XOO2767 protein indicated that XOO2767 has DNA-binding activity and it regulates the *hrp* genes directly by binding to the putative promoter region of *hrpG*. It was also revealed that XOO2767 activates some galactose utilizing genes XOO2768-71 by directly

binding to the intergenic region of *XOO2767* and *XOO2768* (operon) with galactose as a co-inducer, and *XOO2767* does not required galactose for inducing *hrp* gene expression. Pathogenicity and bacterial growth analyses in the host plant rice revealed that *XOO2767* had no significant roles in bacterial virulence and growth at least under the inoculation condition. *In planta* expression of *hrp* gene reveals that the level of *hrp* gene expression was reduced in the *XOO2767* mutant, and the reduced *hrp* gene expression showed no considerable impact on bacterial virulence.

Keywords: *Xanthomonas oryzae* pv. *oryzae*, *XOO2767*, *hrp* regulator, expression, DNA-binding.

Population diversity of *Xanthomonas oryzae* pv. *Oryzae* in Bangladesh and relationship to known bacterial blight resistance genes

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Bacterial blight (BB) disease of rice is one of the most serious diseases of rice occurs in almost all the parts of Bangladesh. Knowledge on population diversity of (BB) pathogen *Xanthomonas oryzae* pv. *Oryzae* as well as their corresponding virulent gene(s) is important to develop a durable BB resistant rice variety. An experiment was carried out to investigate the pathogenic diversity of *Xanthomonas oryzae* pv. *Oryzae* as well as to identify corresponding resistance genes against the major races in Bangladesh. The experiment was conducted at Plant Pathology Division of Bangladesh Rice Research Institute (BRRI), Bangladesh. A total of 172 isolates of BB pathogen were collected from different regions of Bangladesh during 2011-12. The isolates were inoculated on nine BB resistance monogenic IRBB lines developed by IRRI. Plants were inoculated following leaf clipping method at maximum tillering stage. Sixteen BB races were identified for Bangladesh, where race 1 was dominant which occupied 61.0% of the total isolates followed by race 8 and race 3 occupied 10.46% and 9.3% of isolates, respectively. Among the known nine resistant genes, *Xa21* was found most effective gene against the major races in Bangladesh. It showed 89.5% resistant frequencies against the studied isolates. This information will be helpful for developing durable BB resistant rice variety in Bangladesh. *Xa21* gene might be used as a candidate gene for developing BB resistant rice variety which undoubtedly boosts national rice production to a certain extent in Bangladesh.

Keywords: Bacterial blight, *Xanthomonas oryzae*, gene(s), rice.

Effect of temperature and pH on the growth and sporulation of *Fusarium moniliforme*

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Under favourable disease development conditions bakanae disease of rice causes substantial yield losses. Temperature and pH of the growth medium affects the sporulation of *Fusarium moniliforme* (Sheldon), the causal organism of bakane. The objective of the work was to determine the effect of temperature and pH on growth and sporulation of *Fusarium moniliforme*. The experiment was conducted in Plant Pathology Laboratory of Bangladesh Rice Research Institute (BRRI). Six (5, 15, 20, 25, 30 and 35°C) levels of temperature and seven levels of pH (pH 4, 5, 6, 7, 8, 9, and 10) were tested against three period (3, 6 and 9 days) of measurement. Mycelial culture of the fungus grown at 25°C produced the highest colony diameter at all the period of measurement and was significantly higher than the other levels of temperature. However, the culture of *Fusarium moniliforme* at 30°C consistently produced the highest number of spores after nine days of incubation. *Fusarium moniliforme* grew well across all the tested pH levels. However, the widest colony diameter was observed at pH 6 after 9 days of incubation which was statistically similar to the colony diameter of pH 7 and pH 8, respectively. Maximum sporulation also recorded at pH 6. The number of spore production gradually decreased after pH 8 and lowest spore/ml was recorded at pH 10.

Keywords: Temperature, pH, Growth, Sporulation, *F. moniliforme*

RICE FARMING SYSTEMS

Intervention of farming systems technologies for improving livelihood of the resource poor small farm households

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Most of the farmers of Bangladesh have limited land resource, which warrants diversification of their production systems, both crop and non-crop components in order to satisfy their needs. This study was undertaken aiming to increase income of small farm families through the intervention of improved farming system technologies. Three farmers were randomly selected from small farm category (as required for this study) from Moison locality of Kapasia Upazilla under Gazipur district. The study involved bench-mark survey of the selected famers followed by intervention through 7 technologies: (i) N-management through use of leaf colour chart (LCC) in modern Boro and T.Aman rice, (ii) Water saving technologies for rice, (iii) Production of high value summer and winter vegetables in the homestead area, (iv) Production of improved turmeric and ginger in the homestead, (v) Pest management in mango, (vi) Fertilization of bearing trees of jackfruit, and (vii) Fish culture in seasonal ponds. The income and expenditure data of the intervened farmers were collected using structured questionnaire. In this study, income included the total amount of products consumed, distributed to the relatives and their sale price, whereas household expenditure included the total cost of production of the intervened technologies. The collected data were analyzed and compared with bench-mark data. Results indicate that compared to the bench-mark year, the average income of the farmers increased by $30.3 \pm 13.5\%$ (\pm is the standard error). Increased income was generated predominantly through improvements in crop and vegetable sectors. The intervened farmers also increased their expenditure by $23.3 \pm 12.1\%$. The tendency of increasing the expenditure in the line of income reflects the improvement of livelihood in the farm families. The relatively high standard error with both in income and expenditure (13.5% and 12.1%, respectively) indicates that all the farm families could not realize the benefits of intervened improved farming system technologies. Future research should be directed on finding the reasons behind uneven acceptance of technologies and formulate appropriate steps for technology transfer.

Keywords: Farming systems, livelihood improvement, small farmer, technology intervention

Yield and yield components of Boro rice as influenced by timing of nitrogen fertilizer application

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Nitrogen (N) is one of the yield limiting factors in rice production in all agro-ecological regions of Bangladesh. To determine the effect of timing of nitrogen fertilizer application on yield, yield components and N-use efficiency of rice, a field experiment was conducted during Boro season of 2013-14, at the experimental farm of Bangladesh Rice Research Institute (BRRI), Gazipur. The experiment composed of five nitrogen management - three splits of N application (one-third at initiation of tillering + one third at active tillering + one-third at panicle initiation) (N₁), two splits of N application (half at initiation of tillering + half at panicle initiation) (N₂), two splits of N application (one-third at initiation of tillering + two-third at panicle initiation) (N₃), three splits of N application (one-fourth at initiation of tillering + one-fourth at active tillering + half at panicle initiation) (N₄) and N- Control (N₅). The experiment involved RCB design with three replications and two modern varieties- BRRI dhan28 and BRRI dhan29. Each treatment received the recommended optimum rate of 119 kg N ha⁻¹ and 136 kg N ha⁻¹ for BRRI dhan28 and BRRI dhan29, respectively, as urea. The time of N application significantly affected grain and straw yields in both the varieties. The N₃ treatment increased grain yield in BRRI dhan28 and N₄ increased grain yield in BRRI dhan29, respectively. The N₅ treatment produced minimum grain yield both in BRRI dhan28 and BRRI dhan29. Nitrogen management treatments had significant (P<0.05) effects on the number of panicles, 1000 grain weight and grain N uptake. But no significant effect was observed in filled grains per panicle and straw grain uptake. Agronomic use efficiency (AUE) varied from 10 to 14 kg kg⁻¹ in BRRI dhan28 and 14 to 18 kg kg⁻¹ in BRRI dhan29, irrespective of different splits of N treatments. Physiological efficiency (PE) ranged from 93 to 125 kg kg⁻¹ in BRRI dhan28 and 134 to 146 kg kg⁻¹ in BRRI dhan29. The higher PE was observed in N₄ treatment followed by N₁ treatment. In BRRI dhan28, the higher PE was in N₃ treatment followed by N₂ treatment. Agrophysiological efficiency varied from 50 to 55 kg kg⁻¹ in BRRI dhan28 and 60 to 63 kg kg⁻¹ in BRRI dhan29. Apparent recovery efficiency was 18% in BRRI dhan28 and 24% in BRRI dhan29 across different splits of N treatments. The utilization efficiency (UE) varied from 10 to 28 kg kg⁻¹ in BRRI dhan28 and 26 to 47 kg kg⁻¹ in BRRI dhan29, irrespective of different splits of N treatments. Higher UE in BRRI dhan28 BRRI dhan29 was obtained with N₃ and N₄ treatments, respectively.

Keywords: Rice, split of N application, yield and yield components, N use efficiency

Evaluation of sesbania application and weed management practices in transplanted aman under boro-fallow-transplanted aman cropping pattern

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Green manuring with *Sesbania* has potentiality to improve organic matter status of soil. However, incorporation of *Sesbania* through ploughing appeared as a constraint in adoption in farmers' fields. Application of herbicides to put down *Sesbania* may be feasible. To evaluate the effectiveness of herbicide for incorporating *Sesbania* in T. Aman rice, an experiment was conducted during Aman season, 2011-2012 at west-byde of BRRI. *Sesbania* was incorporated on two different dates (30 DAS and 40 DAS) and by two different methods (by herbicide application and by ploughing down). The treatments were 30 day old *Sesbania* applied with herbicide application (SH₃₀), 40 day old *Sesbania* applied with herbicide application (SH₄₀) and 40 day old *Sesbania* applied through ploughing (SP₄₀) and no *Sesbania* (S₀). On the other hand, weeding was done in different times after transplanting. Hand weeding at 15, 30 and 45 DAT (W₁), at 30 and 45 DAT (W₂), at 45 DAT (W₃) and no weeding (W₀) were executed in the experiment. The experiment was laid out in RCB design with three replications. Interaction effect of *Sesbania* incorporation and weeding method demonstrated significant interaction. The highest yield (4.76 t/ha) was obtained from SH₄₀W₁ which was statistically similar to SP₄₀W₁, which yielded 4.26 t/ha. The results suggest that *Sesbania* may be incorporated through herbicide application.

Keywords: Weed infestation, *Sesbania* incorporation, Hand weeding

Evaluation of short duration mustard and double transplanting technologies in single and double rice ecosystems

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Boro-Fallow-Fallow and Boro-Fallow-T. Aman are widely practiced cropping systems covering 1.09 and 1.81 million ha, respectively in Bangladesh,. Declining profitability has compelled us to introduce new crops in existing traditional cropping systems. Short duration mustard may play a vital role in such diversification and intensification. On the other hand, double transplanting technology may be an alternative option either to reduce the yield loss of late planted Boro rice or to keep it at a minimum level. This study aimed to evaluate and disseminate rice double-transplanting technology to intensify single rice and double rice systems. Char Kharicha and Alapur blocks of

Mymensingh Sadar were selected for single and double rice ecosystem, respectively with the joint effort of researcher and extension providers in Mymensingh Sadar upazilla. Two cropping systems were compared with the existing system in six farmer's field in each location during 2011-2013. In single rice ecosystem, the cropping systems were: Mustard (BARI Sarisha15)-Double transplanted Boro (BRRI dhan29)-Fallow-Fallow, Mustard (BARI Sarisha15)-Boro (BRRI dhan28)-Fallow-Fallow and Boro (BRRI dhan29)-Fallow-Fallow (Existing). Whereas in double rice ecosystem, the evaluated systems were: Mustard (BARI Sarisha15)-Double transplanted Boro (BRRI dhan29)-Fallow-T. Aman (BRRI dhan33), Mustard (BARI Sarisha15)-Boro (BRRI dhan28)-Fallow-T. Aman (BRRI dhan33) and Boro (BRRI dhan29)-Fallow-T. Aman (BINA dhan7) (Existing). The introduction of both double transplanting of Boro rice and short duration mustard variety into the rice based cropping systems proved beneficial as higher productivity and returns were obtained from the systems comprised with mustard and double transplanted Boro rice in both ecosystems. In spite of higher cost of double transplanted technology over traditional system, the Mustard-Double transplanted Boro-Fallow-Fallow and Mustard-Double transplanted Boro-Fallow-T. Aman systems gave about 19-31% and 16-21% higher gross margin, respectively than the conventional systems. Short duration mustard and double transplanting of Boro rice can be practiced successfully as an option for optimizing the productivity of single and double rice ecosystems.

Keywords: Productivity, double transplanting, short duration mustard

Crop residue management under permanent raised beds in Rice-Wheat Systems

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Bed planting in Wheat - Mungbean - Rice cropping systems along with crop residue retention may be a technique for improving resource use efficiency, managing soil organic matter and increasing the system productivity. To compare the effect of crop residue retention on the productivity of permanent beds and compare the agro-economic productivity of permanent bed system and conventional method in Wheat - Mungbean - Rice cropping system, a long-term experiment was conducted during 2007 to 2013 in Rabi, Kharif-1 and Kharif-2 seasons at BRRI experimental farm, Gazipur. Five crop establishment options -permanent beds with 100% crop residue retention (T₁); permanent bed with 50% crop residue retention (T₂); permanent bed without crop residue retention (T₃); semi permanent bed (new beds with conventional tillage in every

wheat season) (T₄) and conventional (flat) (T₅-) were evaluated in RCB design with three replications. For the treatments with bed, 70 cm (40 cm top and 30 cm furrow) wide beds with 15 cm height were made. Significantly higher grain yields of wheat (2.25-3.38 t/ha), mungbean (0.77-0.89 t/ha) and rice (3.30-3.84 t/ha) were produced by permanent beds with 100 % crop residue retention over the five years period 2009 to 2013 followed by permanent bed with 50% crop residue retention than conventional. Without crop residue on permanent beds and semi-permanent beds, grain yields of wheat and rice were statistically similar from 2009-13. In 2007-2008, T₅ gave higher rice equivalent yield (REY) compared to the bed practices. The REY increased by bed method (8.74-13.15 t/ha) over conventional (7.48-9.48 t/ha) from 2009 to 2013. Total variable cost was found lower in bed method (Tk 1,17,410-1,26,280/ha) than conventional method (Tk 1,33,870-1,42,940/ha) whereas gross margin in permanent beds with 100 % crop residue (Tk 96,710-1,16,970 / ha) was higher than conventional method (Tk 21,250 - 47,820 /ha) in Wheat - Mungbean - Rice cropping systems. Thus crop residue management in permanent beds appeared to be promising for yield advantage and cost- effectiveness.

Keywords: Permanent bed, Crop residue, Yield and Productivity

Development and validation of suitable cropping pattern for northern region

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This study was done to refine the technology through inclusion of recent rice (BRRI dhan28, 49, 55 & 57), maize (BHM-5), potato (Diamont, Asterix & Cardinal), wheat (BARIgom-26) and mungbean (BARI mug-6) for increasing the agro-economic productivity of potato-maize-T.aman, potato-boro-T.aman and wheat-mungbean-T.aman cropping system. This activity was initiated during November 2013 in 24 plots, 6 each in Pairaband under Mithapukur Upazila of Rangpur district, Holokhan under Kurigram Sadar Upazila of kurigram district, Khoksabari under Nilphamari Sadar Upazila of Nilphamari district and Sarpukur under Aditmari Upazila of Lalmonirhat district. BHM-5 decreased the agro-economic productivity of potato-maize-T.aman cropping systems due to low yield compared to existing maize variety NK-40. BRRI dhan28, 49, 55 & 57 was highly profitable due to high yield and short duration compared to existing variety BR11 and Swarna in potato-boro-T.aman cropping systems. BARIgom-26 and BARI mug-6 increased the agro economic productivity in rice-wheat ecosystem compared to existing wheat (Kanchan) variety and

inclusion/substitution of BARImug-6 in wheat-fallow-T.Aman/wheat-jute-T.Aman cropping systems.

Keywords: Agro-economic productivity, Existing cropping pattern, improved cropping pattern, Northern Region

Evaluation of rice-based cropping pattern in partially irrigated ecosystem

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Bangladesh is mainly a rice-based country where increase in food production and food security as well as diversification of rice-based system to increase productivity per unit resource are very pertinent. A field experiment was conducted during the period from Rabi 2013 to Aman 2014, at the experimental farm of Bangladesh Rice Research Institute (BRRI), Gazipur, to evaluate the performance of some recently released BRRI varieties in Vegetable-Mungbean-DS Aman cropping system in terms of both combined yields and economic performance. Five cropping patterns viz. Tomato (BARI hybrid tomato-5)-Mungbean (BARI mug-6)- DS Aman (BRRI dhan57) (CP₁), Tomato (BARI hybrid tomato-5)- Mungbean (BARI mug-6)- DS Aman (BRRI dhan56) (CP₂), Tomato (BARI hybrid tomato-5)- Mungbean (BARI mug-6)- DS Aman (BRRI dhan62) (CP₃), Tomato (BARI hybrid tomato-5)- Mungbean (BARI mug-6)- DS Aman (BRRI dhan39) (CP₄) and Tomato (BARI hybrid tomato-5)- Mungbean (BARI mug-6)- DS Aman (BRRI dhan33) (CP₅) were evaluated in RCB design with three replications. Rice varieties did not differ significantly in terms of grain yield (t ha⁻¹). The rice equivalent yield (REY) among the different cropping patterns also showed insignificant. From economic evaluation, higher gross return, gross margin and benefit cost ratio (BCR) were obtained from CP₄ (Tomato-Mungbean-BRRI dhan39) followed by CP₅ (Tomato-Mungbean-BRRI dhan33) and CP₁ (Tomato-Mungbean-BRRI dhan57). The total variable cost (TVC) was found similar in the tested cropping patterns due to similar monetary involvement.

Keywords: DS Aman, cropping pattern, Tomato, Mungbean.

Planting and fertilizer management options for double transplanted late aman and boro rice

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Double transplanting of rice is a good option to minimize yield loss of both *T. Aman* and *Boro* rice under late planting situation. Recommended planting and fertilizer management options for double transplanted *T. Aman* and *Boro* rice is absent. The

experiment was conducted at BRRI east *byde* during *T. Aman* 2013 and *Boro* 2014 to evaluate 7 packages of planting and fertilizer management options for *T. Aman* and *Boro* rice to obtain suitable recommendation. BRRI dhan49 and BRRI dhan29 were transplanted on 25 September and 25 February during *T. Aman* and *Boro* seasons, respectively. The packages for *T. Aman* were T₁- Usual transplanting of 60 day-old-seedlings with recommended fertilizer, T₂- Usual transplanting of 45 day-old-seedlings with recommended fertilizer, T₃- Usual transplanting of 30 day-old-seedlings with recommended fertilizer, T₄- Double transplanting of 60 day-old (30 day in seedbed and 30 day in 1st transplanted plot) cent percent removed seedlings from 1st transplanted plot with no fertilizer, T₅- Double transplanting of 60 day-old (30 day in seedbed and 30 day in 1st transplanted plot) cent percent removed seedlings from 1st transplanted plot with 1st split urea, T₆- Double transplanting of 60 day-old (30 day in seedbed and 30 day in 1st transplanted plot) 75% removed seedlings from 1st transplanted plot with 1st split urea and full basal fertilizer and T₇- Fully fertilized normal time 1st transplanted plot on 25 August. The packages for *Boro* were T₁- Usual transplanting of 80 day-old-seedlings with recommended fertilizer, T₂- Usual transplanting of 60 day-old-seedlings with recommended fertilizer, T₃- Usual transplanting of 40 day-old-seedlings with recommended fertilizer, T₄- Double transplanting of 80 day-old (40 day in seedbed and 40 day in 1st transplanted plot) cent percent removed seedlings from 1st transplanted plot with no fertilizer, T₅- Double transplanting of 80 day-old (40 day in seedbed and 40 day in 1st transplanted plot) cent percent removed seedlings from 1st transplanted plot with 1st split urea, T₆- Double transplanting of 80 day-old (40 day in seedbed and 40 day in 1st transplanted plot) 75% removed seedlings from 1st transplanted plot with 1st split urea and full basal fertilizer and T₇- Fully fertilized normal time 1st transplanted plot on 15 January. In T₇ treatment in both *T. Aman* and *Boro*, primarily the spacing in 1st transplanted plot was 10 x10 cm and finally it was 20 x 20 cm after 75 % seedling removal for 2nd transplanting. During *T. Aman*, under late planting on 25 September, the highest yield of BRRI dhan49 was 5.25 t ha⁻¹, which was obtained from double transplanted T₆ treatment, while no, 3.50 and 2.86 t ha⁻¹ yields were obtained from T₃, T₂ and T₁ treatments, respectively with usual transplanting of 30, 45 and 60 day-old-seedlings. During *Boro*, under late planting on 25 February, the highest yield of BRRI dhan29 was 8.08 t ha⁻¹, like *T. Aman*, which was also obtained from double transplanted T₆ treatment, while 6.92, 6.86 and 6.91 t ha⁻¹ yields were obtained from T₃, T₂ and T₁ treatments, respectively with usual transplanting of 40, 60 and 80 day-old-seedlings. Under late planting situation, double transplanting of 60 day-old-seedlings of BRRI dhan49 in *T. Aman* and 80 day-old seedlings of BRRI dhan29 in *Boro* with 75%

removed seedlings from 1st transplanted plot with 1st split urea and full basal fertilizer may be recommended.

Keywords: Double transplanting, Late transplanting, Planting management, Fertilizer management

FARM MECHANIZATION

Design and Develop a Self-propelled Reaper with Simple Power Transmission Gearbox

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Harvesting of cereal crops by machine is an important part of mechanized agriculture. Timely harvest of crop is very important to achieve better quality and higher yield of the crops. Delayed harvesting due to shortage of labor and early flood often cause yield loss which can be minimized by the use of reaper. This study was undertaken to design and develop a low cost self-propelled reaper with simple power transmission gearbox using locally available materials. All the drawings of self-propelled reaper were completed with the help of AutoCAD tools. Fabrication of the self-propelled reaper was also completed at research workshop, Bangladesh Rice Research Institute (BRRI), Gazipur. A simple gearbox was used for one forward and one reverse speed. To evaluate the overall performance of the BRRI developed self-propelled reaper, some tests were conducted during last three years (2011, 2012 and 2013) comparing with imported self-propelled reaper. In these tests BRRI dhan28 were harvested in Boro and Aman seasons at Rangpur, Jhenaidah, Gazipur and Rajshahi Regional stations of BRRI. Results showed that the average field capacity of the BRRI reaper was 0.272 ha/hr (67.30 decimal/hr) compared to 0.204 ha/hr (50.38 decimal/hr) for imported reaper. On the other hand, average field capacity of manual harvesting was 0.008 ha/hr (1.90 decimal/hr). The labor requirements including bundle making for both reaper and manual harvesting were 67 m-hr/ha and 264 m-hr/ha, respectively. The grain losses for rice in manual and reaper harvesting were 7.40% and 2.43%, respectively. The costs of harvesting operation (including labor for bundle making and collecting) were Tk. 3,645 for reaper harvesting and Tk. 11,550 for manual harvesting. The average fuel consumption of imported reaper and BRRI developed self-propelled reapers were 0.733 l/hr and 0.825 l/hr, respectively. The walking speed of BRRI reaper (3.78 km/hr) was higher than that of imported reaper (2.33 km/hr). But this higher speed is not a problem for an operator to operate the reaper during field operation as it is adjusted for on road and off road condition. The break-even point of the machine is 4.0 ha/year; therefore, if the machine works on less than this amount, it is not economically beneficial. The purchase price of imported reaper is almost double than that of BRRI developed self-propelled reaper. The same power unit of the reaper was used for garden tilling purposes changing the tiller accessories instead of reaper unit.

Keywords: Reaper, harvesting, performance, labor requirement

Development and modification of Engelberg huller for securing higher milling yield

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Rice processing in the Engelberg rice mill still occupies more than 60% of the total production. Depending upon rice varieties, air blowing type of Engelberg rice mill may give an additional 1-3% yield of head rice compare to the traditional Engelberg rice mill. Moreover, air blowing type of Engelberg rice mill has greater efficiency and capacity to control over degree of polishing. Experiments were conducted in the Farm Machinery and Postharvest Technology Division's Milling Research Laboratory to improve the traditional Engelberg rice mill. The capacity of the modified air blowing type Engelberg rice mill was increased by 250% compared to the traditional Engelberg rice mill. The machine efficiency is 99% and can save Tk 1300.00 per 1000 kg of paddy processing compared to traditional Engelberg milling. It was calculated that, if 50% of the total traditional Engelberg hullers are modified to be air blowing type Engelberg rice mills, then 0.3 million tons in extra yield can be obtained, and, if 100% of the traditional Engelberg hullers are modified to be air blowing type Engelberg rice mills, then 0.6 million tons in extra yield can be obtained.

Keywords: Engelberg Huller, milling yield, degree of milling

Paddy yield as influenced by different tillage depths

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Experiments were conducted at Harinakundu upazilla, Jhenidah district under Mujib Nagar project in boro 2014 and aman 2014 seasons to determine paddy yield as influenced by different tillage depths. Tillage is an important agronomic practice to make soil physically, chemically, and biologically suitable to improve seed germination, seedling emergence and for optimal plant growth and crop productivity. Tillage improves soil conditions by altering mechanical impedance to root penetration, aggregate size distribution, hydraulic conductivity and water holding capacity, which in turn, affects plant growth of rice. There were three tillage depths such as: 4-5 inch, 5-6 inch and 6-7 inch. The tillage depths were maintained by a power tiller. BRRI dhan28 was cultivated in Boro 2014 season and BRRI dhan56 was cultivated in Aman 2014 season. Tillage depths significantly affected both the yield of BRRI dhan28 and BRRI dhan56 in 2014. The highest grain yield of BRRI dhan28 was found 7.50 t/ha in the

tillage depth up to 6-7 inch and the lowest yield was found 6.88 t/ha in the tillage depth up to 4-5 inch in Boro season. On the other hand, in Aman 2014 season, the highest grain yield of BRRI dhan56 was found 5.40 t/ha in 6-7 inch tillage depth and the lowest yield was found 4.40 t/ha in 4-5 inch tillage depth. The highest yields of both the seasons were found under the higher tillage depths up to 6-7 inch and the lowest yields were obtained in the tillage depth up to 4-5 inch. The deep tillage (6"-7") might have favoured the roots to proliferate down into the deeper layers of the soil profile to extract more nutrients and moisture that has led to yield of paddy in both seasons. Higher tillage depth favorably influenced the soil-water-plant ecosystem, thereby improved crop yields.

Keywords: Tillage depth, power tiller, rice yield

Cone penetration resistance of BRRI farm soil

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In-situ cone penetration resistance of BRRI west byed rice bed soil was determined by a proving ring cone penetrometer to develop a mathematical relationship for cone penetration resistance in terms of density and moisture content for the soil type and find optimum moisture content for minimum tillage. The soil of the study area was found clay loam (Sand = 37.9%, Silt= 38.0%, Clay 28.1%) by investigation under controlled laboratory conditions. The physical properties of soil such as bulk density, dry density, moisture content, texture, soil consistency limit analysis and cone penetration resistance were determined at 10, 15 and 20 cm depths. The bulk densities, dry densities, moisture content of soil ranged from 1.28 to 1.78 gm/cc, 1.05 to 1.50 gm/cc and 14.82 to 25.84% respectively. The plastic and liquid limits for the experimental soil were 20.1 and 33.25%. The penetration resistance of a soil depends on texture, moisture content, dry and bulk densities. The cone penetration resistance of the soil varied from 147.05 to 5605 kN/m². For rice bed (clay loam) soil, the minimum cone penetration resistance was 147.05 kN/m² at 22.1% moisture content. A mathematical model for cone penetration resistance as a function of moisture content and dry density was developed for clay loam soil. The relationship among cone penetration resistance, dry density and moisture content in 3-D space for a soil enables one to make practical use of cone penetration test for soil compaction related studies. The liquid and plastic limits were determined for classifying soil and indication of mechanical behavior of soil. The measured cone penetration resistance as an index of a wide range of soil physical and mechanical properties can be used in vehicle mobility and agricultural soil mechanics.

Keywords: Cone penetration resistance, bulk density, dry density, moisture content

Field evaluation of 6-row riding type mechanical rice transplanter

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Six-row riding type mechanical transplanter is one of the important machines for mechanization. The machine had options for nine seedling densities, three depths of transplanting and four spacing. Evaluation of the 6-row riding type transplanter involved participatory public private partnership research approach in farmers' fields, at Chandpur, Natore, during 2014 aman season. Fuel consumption and seedling requirement (number of seedling-tray) of the transplanter was determined using rice variety BRRI dhan49 and BINA dhan7. The tested transplanter consumed 18 L fuel per ha and required 175 trays per hectare (about 6% of seedling trays were required for manual transplanting in the irregular areas of the plot). Transplanting activity included operating, movement, cleaning and idle time of the machine. On an average, plot to plot movement and idle time consumed about 52% of the time. We observed that the smaller the plot size the lower the daily area coverage by the transplanter. The tested 6-row riding type transplanter had field capacity of one hectare per day. Various factors such as plot size and shape, land preparation, land leveling, water height, plot to plot distance affected machine field performance.

Keywords: Fuel consumption, seedling-tray, field capacity

Conservation tillage in unpuddled rice-maize cropping system

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Over the last two decades, rice (*Oryza sativa* L.)-maize (*Zea mays* L.) cropping systems become one of the most dominant cropping systems in Bangladesh. A three-year trial examined the prospects of conservation agriculture practices for rice-maize cropping in Bangladesh, with respect to minimum tillage and residue retention. Main plot tillage treatments of conventional full tillage, single pass wet tillage in rice (rotated with zero tillage in maize), bed planting and strip tillage were combined with residue retention treatments of 0, 50 and 100% in sub-plots. Compared to conventional tillage, minimum tillage saved 60-66% of fuel and 70-74% of labour required for land preparation. Although minimum tillage reduced the land preparation cost significantly through saving fuel and labour, weed infestation was higher compared to conventional tillage, which influenced the cost of production. Rice seedlings transplanted under unpuddled

strip tillage required more time than in conventional or single pass wet tillage due to poor visibility of strips and the hard surface of untilled soil. Bed planting incurred the lowest production cost. Tillage methods and residue treatment gave no significant grain yield differences. Rice grown with single pass wet tillage and maize grown with strip tillage gave the highest gross margin over time. Despite lack of treatment effects on yields, the results suggest that profitability of rice-maize cropping could be increased with minimum tillage, provided there is adequate control of weeds by herbicides.

Keywords: conventional tillage, single pass wet tillage, strip tillage

Evaluation of mechanical transplanter in unpuddled transplanting of wet season rice in sandy loam soil

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Alternate to puddling, unpuddled transplanting is a new concept of rice cultivation. An experiment was conducted to evaluate the performance of mechanical rice transplanter in unpuddled condition under minimum tillage practices in drought prone zone representing sandy loam soil in wet season 2012. Tillage treatments were (i) conventional puddling (CT) in puddled condition and (ii) no tillage (NT) (iii) bed planting (BP) (iv) and strip tillage (ST) in unpuddled condition. Results indicated that unpuddled transplanting saved fuel, time and labour remarkably in land preparation. Compared to puddled field, unpuddled field required more time for transplanting and showed more floating hills. Unpuddled transplanting and puddled transplanting plots gave similar grain yield. Water productivity was the lowest in unpuddled than puddled transplanting. Input cost was higher in conventional puddling than unpuddled transplanting. Unpuddled transplanting may be recommended in sandy loam soil.

Keywords: Bed planting, strip tillage, floating hill

Evaluation of Tegra mechanical rice transplanting in farmers' fields

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The study was conducted in the farmers' fields, Nandigram, Bogra during aman season 2013 and boro season 2014. Soils of the experimental areas belonged to clay loam texture, AEZ 25 level Barind tract. In each season, six farmers within one kilometer radius were selected to conduct the study. Each farmer's field received manual transplanting (MT) and transplanter transplanting (TT). The Tegra mechanical

transplanter is a four-row walking-type self-propelled rice transplanter was used for TMT. The machine had provisions for adjustments of planting depth, number of seedlings per hill, floats pressure against soil, hill spacing and planting speed. Both the MT and TT plots received conventional puddling and leveling using two-wheel tractor. The TMT used seedlings raised in plastic tray by using Syngenta media at 2-3 leaves and 10-12 cm height. The MT plots were transplanted with about 30-day-old seedlings. Both TT and MT plots received equal amounts fertilizer application. Mechanical transplanting was faster than hand transplanting. The mechanically transplanted plots had only a few missing or floating hills. Mechanical transplanter consumed 4.5 L fuel per ha, which is equivalent to the cost of 1.5 laborers. Although plant height for both the TT and MT plots were similar, TT plots produced more tiller than TT one. Compared MT, TT plots produced 14-23% higher grain yield in both seasons. Farmers preferred MT over TT in both seasons. The total cost of production, gross return, gross margin and BCR were higher in MT than TT in two seasons due to higher grain and straw yield.

Keywords: Manual transplanting, grain yield, fuel consumption

Energy consumption under conservation tillage in unpuddled rice-maize cropping systems

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Energy budget in agricultural production became essential for efficient management of the resources. The energy balance under different conservation tillage management practices in rice-maize cropping system during 2009-12 was assessed by for energy input and output, energy productivity and energy output:input ratio. Energy input in conventional tillage (CT), strip tillage in rice followed by zero tillage in maize (SPWT), bed planting (BP) and strip tillage (ST) appeared as 48.93, 41.51, 41.89 and 41.05 GJ ha⁻¹, respectively in rice-maize cropping system. Chemical fertilizers consumed the maximum energy. Tillage energy ranked second in conventional tillage and ranked fourth in minimum tillage options. The lowest energy input was required for maize and the highest for rice due to less irrigation water requirement in maize. The energy output under all tillage options was two-fold higher in maize than rice due to increased grain yield. Energy output was insignificant due to insignificant yield difference. Minimum tillage showed 14-17% increase in energy productivity and 19-26% increase in energy output:input ratio. However, from the energy saving point of view, single pass shallow tillage in rice production followed by zero tillage in maize cultivation may be

considered better options depending on the resources availability in rice-maize cropping system.

Keywords: Minimum tillage, energy balance, energy productivity, energy ratio

Evaluation of urea fertilizer applicator at farmer's field

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Prilled urea applicator (PUA) for lowland is an innovation of Bangladesh Rice Research Institute. An experiment was conducted to evaluate the performance of PUA in farmers' fields in Shailkupa upazila under Jhenaidah district and in Mithapukur upazila under Rangpur district during boro 2015 season. Three treatments—hand broadcasting of urea at recommended dose (HB), application of 70% of the recommended dose of urea through PUA (PUA) and application of 70% of urea as super granule through BRRI USG applicator (USGA) were compared. The experiment was laid out in randomized complete block design (RCBD) and replicated in four farmers' plot using BRRI dhan28 as test variety. Before field experiment, prilled applicator was calibrated and urea dispensed was set to 14 g in one revolution of drive wheel for boro season. BRRI prilled urea applicator and BRRI USG applicator safely dispensed urea fertilizer at subsurface zone of soil. The PUA and USGA demonstrated similar field capacity (0.09-0.10 ha/hr) in both locations. PUA had field efficiency of 64–65% compared to 68–69% with USGA. PUA and USGA saved 29-32 percent urea fertilizer compared to HB. Urea application cost in HB, PUA and USGA incurred Taka 4,624, 3,216-3,424 and 3,305-3,483 per hectare. Grain yield showed similar in PUA, USGA and HB. Only urea fertilizer cost varied and other input cost in the form of labor and material obtained similar in all urea application plot. PUA and USGA reduced 2-2.5% input cost than HB in crop cultivation. The biggest advantage of the applicator is the savings of urea fertilizer and reduced the burden on foreign currency as government imported the fertilizer and supplied to farmer at subsidized price.

SOCIOECONOMIC AND POLICY

Impact assessment of seed production and demonstration program (SPDP) on quality seed and rice production

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Demonstration is one of the recognized methods to create awareness and dissemination of technology. Adaptive Research Division of BRRI disseminated BBRI developed new varieties along with different production technologies through seed production and dissemination program (SPDP). The present study was undertaken to evaluate the impact of SPDP on rice seed production as well as creation of awareness about demonstrated rice varieties at farm level. A total of 52 (21 participated and 31 non-participated) farmers from Batiaghata and Fultala Upazila under Khulna and Bheramara and Kustia Sadar under Kustia district were randomly selected for this study. In Khulna, only Boro varieties like BRRI dhan28, BRRI dhan29, BRRI dhan47 and BBRI Hybrid dhan2 were demonstrated and in Kustia, BRRI dhan28, BRRI dhan50, BRRI dhan55 for Boro and BRRI dhan39 for T. Aman and BRRI dhan48 for Aus seasons were demonstrated. In both the districts, almost 100% farmers accepted BRRI dhan28 variety in Boro season because of its fine grain, short duration and high market price. BRRI dhan29 was found not suitable due to long duration and BRRI dhan47 was not popular for its coarse grain and high shattering in Khulna. BRRI dhan39 was accepted by more than 70% participated farmers due to short duration and BRRI dhan48 was more popular and accepted by around 80% participated farmers for higher yield in Kustia district. Some non-participant farmers convinced and accepted BRRI dhan39 and BRRI dhan48 in Kustia district. Farmers did not get actual price of BRRI dhan50 as they were exploited by the middleman. In Kulna, farmers reported their insufficient seed in the next season as they have no storage facility but in Kustia, few farmers produced seed and some portion sold to other farmers.

Keywords: Impact assessment, seed production and demonstration, rice variety,

Comparative economic performance of urea spray and magic growth technology

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Nitrogen fertilizer is one of the key elements that brings variation in cost of production, yield obtained as well as economic profitability. As a part of the continuous effort of

finding cheaper alternatives for nitrogen management to provide the farmers with an economic relief, this study evaluated the economic performance of Magic Growth (MG) technology on BRRI dhan28. A field experiment with 10 different fertilizer treatments was set at Bangladesh Rice Research Institute Farm, Gazipur during Boro 2013-14 season. Another field experiment with 6 treatments of urea spray technology was also conducted for comparing the performance of urea spray technology with BRRI recommended method of nitrogen (N) management. Both the experiments were designed following RCBD with three replications. Soil test based (STB) N dose of 116 kg/ha and flat dose of P-K-S-Zn @ 17-60-20-4 kg/ha was applied, respectively. Cost of input used was calculated and profitability was analysed. Variable cost for the treatments was calculated considering seedling treatment cost, fertilizer cost and labour cost for fertilizer application. Fertilizer used includes both soil and foliar application. The result showed that the MG solution is the key element for the variation in costing. Variable cost stood the highest (17698 Tk/ha) for the treatment 100% N + MG followed by all other treatments that involved MG applications. The application of MG did not show any economic benefit over without MG spray. Gross margin and BCR (109033 Tk/ha and 10.61 respectively) of T₂ treatment with the reduced N dose of 35% was comparably equal to that of T₅ treatment (109201 Tk/ha and 9.43) with 25% reduced N dose where urea spray technology was used. From this result it is revealed that urea spray technology was not effective for rice cultivation. Thus, based on the above findings it may be concluded that, applying MG technology and urea spray are less effective alternatives for nitrogen management in rice production.

Keywords: Profitability, Grain yield, Nitrogen management.

Assessment of technical efficiency of rice farmers in a selected empoldered area of Bangladesh

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The study was conducted in a coastal empoldered area of Bangladesh, namely Dacope Upazia of Khulna district. This paper assesses the technical efficiency of rice farmers in Bangladesh using a Cobb-Douglas stochastic frontier approach and also estimating the profitability of *T. Aman* rice farming. Farm-specific technical efficiencies are estimated using farm-level cross-sectional survey data in a single estimation technique, which includes both stochastic frontiers and inefficiency effects models, applying the maximum likelihood estimation method. One hundred sample rice farmers were

interviewed with a pretested interview schedule. The Activity Budgeting Technique was used to estimate the profitability of *T. Aman* rice farming. *T. Aman* rice production was found profitable at the study area as benefit cost ratio (BCR) was 1.75 on full cost basis. The average level of technical efficiency of the sample farmers was about 75%, implying that given the existing technology and level of inputs, the output could be increased by 25%. Farmer's education and training had significant positive effect on *T. Aman* rice production. Farmers of the study area mentioned some economic, technical and social constraints which were the cause of deviation from the highest level of production at farm level. The economic constraints were high price of input, low price of output and lack of sufficient fund. The technical constraints were high salinity, lack of scientific knowledge & technology, lack of quality seedlings, attack of disease & insecticides, lack of required pesticide, lack of good water management; and the social constraints recorded as illegal cuts of embankment, poor communication, transport & marketing facilities and *Hurry* (a local leasing system). After all, saline tolerant rice varieties can be introduced and farmers should be trained enough for the efficient rice farming in the study area.

Keywords: Production frontier, Profitability, Technical efficiency and *T. Aman* rice.

Projection of irrigation cost over next 10 years by using ARIMA models

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During 2011-12, irrigated area in Bangladesh covered about 5.32 million hectares out of the 8.30 million ha net cultivable area. An ensured irrigation water supply requires a well irrigation plan. Increasing costs of fuel, electricity and labor, and pumping from deeper water table contribute to the irrigation. Projection of irrigation cost is important for future crop production planning in a given environment. We predicted irrigation cost trend over next 10 years by autoregressive integrated moving average (ARIMA) models. The study involved time-series data from 1990 to 2014 (collected from various sources). The ARMA model revealed that irrigation cost for Boro rice production gradually increased over the last 24 years (1990 to 2014) in both DTW and STW irrigated areas. The estimated irrigation costs were Tk. 12,945 and Tk. 14,928 per hectare on DTW and STW, respectively in 2014. The projected irrigation cost will increase gradually and it would reach to Tk. 15,335 and Tk. 17,924 per hectare on DTW and STW, respectively in 2024, which was 19% for DTW and 20% for STW higher than the base year 2014. Availability of irrigation water at the farm level was closely related to the crops grown. Irrigation water scarcity and high prices decreased the crop area and

thus reduced input use and net farm income. About 10% decrease or increase in water price would not impact farm income and input use. But 20% increased water price may decrease farm income by 5%. Increased water price would negatively affect land use, input use and net farm income. Therefore, steps should be taken to improve on farm water management practices including minimization of water distribution loss, adoption of alternate wetting and drying methods etc. to minimize irrigation cost. Agricultural extension workers could assist in this regard. In general, policies should be taken to promote water management training to farmers for better understanding of on farm water management.

Key words: Irrigation cost, Projection, DTW, STW and ARIMA Model

Impact of climate change on rice production in Bangladesh

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Bangladesh is strongly recognized as the most vulnerable country to climate change, and frequently experience devastating natural calamities. This aimed to develop the equilibrium supply and demand model and make outlook of production and market of rice under climate change condition. The study found that production is increasing in both *Aman* (16thMay to 15thDecember) and *Boro* (16th November to 15thMay) seasons and thereby boosting up the aggregated production of rice. The trend of rice production in *Aus* (15thMarch to 16thAugust) season is declining under all scenarios. The total rice production will be in increasing trend upto 2030. It is impressive that the quantity of imports was negative after 2013 meaning that the country reached at rice self-sufficient in rice and now supposed to go for exporting rice to world market. Eventually, the upward trend of rice production will result to increase the volume of buffer stock gradually. Negative sign of per capita income and strongly significant substitute elasticity of wheat confirms the changing in consumers' food habits. It means the constant per capita consumption of rice and increasing the non-cereal food intake. However, total demand of rice will increase as population is still increasing and about one-third of them under poverty level. The simulation research findings based on equilibrium supply and demand model would be useful for future policy implications.

Key words: Climate change, Supply and demand of rice, elasticity, Rice

Effect of rainfall and maximum temperature on aman rice production of Bangladesh for last decade

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Aman, the dominant monsoon crop, depends mainly on rainfall and temperature. We assessed the relationship of aman production with the changes of rainfall and maximum temperature across different region of the country. . Data on rainfall, maximum temperature and Aman rice production were collected for the period 2002 to 2012 from Bangladesh Meteorological Department (BMD) and Bangladesh Bureau of Statistics (BBS) respectively. From the time series data of rainfall and maximum temperature maps were prepared using spatial analyst tool of ArcGIS 10, where kriging in interpolation (contour) of the spatial analyst tool which is used to examine the semi-variance analysis with GS+ software. Correlation analysis was performed among the aman rice production with rainfall and maximum temperature of Bangladesh. Based on analysis and mapping Bangladesh was divided into four regions as Northeastern Region, Southeastern, Southwestern and Northwestern. In the Northeastern region Aman production is proportional to rainfall while maximum temperature showed little influence. In the Southeastern region both rainfall and maximum temperature showed less effect on production which indicates variables other than rainfall and temperature are prominent in this region. In Southwestern region the both rainfall and maximum temperature were prominent to influence Aman production. In Northwestern region, Aman production increased in spite of significant decrease in rainfall and increase in maximum temperature. Maximum temperature was the dominant climatic factor for increasing Aman rice production in Northwestern region of the country. Ten-year data analysis showed variable changes in rain fall and temperature in different regins of Bangladesh. Increasing trend of maximum temperature coupled with decreasing trend of rainfall in North-western region may badly affect agriculture there in near future. We need to introduce rainfed and heat tolerant Aman rice variety for upcoming diverse climatic situations.

Keywords: Aman rice production, kriging, Maximum temperature and Rainfall.

Estimating area and production of rice in Bangladesh

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Crop-cut is a widely used and well accepted procedure for estimating rice yield. Department of Agricultural Extension (DAE) and Bangladesh Bureau of Statistics (BBS) adopted two different methods of crop-cut for yield estimation. DAE estimate yield from a rectangular area of 20 square meter and BBS estimate from a circular area of 8.40 square meter. At least one of the methods may have some limitations as their estimates differ by a substantial degree. Bangladesh Rice research Institute (BRRI) proposed a new protocol to estimate rice yield from a circular sampling area of 10 square meter (radius = 178.5 cm). The crop-cut protocol of DAE and BBS were compared along with BRRI protocol in farmers' fields. Yield was estimated using a modified procedure (Method C proposed) where all hills within the circular area of radius 9.248m² were considered to be harvested through a single cut instead of harvesting crops in three portions under method B. For the present exercise, the fresh weight of paddy obtained from three portions of a circular cut under method B were added and the average moisture content of nine measures of moisture content was used to estimated the rice yield. The fresh weight (total of three portions of a circular cut) was then adjusted to 14% moisture content and converted to t/ha. The results suggest that proposed crop cut method C i.e., a single circular cut where the plants falling inside the circumference of the circle are harvested, may be followed for crop-cut in estimating transplanted rice yield. It is suggested to make at least two cuts in each plot to minimize the chance of over or under estimation of the whole plot yield and the radius of the circle should be 178.5cm so that the cut area becomes 10m² in order to easy conversion of the crop-cut yield to t/ha.

Keywords: Crop cut, BBS, DAE, Rice area and production.

Development and validation of producer and consumer preference models for rice varieties in Bangladesh

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The production of rice depends on both producers' and consumers' preference. The consumption of rice depends on consumers' taste and habits. The objectives of this study were to develop and validate mathematical models for producers', consumers' and producers-cum-consumers' preference to rice varieties and identify the factors

contributing to decision making by producers and consumers. Chi-square (χ^2) tests were used to explore the significant difference of preferring rice varieties among the groups of people and compared the results with the proposed models for validation. Producers and producers-cum-consumers preferred BR11, BR22 and BRRI dhan32 in T. Aman; BR16, BRRI dhan28 and BRRI dhan29 in Boro; and BR9, BR16 and BR20 in Aus seasons, respectively. Grain whiteness, brokenness, shape, amylose (%), aroma, cooking quality, hardness and chalkiness influenced the consumers and producers preference. Consumers also preferred rice varieties on the basis of its tastiness and fineness.

Keywords: χ^2 test

An Application of Box-Jenkins method for forecasting of aus, aman and boro rice production in Bangladesh

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Forecasting of Aus, Aman and Boro rice production, with a reasonable accuracy, become very important for the country to make a better planning and decision making regarding land use allocation, food security and environmental issues. The study aimed to forecast the Aus, Aman and Boro rice production in Bangladesh for the period 2015 to 2024. Data on Aus, Aman and Boro rice production for the period 1972 to 2014 were collected from Bangladesh Bureau of Statistics (BBS) which was analyzed by time series method. Time series modeling using Autoregressive Integrated Moving Average (ARIMA) model was developed for individual univariate series of Aus, Aman and Boro rice production in Bangladesh. Validity of the models was tested using standard statistical techniques. ARIMA (1,1,4), ARIMA (0,1,5) and ARIMA (1,1,4) models appeared appropriate to forecast Aus, Aman and Boro rice production in Bangladesh for upcoming ten years, respectively. The forecasted production for Aus, Aman and Boro rice production for the year 2015 was 2,06, 13,30 and 19,22 million ton, respectively. The forecasted production-range appeared as 1.77–2.35 for Aus, 13.21–13.39 for Aman and 19.06–19.38 for Boro, respectively. The models forecasted Aus rice production would decrease gradually while Aman and Boro rice production would increase in near future years.

Keywords: Autocorrelation function, partial autocorrelation function, Augmented Dickey Fuller test, residual analysis and forecasted production.

Labor efficiency as affected by direct supervision for rice cultivation

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This experiment was conducted during T. aman 2011 and T. aman 2012 seasons at the West Byde of BIRRI Farm, Gazipur to find out the effect of different period of direct supervision on labor efficiency. The treatments were different period of direct supervision such as 100 %, 80%, 60%, 40%, 20% and no supervision. Labor requirements for different operations such as seedling uprooting, transplanting, weeding, harvesting and post-harvest operation were taken. It was observed that 100% supervision required less number of labors and the labor number increased with the decreasing of supervision period. It was 188±8, 198±9, 209±9, 220±9, 252±11, and 305±31 man-day per hectare in 100%, 80%, 60%, 40%, 20% and no supervision, respectively. Therefore, to increase the labor efficiency supervision must be confirmed.

Cost and return of rice cultivation in aus, aman and boro seasons

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An experiment was conducted during aus'13, T.aman'13 and boro'13-14 seasons at the West Byde of BIRRI Farm, Gazipur to determine the cost and return of HYV rice cultivation in present situation. The rice varieties BR26, BIRRI dhan41 and BIRRI dhan29 were used in aus, aman and boro season, respectively. BIRRI laborers were engaged in this experiment. Total labor requirement was 264, 267 and 270 md ha⁻¹ in aus, aman and boro season, respectively. The total variable cost (Tk. 120934.0, 102182.0 and 93102.0), gross return (Tk. 192550.0, 162650.0 and 110750.0) and gross margin (Tk. 71616.0, 60468.0 and 17648.0) was highest in boro season followed by aman and lowest in aus season but the cost of production of per kg of rice was highest in aus season (Tk 23.28) followed by aman (Tk 16.48) and boro season (Tk 16.34). The BCR was 1.29, 1.71 and 1.72 in aus, aman and boro seasons, respectively.

Monitoring labor wage rate at different locations of Gazipur, Bangladesh

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A survey was conducted to find out the laborers' wage rate at different locations of Gazipur, Bangladesh such as Joydebpur, Chowrasta, Salna, Board Bazar, Tongi, Konabari during 2007-08 to 2013-14. The average wage rate per day increased year after year. Wage rate increased linearly in all the locations. During 2007-08 the wage rate Tk.

230-255 in which increased to Tk. 340 to 375 in 2013-14. Labor wages had three peaks in each year—May, July-August, and December January. Harvesting and post-harvest operations of boro rice and transplanting of aus rice, harvesting and post-harvest operations of aus and transplanting of aman rice and harvesting and post-harvest operation of aman rice and transplanting of boro rice are the main cause three peaks.

TECHNOLOGY TRANSFER

Zinc enriched rice genotypes in different agro-ecological zones of Bangladesh

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In Bangladesh, many people especially the children and pregnant woman are victims of malnutrition. The children become stunted growth which might be due to deficiency of micronutrients specially the zinc. Rice variety enriched with zinc may be a good source of zinc for those malnourished people. BRRI has recently developed two advanced lines, which are zinc enriched. Aiming to evaluate the zinc enriched rice lines—BR7671-37-2-2-3-7 and BR7833-11-1-1-2-1-2B5—along with BRRI dhan28 and BRRI dhan60 we conducted adaptive trials in Boro 2014. The trials involved 11 locations—BRRI research farm (Gazipur), Jessore (Zikorgacha), Chittagong (Hathazari), Comilla (Muradnagar), Jhalokathi (Sadar), Rajshahi (Godagari), Dinajpur (Sadar), Sylhet (Golapgonj), Faridpur (Modhukhali), Kishoregonj (Pakundia) and Khulna (Dumuria). Having the highest averaged yield (7.09 t/ha) among the advanced lines and check varieties, the line BR7671-37-2-2-3-7 appeared as the highest yielder. Its yield ranged from 6.61 to 8.10 t/ha in 8 locations except Kishoregonj, Sylhet and Rajshahi out of eleven. The line BR7833-11-1-1-2-1-2B5 produced the highest yield (6.43 t/ha) only in Rajshahi, having average yield of 6.50 t/ha which was higher than BRRI dhan28 (6.31 t/ha) but lower than BRRI dhan60 (6.82 t/ha). The growth duration of BR7671-37-2-2-3-7 had 156-days growth, 5 and 9 days longer than the check variety BRRI dhan60 and BRRI dhan28, respectively. BR7833-11-1-1-2-1-2B5 matured in 144 days, which was the shortest among the entries. The BR7833-11-1-1-2-1-2B5 had 1000-grain weight of 19.6 g compared to 27.7 g in BR7671-37-2-2-3-7. Most farmers preferred BR7671-37-2-2-3-7 mainly for its higher yield, lodging tolerance, green erect flag leaf and almost freeness from insects and diseases attack. Farmers also preferred another line BR7833-11-1-1-2-1-2B5 due to its shorter growth duration, relatively better yield, fine grain and attractive color. But it had shattering habit at maturity stage which might be a cause of dissatisfaction of the farmers in future. Considering micronutrient (zinc) enriched, higher yield, medium growth duration, non-shattering habit and farmers' opinion, BR7671-37-2-2-3-7 may be recommended for Proposed Variety Trial (PVT).

Keywords: Micronutrient, zinc enriched, advanced lines, non-shattering, PVT

Salt tolerant rice genotypes in coastal regions of Bangladesh under irrigated dry season

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Soil salinity in the coastal area of Bangladesh, especially in Boro season, became a concern to rice farmers. Addressing the salinity issue, BRRI has developed four salt tolerant advanced lines—BR7100-R-6-6, IR78794-B-Sat 29-1, IR59418-7B-21-3 and BRRI dhan28-Saltol. The salt-tolerant advanced lines were tested against BRRI dhan47 and BRRI dhan28 at BRRI research farm (Gazipur), Satkhira (Ashasuni, Debhata, Kaligonj & Shamnagar), Patuakhali (Kalapara), Borguna (Amtoli) and Khulna (Paikgacha) during Boro, 2013. Soil salinity of the experimental area were monitored from transplanting to maximum tillering stage in every 15 days interval. Among the locations, in Satkhira (Ashasuni) only IR59418-7B-21-3 and IR78794-B-Sat 29-1 entries were survived and others were damaged due to the salinity stress. The tested entry IR59418-7B-21-3 gave the highest grain yield in 3 locations out of 7 having average yield of 6.39 t/ha. The 2nd highest yielder was IR78794-B-Sat 29-1 which gave the highest yield in one location having average yield of 6.19 t/ha. These two entries, IR59418-7B-21-3 and IR78794-B-Sat 29-1 were survived in Satkhira (Ashasuni) and which yielded 5.91 t/ha and 4.01 t/ha respectively. Another two entries, BR7100-R-6-6 and BRRI dhan28-Saltol produced 5.82 and 5.30 t/ha, respectively whereas the check varieties BRRI dhan47 and BRRI dhan28 yielded 6.03 t/ha and 5.54 t/ha, respectively. The growth duration of the tested lines ranged from 143-150 days, which was earlier than the check variety BRRI dhan47 that matured in 152 days. The 1st and 2nd highest yielder IR59418-7B-21-3 and IR78794-B-Sat 29-1 matured in 143 and 147 days, respectively. Considering grain yield, growth duration, farmers' opinion and non-shattering character the lines, IR59418-7B-21-3 and IR78794-B-Sat 29-1 were found to be more suitable and recommended for PVT.

Keywords: salinity, advanced lines, coastal region, PVT.

Promising rice genotypes suitable for broadcast aus season in different agro-ecological conditions of Bangladesh

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Rice cultivation in Aus season is very much essential for sustainable food security of Bangladesh. Moreover, it is also environment-friendly because, it grows under rain water. So it needs potential Broadcast Aus (B. Aus) variety with higher yield and

shorter growth duration. With this view, four promising advanced aus lines—BR6855-3B-12, BR6855-3B-13, BR6848-3B-12 and BR6976-2B-11-1— were tested against BRRRI dhan43 in eight locations. The test locations were BRRRI research farm (Gazipur), Sylhet (Golapgonj), Faridpur (Modhukhali), Kushtia (Bheramara), Magura (Sadar), Gazipur (Kapasia), Feni (Sonagazi), and Noakhali (Sadar). The trials were conducted in RCBD with three replications in each location. All the tested advanced lines except BR6976-2B-11-1 performed better than the check variety BRRRI dhan43. Having the highest average grain yield (3.49 t/ha) among the genotypes including check variety, the line BR6848-3B-12 gave consistently the highest yield, ranging from 2.02 to 4.81 t/ha, in 6 locations out of eight. Ranging from 2.10 to 4.56 t/ha, the 2nd highest yielder line BR6855-3B-13 produced the average yield of 3.28 t/ha giving the highest yield in 2 locations. The entry BR6855-3B-12 also gave higher average yield (3.13 t/ha) which was about 0.5 t/ha higher than the check variety (2.64 t/ha). Mean growth duration of the tested genotypes ranged from 104 to 109 days. The highest yielder, BR6848-3B-12 matured within the shortest period (104 days) which was 2 days earlier than that of check variety. The growth duration of 2nd (BR6855-3B-12) and 3rd (BR6855-3B-12) highest yielder were 107 and 109 days, respectively. On an average, 1000-grain weight of the tested genotypes ranged from 23.2-28.7 g which were higher than the check variety BRRRI dhan43 (23.0 g). The 1000-grain weight of the highest yielder was 24.3 g which was much lower than that of 2nd and 3rd highest yielder (28.7 g). Sheath blight prevailed at the test plots of BRRRI research farm, Gazipur and Sylhet but all the lines were found almost disease free in other six locations. Among the tested lines, the highest yielder, BR6848-3B-12 had relatively lesser infected by disease. In addition this line had about 1.0 t/ha yield advantage over the check variety BRRRI dhan43. Although BR6848-3B-12 showed sheath blight susceptibility, but considering the yield advantage, fine grain size, shorter growth duration and better phenotypic acceptance, BR6848-3B-12 may be recommended for proposed variety trial (PVT), provided the disease reaction is accepted by pathologist.

Keywords: advanced lines, broadcast aus, PVT.

Drought tolerant advanced rice genotypes under drought prone rainfed condition

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Drought regularly occurs on 1.6 million ha of rice land in north and northwest parts of Bangladesh. Four advanced lines— IR83383-B-B-129-4, IR83373-B-B-27-4, IR87707-446-B-B-B and IR82589-B-B-84-3 —along with BRRRI dhan56 as check were evaluated under drought

prone rainfed condition for yield potential and adaptability. Twenty-five 30-day-old seedlings were transplanted in RCBD with 3 replications at Rajshahi, Chapainawabganj, Naogaon, Joypurhat, Dinajpur, Jhinaidah, Rangpur and BRRI Gazipur during T. Aman 2013. Fertilizers were applied @ 83, 15, 40, 11 and 2.7 kg NPKSZn ha⁻¹. Drought stress was initiated at 28 DAT through proper draining of water from the field up to maturity. Genotypes × locations demonstrated significant interaction ($p = 0.01$) for grain yield, growth duration, plant height, panicles m⁻², 1000-grain weight, grains panicle⁻¹ and sterility. Most of the tested entries performed better than the check variety BRRI dhan56 under drought stress. Across the locations, mean yield of IR83383-B-B-129-4, IR82589-B-B-84-3 and IR83373-B-B-27-4 was comparable (3.81 – 3.90 t ha⁻¹), but significantly higher than the check BRRI dhan56 (3.53 t ha⁻¹). Across the locations, the crop experienced medium to severe drought stress at reproductive phase so that mean yield was a bit lower compared to favorable condition. Average growth duration of the advanced lines ranged from 117 to 119 days that was 5 days longer than BRRI dhan56. Thousand-grain weight of the genotypes ranged from 23.7 to 25.1 g compared 24.0 g for the check variety. Sterility of the genotypes, ranged from 18-24% which was in acceptable range for drought stress. All the tested entries including check variety were almost pest free in all the locations except Gazipur and Dinajpur where found bacterial blight and sheath blight disease infection in IR87707-446-B-B-B and BRRI dhan56. Phenotypic acceptability of IR83383-B-B-129-4 and IR82589-B-B-84-3 was better compared to IR83373-B-B-27-4, IR87707-446-B-B-B and BRRI dhan56 especially for its erect and green flag leaf even at ripening. Among the genotypes, IR83383-B-B-129-4 and IR82589-B-B-84-3 were selected for drought-prone rainfed environment.

Keywords: Grain yield, phenotypic acceptability, panicle and sterility.

Rice genotypes suitable for low water holding capacity soils in different agro-ecological conditions of Bangladesh

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Sandy and sandy loam soils where water holding capacity is very low but farmers grow Boro rice in those soils in Northern part of the country. BRR developed some rice lines, which need low water for their growth and development. With this objective three advanced lines—IR83140-B-36-B-B, IR83142-B-71-B-B and PSBRC82— along with BRRI dhan28 as check were tested in BRRI research farm (Gazipur), Rajshahi (Godagari), Natore (Sadar), Lalmonirhat (Sadar), Rangpur (Sadar), Dinajpur (Sadar) and Thakurgaon (Sadar) during Boro 2014. The experimental sites were selected in

representative Boro areas with high land and free from water stagnation. The characteristics of the soils of selected sites were low water holding capacity and water is percolated very quickly after irrigation. Among the entries, the advanced line IR83140-B-36-B-B gave consistently the highest yield in all locations ranging from 6.15 t/ha (Rajshahi) to 7.97 t/ha (Lalmonirhat) having the highest mean grain yield (7.32 t/ha). Another advanced line IR83142-B-71-B-B produced the 2nd highest mean yield (6.66 t/ha) followed by PSBRC82 (6.43 t/ha). All the advanced lines except PSBRC82 gave higher mean yield than the check variety BRRI dhan28 (6.28 t/ha). The test entries showed growth duration of 152–158 days compared to 148 days in BRRI dhan28. The tested advanced lines produced coarser grain (24.5 – 26.8 g/1000 grain) compared to 22.5 g in BRRI dhan28. Most farmers preferred the tested entries IR83140-B-36-B-B and IR83142-B-71-B-B for its higher yield, bold grain, lodging tolerant, green erect flag leaf and freeness from insect and disease attack. Considering the above situation and farmers' opinion the tested entries IR83140-B-36-B-B and IR83142-B-71-B-B may be recommended for Proposed Variety Trial (PVT).

Keywords: Low water, advanced lines, water holding capacity, PVT

Rainfed low land rice genotypes in different agro-ecological conditions of Bangladesh

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Rainfed Lowland Rice (RLR) ecosystem covers major potential area of rice production in Bangladesh. But the productivity of rice in RLR ecosystem is relatively low because of uncertainty of rainfed and other physiological and environmental constraints. Genetic improvement of rice under these complex and adverse conditions became major challenge for the rice breeders. With this view, three advanced lines such as BR7472-16-2-1-2-3, BR7622-5-1-1-1 and BR7639-68-2-1-1 along with BRRI dhan39 and BRRI dhan49 as checks were tested during T. Aman, 2013 in eight locations—BRRI research farm (Gazipur), Rajshahi (Godagari), Barisal (Sadar), Chittagong (Hathazari), Comilla (Muradnagar), Rangpur (Pirgonj), Sylhet (Sadar) and Jessore (Jhikoregacha). The trial was conducted in RCBD with three replications in each location. The unit plot size for each entry was 15 m² (5 x 3 m). Seeding time was 20 July 2013 and seedling ages varied from 25 to 30 days. Fertilizers were applied at 90: 15: 50: 12: 3.6 kg NPKSZn/ha. Among the tested genotypes all the advanced lines out yielded the check variety BRRI dhan39 (4.33 t/ha) but gave similar yield to another check variety BRRI dhan49 (4.74

t/ha). Among the entries, BR7472-16-2-1-2-3, having average yield of 4.68 t/ha, gave the highest yield in two locations out of eight. The entries BR7639-68-2-1-1 and BR7622-5-1-1-1, having average yield of 4.65 and 4.58 t/ha respectively, each gave the highest yield in one location. Having average yield of 4.74 t/ha, the check variety BRRI dhan49 gave the highest yield in four locations. Average growth duration of all entries ranged from 124-128 days which was 4-8 days earlier than the check variety BRRI dhan49 (132 days). However, it was 123 days for other check BRRI dhan39. The grain size of the three lines including check variety BRRI dhan39 were very similar (1000-grain wt. 23.5 g - 24.4 g) but very small grains were found in other check variety BRRI dhan49 having 1000-grain weight of 21.4 g. Mean plant height of all advanced lines ranged from 104 to 110 cm and it was higher than the check variety BRRI dhan49 (99 cm) and BRRI dhan39 (103 cm). Most farmers preferred the check variety BRRI dhan49 for its good yield and excellent grain quality. Some farmers also preferred BR7472-16-2-1-2-3 and BR7622-5-1-1-1 for their good yield and shorter growth duration than BRRI dhan49. Based on shorter growth duration, grain yield, acceptable grain quality and farmers' opinion, BR7472-16-2-1-2-3 and BR7622-5-1-1-1 was recommended for Proposed Variety Trial (PVT).

Keywords: RLR, ecosystem, advance line, PVT

Green super rice genotypes in different agro-ecological conditions of Bangladesh

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Generally modern rice varieties have been bred for better response under favourable conditions. So, those varieties do not reach their maximum yield potential level when nutrients, pest management and water supply are not at optimal. But the green super rice requires low input and has multiple stress tolerance which is very much needed for our sustainable crop production. Therefore, five advanced lines: IR83140-B-11-B, SAGC-06, ZHONGZU 14, Weed tolerant rice (WTR) and HUA 565 along with BRRI dhan44 as check were tested in BRRI research farm (Gazipur), Rajshahi (Godagari), Barisal (Sadar), Mymensingh (Bhaluka), Comilla (Muradnagar), Rangpur (Pirgonj), Kushtia (Sadar), Jessore (Sadar) and Chittagong (Hathajari) of Bangladesh during T. Aman, 2012. The trials were conducted in RCBD with 3 replications in each location. The unit plot size for each entry was 15 m² (5 x 3 m). Seeding time was 06 July 2012 and seedling ages varied from 25 to 30 days. Fertilizers were applied at 80: 18: 40: 10: 3 kg NPKSZn/ha.

Among the entries HUA 565 gave the highest grain yield in six locations out of nine having average yield of 4.69 t/ha comparable to 4.78 t/ha in BRRI dhan44. Yield of IR83140-B-11-B and ZHONGZU 14 was 4.27 t/ha. HUA 565 had the shortest growth duration of 110 days compared to 112 and 114 days in IR83140-B-11-B and ZHONGZU 14 and 140 days in BRRI dhan44. Other two entries, SAGC-06 and WTR had shorter growth duration (110-115 days) with yield of 3.95-4.17 t/ha. The advanced lines HUA 565 had 1000 grain weight of 21.72 g compared to 23.81 g in BRRI dhan44. Most farmers preferred HUA 565 for its better yield, shorter growth duration, less disease infection and also fine grain quality with light aroma. Considering the important characteristics and farmers' opinion, HUA 565 was selected as the most suitable green super rice and recommended for Proposed Variety Trial (PVT).

Keywords: Green super rice, advanced lines, PVT

Salt tolerant rice genotypes in coastal region of Bangladesh under rainfed condition

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Salinity in soil and water is a major problem for rice production in coastal areas of Bangladesh. Although the problem is not so acute in T. Aman season due to the availability of rain water, still there are problems in coastal areas where tidal water frequently or occasionally carries saline water and increased the soil and water salinity affecting rice production. BRRI developed three advanced lines—IR78761-B-SATBI-28-3-24, IR78761-B-SATBI-28-3-26 and IR78761-B-SATB2-4-25-3, which were evaluated against BRRI dhan53 and BRRI dhan54 at BRRI research farm (Gazipur), Khulna (Batiaghata and Dumuria), Bagerhat (Rampal), Patuakhali (Kalapara), Borguna (Amtoli), Satkhira (Debhata and Shamnagar) during T. Aman, 2013. The unit plot size for each entry was 15 m² (5 x 3 m). Seeding time was 20 July 2013 and seedling ages varied from 25 to 35 days among the locations. Seedlings were transplanted at 20 x 15 cm spacing. Fertilizers were applied at 90: 15: 50: 12: 3.6 kg NPKSZn/ha. Other standard management practices were followed uniformly to all entries. Among the tested entries, IR78761-B-SATBI-28-3-26 gave the highest grain yield in 5 locations out of eight, having average yield of 4.59 t/ha which was significantly higher than the check varieties, BRRI dhan53 (3.95 t/ha) and BRRI dhan54 (4.16 t/ha). With an average yield of 4.45 t/ha, the 2nd highest yielder IR78761-B-SATBI-28-3-24 also gave the highest

yield in two locations out of eight. Growth durations of the entries varied from 119 to 126 days whereas the highest yielder IR78761-B-SATBI-28-3-26 matured in the shortest period (119 days) followed by IR78761-B-SATBI-28-3-24 (121 days). The growth duration of check varieties, BRRI dhan53 and BRRI dhan54 were 124 and 126 days, respectively. Considering grain yield, growth duration and farmers' opinion the tested lines, IR78761-B-SATBI-28-3-24 and IR78761-B-SATBI-28-3-26 may be recommended for Proposed Variety Trial (PVT).

Keywords: Rainfed, salinity, advanced lines, coastal region and PVT

Capacity building of new scientists through training

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Acquisition of knowledge and skills, and the capability that developed through training is very useful for all professions, especially for initial professionals. Training Division of Bangladesh Rice Research Institute (BRRI), Gazipur conducted a two-month training programme on rice production for new scientists during 16 February to 16 April 2014. The objectives of the training programme was to increase the capability of the participants so that they can plan and execute research programme on rice and rice based farming system; analyze, write and interpret the research findings; recognize and apply the major concepts, principles and techniques of modern rice production activities; identify and solve rice related field problems; and conduct rice production training programme. Thirty new scientists from BRRI headquarter and regional stations participated in that course. The course curriculum was designed as per requirement and objectives of the course. Knowledge improvement was measured in terms of percentage based on the differences between benchmark and final evaluation of individual participant. In the two-month training course, the baseline marks of the participants varied widely and ranged from 9 to 42% in theory and from 15 to 37% in skill. In the final evaluation, the average score was 83% for theory and it ranged from 80 to 90%. In case of skill it ranged from 62 to 89% with an average of 84%. The improvement of knowledge through this training was very attractive. On an average, it was 286% for theory and 214% for skill which justified the importance of training at the beginning of the service. Three categories certificates were given based on the final evaluation. The certificate categories were distinction (80-100% marks), satisfactory (60-79% marks) and participatory (less than 60% marks). The participants of this training showed extraordinary performances and all the scientists got distinction certificate. Need based course curriculum, concentration of the trainees and trainers on the subject matter intra competition might be the reasons for this excellent result. Training on rice production

and administration for new scientists is very important to improve their knowledge and skill in the field of rice production and rice based technologies, and to understand their responsibilities.

Keywords: Training, scientist and capacity building

Evaluation of resource persons for rice production training of BRRI scientists

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Performance of resource persons is one of the important components for an effective and quality training course. Evaluation of different aspects of training helps improvement and designing next training courses. Therefore, a study was taken to evaluate the performances of the resource persons (speaker) of two-month rice production training course for the new scientists of Bangladesh Rice Research Institute (BRRI). The duration of the course was 16 February to 16 April 2014 and the training was organized by Training Division of BRRI. A pre-structured questionnaire was used to evaluate the performance of the speakers. Thirty trainees provided their remarks on the basis of each class-performance based on five criteria which were style of presentation, question handling, use of training materials, time management and handout (quality, relevance to the topic and timely supply). Scoring scale of the each criterion was as excellent (4.5 - 5.0), very good (4.0 - 4.4), good (3.5 - 3.9), satisfactory (3.0 - 3.4) and not satisfactory (0 - 2.9). A total of 153 classes were considered for this evaluation. Presentation styles of the speakers were 46.87% excellent, 39.07% very good, 8.09% good, 5.33% satisfactory and only 0.33% not satisfactory. Qualities of handout of some speakers were not good and some speakers did not supply it in time. Based on five criteria, average performances of the speakers were 47.39%, 38.84%, 6.65%, 6.61% and 0.85% under excellent, very good, good, satisfactory and not satisfactory categories, respectively. The overall performances of the BRRI's speakers' were very good to excellent.

Key words: Evaluation, resource person, training and rice production

REGIONAL STATION

A promising breeding line for Comilla region during boro season

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Regional Yield Trail (RYT) was conducted at BRRI Regional Station, Comilla, Bangladesh during Boro 2012-13 season for evaluation of specific and general adaptability of the genotypes in on-station condition. We evaluated six breeding lines against standard checks—BRRI dhan28 and BRRI dhan50—following randomized complete block design (RCBD) with three replications. Forty- day-old seedlings of each genotype were transplanted @ 2-3 seedlings with a spacing of 25 × 15 cm. The experimental field received 120 N, 20 kg P, 60 kg K, 20 kg S and 4 kg Zn per ha. All amount of P, K, S and Zn were applied at the time of final land preparation and nitrogen was applied in 3 equal splits at 15 days after transplanting (DAT), maximum tillering and before panicle initiation (PI) stage. Among six tested breeding line, genotype BR7372-30-1-1-1 produced higher yield (7.4 t/ha) compared to both standard checks. BR7372-30-1-1-1 showed 137 days growth duration which was 4 days earlier than standard check BRRI dhan50 and 3 days longer than standard check BRRI dhan28. So considering the yield potential and growth duration genotype BR7372-30-1-1-1 was selected for Comilla region and suggested for evaluation in Proposed Variety Trial (PVT) during next Boro 2013-14 season.

Multi-location testing of BRRI dhan46-BRRIdhan29-fallow cropping pattern in different locations of Bangladesh

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In medium highland phase II, farmers usually grow local/old T. Aman varieties after recession of flood water in T. Aman-Boro-Fallow cropping pattern. Delayed planting of old T. Aman varieties in September gives poor yield and the total system productivity become very low. To address the situation, BRRI has recently developed a photosensitive variety BRRI dhan46, which could be transplanted safely up to 25 September with at least 1 t/ha yield advantage over local varieties/old ones. Multi-location trial of BRRI dhan46-BRRIdhan29-Fallow cropping pattern in medium highland phase II was conducted at Madhabpur Upazila of Habiganj district during 2011-14 with the objective to increase the systems productivity and farmers income.

Block demonstration was done at six bigha land of six farmers. Each farmer's field was considered as one replication. BRRI recommended management practices were adopted in T. Aman and Boro seasons. The recommended patterns gave 14-15% higher grain yield and gross margin over existing farmers' patterns (BR22-BRRIdhan28-Fallow) during 2011-12-2013-14, respectively. The recommended cropping pattern gave the yield of 12.15 t/ha, 11.65 t/ha and 11.72 t/ha and gross margin of Tk. 1,94,400/ha, Tk. 2,21,350/ha and Tk. 2,22,680/ha while 10.70 t/ha, 10.23 t/ha and 10.18 t/ha and Tk. 1,71,200/ha, Tk.1,94,370/ha and Tk. 1,93,420/ha in existing pattern during 2011-12, 2012-13 and 2013-14 season, respectively. Inclusion of BRRI dhan46 enabled to accommodate BRRI dhan29 in the system and resulted in higher yield both in T. Aman and Boro season and eventually the system productivity. BRRI dhan46-BRRIdhan29-Fallow pattern is recommended for this area because of its higher productivity.

Keywords: Yield, Photosensitive variety and Multi-location trial

Diversity of *Pyricularia Grisea* in Bangladesh

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Rice blast, caused by *Pyricularia grisea* Sacc. (telemorph: *Magnaporthe grisea* (Hebert) Barr.), is one of the most important diseases of rice. Clear understanding about the diversity of pathogen population is important for development blast resistant rice variety. A study was undertaken to determine the pathogenic and the genetic diversity of *Pyricularia grisea*. Isolates were collected from five agro ecological zones — AEZ2, AEZ13, AEZ19, AEZ23, and AEZ28. Pathogenicity were tested against 26 japonica typedifferential rice varieties (DVs) having 23 resistance genes —*Pish*, *Pib*, *Pit*, *Pia*, *Pii*, *Pi3*, *Pi5(t)*, *Pik-s*, *Pik-m*, *Pi1*, *Pik-h*, *Pik*, *Pik-p*, *Pi7(t)*, *Pi9*, *Piz*, *Piz-5*, *Piz-t*, *Pita-2*, *Pita*, *Pi12(t)*, *Pi19*, and *Pi20(t)*. The virulence analysis showed that four genes, *Pish*, *Pi9*, *Piz* and *Pita-2* revealed a wide spectrum of moderate resistance to those isolates. The isolates were categorized into 94 races on the basis of the reaction patterns against rice differential varieties harboring twenty-three resistance genes and one susceptible variety, Lijiangxintuanheigu (LTH) by the latest designation system. The findings demonstrate the existence of a wide variation in blast pathogens in Bangladesh. The average virulence of isolates from individual AEZ reveals that the maximum virulent isolates occur in AEZ2 (67%) followed by AEZ19 (63%) and AEZ28 (55%). On the basis of principal component analysis, the tested 100 *Pyricularia grisea* isolates were grouped into five clusters viz. I, II, III, IV and V. Cluster I, II and III comprised of 18, 31 and 16 isolates, respectively. Twenty-three isolates were placed in cluster IV and 12 isolates

belonged to cluster V. The monogenic lines selected as differential varieties and the primarily selected 25 blast pathogen isolates may be used as the first differential system, which can be used to characterize the resistance of rice varieties. The genetic diversity of isolates was determined using DNA fingerprints generated by amplification of DNA segments between copies of the transposable element *Pot2*. Out of 100 isolates tested, 10 did not show any band. Rest of the 90 isolates was grouped into 31 fingerprint types. Data were analyzed geographically and by rice variety infected. Studies showed that several *P. grisea* strains existed within the most affected areas. The *Pot2* PCR revealed that the majority of isolates (82%) clustered into a single group with approximately 20% similarity level. So differential varieties of indica type rice need to be developed for proper identification of the *P. grisea* races occur in the country.

Keywords: Rice, Blast, *Pyricularia grisea*, Diversity, DNA fingerprinting.

Mass rearing of *Trichogramma zahiri* Polaszek on alternate host, *Corcyra cephalonica* Stainton egg and it's natural host, *Dicladispa armigera* (Olivier) egg

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An experiment was conducted at the Parasitoid Rearing Laboratory, Bangladesh Rice Research Institute (BRRI) aimed to evaluate rice meal moth (*Corcyra cephalonica* Stainton) as an alternate host for *Trichogramma zahiri* Polaszek (Hymenoptera: Trichogrammatidae). *Trichogramma zahiri* Polaszek (Hymenoptera: Trichogrammatidae) were reared both on rice hispa *Dicladispa armigera* (Olivier) (Chrysomelidae: Coleoptera) egg and rice meal moth, *Corcyra cephalonica* Stainton eggs. in *T. zahiri* emerged successfully from both hosts. The parasitoid parasitized about 58% of rice meal moth eggs whereas it parasitized about 87% of rice hispa eggs. On an average 1.99 parasitoids emerged from a single hispa egg and only 0.40 from a single rice meal moth egg. This result indicates that rice meal moth was less suitable for *T. zahiri* compared to natural host. Developmental duration from egg to adult of *T. zahiri* was similar (10 - 11 days) on both hosts with same temperature regime 25-30°C. The population of *T. zahiri* developed from both hispa egg and rice meal moth eggs parasitized almost equally 86.6-87.2%. The parasitoid developed from rice meal moth eggs was capable to parasitizing rice hispa eggs and also developing its offspring successfully. Rice meal moth egg could be used as a potential alternate host of this egg parasitoid. However, determining the performance and comparing availability of both hosts for mass rearing

of *T. zahiri* on alternate host may not be required in practice as the usual host showed its superiority in all aspects.

Keywords: Rice meal moth, egg parasitoid, rice hispa

Development of simple seed germination and seedling emergence technique in cold environment

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Rice seed germination in Boro season is a challenge to farmers and a simple technology/device for safe seed germination is very important. We developed a simple low cost seed germination technique/method in cold environment. The experiment was conducted during Boro, 2012-13 and 2013-14 at BRRI, Rajshahi. Seeds of BRRI dhan29 and BRRI dhan50 were soaked in water for 22-24h. Soaked seeds rapped with moist sac and preserved following the traditional "Zag-method" and in a frame covered with air tight heat insulating tripal i.e., thick polyethylene (called "Ankuri"- germination chamber). Vapor therapy was provided inside Ankuri and maintained 25-35°C temperature with high humidity. Temperature of both outside and inside the Ankuri was recorded at 3h interval starting from 6:00 am to 9:00 pm. Seed germination was checked at 24h interval for two days and then at 12h interval. Seed sampling was done from the seed bags randomly with three samples keeping consideration of both inner and outer side seeds in the bag. Germination percentage was calculated by counting the seeds germinated and the total number of seeds. Germinated seeds in Ankuri were sown (100-120 g/tray) in nine trays previously prepared with sandy loam soil following tray seeding method. Six trays were placed outside where three trays covered with polythene. Another three trays were placed in Ankuri. Furthermore, dry seed was directly sown in six trays of which three was placed outside under polythene and the rest in Ankuri. Vapor therapy was given as described above. Trays were checked every 12h interval to observe the radical growth. After seedling emergence, the trays were taken to inside the polythene from Ankuri for raising seedling.

The germination percentage of the tested varieties in Ankuri ranged from 82-96% compared to 64-92% in traditional Zag-method. High variation of germination in Zag-Method was due to improper temperature and humidity during Zag period. Seed germination was faster in Ankuri which observed within 2.5 days. This was also 2.5 days earlier in comparison with the Zag-method. Soaking period is generally practiced for 22-24h outside in cold water/weather. But 18h soaking in Ankuri resulted good germination. Seedling emergence was similar and 2-3 days earlier both in dry seed and

soaked/germinated seed sown in trays in Ankuri than polythene covered trays. But no seedling emergence observed in open trays. Average air temperature from 18:00-9:00 was cooler (<15^o C: ranged 9-20^o C) than 9:00-18:00 period (>15^o C: ranged 10-28^o C). Ankuri maintained the temperature 25-35^o C and high humidity which favored germination and growth. Therefore, Ankuri could be effective germination technique which facilitated faster germination and higher plumule growth in trays. Thin polyethylene is being tried to use instead of tripal for minimizing the cost. Ankuri germination chamber has been designed. Commercial exploitation and adoption of Ankuri at farmers' level will minimize seed loss ensuring germination and economic benefit.

Evaluation of CMS lines for higher out crossing rate and their hybrids for yield contributing traits in rice (*Oryza sativa* L.)

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To design a hybrid rice breeding program, it is necessary to identify CMS lines with higher out crossing and to identify high yielding hybrids that combine from a promising CMS line. In the present investigations, 16 CMS lines for floral traits along with resultant 16 hybrids (lines x tester mating design) for estimating heterosis and combining ability effects in yield contributing traits were studied. Out of 16 CMS lines, IR75606 A, IR78369 A, IR73793 A, IR80561A, IR62829 A and IR6888 A were completely pollen sterile. However, CMS lines IR80561A, IR73793 A and IR62829 A were found promising for higher pollen sterility and for higher panicle exertion (more than 70 %), as well for higher stigma exertion (more than 35 %) and higher out-crossing rate (more than 40%) which is better for development of hybrids. Further, results indicated that 10 hybrids involving those CMS lines exhibited superiority over better parent or standard check variety for fertile spikelets and higher grain yield/plant. Considering, heterosis (more than 20%) and significant *sca* effects for grain yield, the hybrids IR73793 A /BR7166-5B-1, IR80561A /BR7166-5B-1 and IR62829 A /BR7166-5B-1 were promising. Within the CMS lines, IR80561A and IR80561A appeared as better general combiner for most of the traits. High out crossing of CMS lines and more than 70% yield heterosis for correspondence hybrids- the cross IR80561A /BR7166-5B-1 was identified as the best for commercial exploitation. The present study contributes to the knowledge for characterization of CMS lines along with respective hybrids in hybrid rice breeding program.

Keywords: Higher out crossing, High yielding hybrids, heterosis, *sca* effects

Phosphorus fertilizer management effect on phosphorus fractions in soil and nutrition in wetland rice

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Phosphorus deficiency, resulted from improper fertilizer management, is one of the most yield-limiting factors in lowland rice soils. The present investigation aimed to (i) determine the changes of P fractions in long-term experimental field soils, (ii) understand P availability in soils (Sonatala silt loam and Chhiata clay loam soil) amended with cowdung (CD), poultry manure (PM) and inorganic P (TSP) under alternate wetting-drying (AWD) and continuous water logging (CWL) conditions, (iii) evaluate CD and PM as alternate sources of chemical P fertilizer and (iv) determine cut-off yield for P deficiency in lowland rice. The study involved P-fractionations of soils from different layers of long-term field experiment, incubation (480 days) of P deficient soils with variable rates of P (0 - 18 mg kg⁻¹) from TSP, CD and PM and net house experiment on rice with variable P rates (0 - 18 mg kg⁻¹) from TSP, CD and PM. A field experiment on a range of soil available P levels (2.5 - 16.9 mg kg⁻¹) was conducted with required application from TSP, CD and PM for rice. Long-term field experimentation without P application decreased solution P, NaHCO₃-P, NaOH-P_i, NaOH-P₀ and acid-P substantially while the application of P increased these P fractions. The change in soil P fractions with or without P application was confined to 20 - 30 cm. The incubation study showed that the P amendment increased P availability from 40 - 150% depending on the rate of application. At early stages of incubation (15 - 60 days) P availability was higher with TSP compared to CD and PM. At 240, 360 and 480 days of incubation, PM showed greater P availability followed by CD and the least in TSP. AWD water management showed lower P availability than that in CWL condition. At a given P management condition, P availability was higher in Sonatala silt loam soil than that in Chiata clay loam soil. About 77 - 90% of the applied P through TSP, CD and PM was fixed as unavailable form in the soil. Increase in the rate of P application, increased P fixation in both the soils. Phosphorus fixation decreased logarithmically with the increase in time of incubation. Phosphorus fixation was higher in TSP than in CD and PM. Irrespective of soils and P sources, AWD conditions favored more P fixation than continuous submergence. Net house experiment demonstrated significantly higher grain yield with the application of P in both Sonatala silt loam and Chiata clay loam soils. Receiving P application, grain yield in Sonatala silt loam soil was higher than that in Chiata clay loam soil. The net house experiment proved superiority of PM and CD over TSP as a source of P for lowland rice. Field experiments demonstrated prominent

influence of the applied P through TSP, CD and PM on tiller and panicle production, flowering time and yield of rice both in Aman and Boro seasons. Phosphorus deficiency delayed rice flowering by about one week in Aman season and two weeks in Boro season. Sources of P showed no significant difference in flowering time in both Aman and Boro season. Application of P increased rice yield by 0.27 – 0.56 t ha⁻¹ with CD, 0.46 – 0.76 t ha⁻¹ with PM and 0.47 – 0.67 t ha⁻¹ with TSP in Aman season. In Boro season, yield increase due to P application varied from 2.84 to 4.49 t ha⁻¹ in different levels of P application. In plot with less than 3.0 mgkg⁻¹ available P, rice yield in CD treated plots gave relatively lower than that in PM and TSP, but in other plots all the three sources of P was similar. Rice plant showed apparent P recovery of 37 – 47% in Aman season and 62–99% in Boro season. The estimated cut-off yield of the high-yield sub-population for P in T. Aman and Boro was 4.41 and 4.92 t ha⁻¹, respectively.

Keywords: P-fraction, P-nutrition, P-fixation, Organic material, Wetland rice.

Long-term effect of industrial waste water irrigation on soil chemical properties

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The soil chemical properties in different layers of wetland rice soil varied considerably due to long-term irrigation with industrial effluents. A laboratory experiment was conducted in Soil Science Division, Bangladesh Rice Research Institute (BRRI) during 2012 with industrial waste water irrigated rice soils profile aimed to determining the vertical distribution of soil chemical properties under long-term industrial waste water irrigated rice field. Waste water irrigated rice field seemed to create some differences in soil chemical properties. The pH_w and pH_{KCl} in all soil depth was higher with waste water irrigated rice field. Relatively more negative charges developed with waste water irrigated rice field. Irrigation with waste water increased electrical conductivity (EC) in rice soils profile. Organic carbon content was higher with waste water irrigated rice soils and it decreased sharply with the increase in soil depth. Total nitrogen (%) was higher with underground water irrigated rice soils in surface but at deeper layers total N was similar in both the soils. Olsen P (mg/kg) was higher with underground water irrigated soil at 0-5 cm depth but at 5-100 cm soils profile it was higher with waste water irrigated rice soils. Micronutrients (Zn, Fe, Cu and Mn) and heavy metals (Pb, Cd, Ni and Cr) in soils were increased significantly through irrigation with waste water in rice-rice cropping pattern. Continuous irrigation with industrial waste water in rice

fields increased soil pH which developed soil salinity in study area of Gazipur district in Bangladesh.

Keywords: long-term, soil chemical properties, industrial waste

Minimizing rice yield gap in Jhenaidah district

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Farmers' field experiments were conducted in Shailkupa, Jhenaidah sadar and Kotchandpur upazillas of Jhenaidah district during T. Aman, 2011 to Boro, 2013-14 for identifying location specific rice cultivation problem and minimizing rice yield gap through BRRI developed technologies. BRRI released rice varieties BRRI dhan49, BRRI dhan39 and BR10 in T. Aman season and BRRI dhan28 in Boro season were used. Two treatments such as BRRI recommended practice which covered in 66 decimal areas; another was farmer's practice in 33 decimal areas. Twenty-three to thirty-five-day-old seedlings in T. Aman and thirty-five to fifty-five-day-old seedlings in Boro were transplanted in 66 decimal areas following BRRI recommended practices. Other 33 decimal areas were cultivated followed by farmer's won practices. The yield of BRRI recommended practices was higher than the farmer's practices. The yield advantage was 0.86 t/ha, 1.90 t/ha and 1.21 t/ha in Shailkupa, Jhenaidah sadar and Kotchandpur respectively in T. Aman, 2011. In the subsequent year 2012 it was 0.35 t/ha, 0.27 t/ha and 0.58 t/ha and 2013 it was 0.26 t/ha, 0.63 t/ha and 0.23 t/ha in the same places. Overall, yield gap between BRRI recommended practices and farmers' practices was observed in T. Aman 2011 as 24.7%, which decreased to 8.84 and 8.91% in 2012 and 2013, respectively. In Boro 2011-2012, yield advantage due to recommended practice was 1.25, 0.79 and 0.77 t/ha in Shailkupa, Jhenaidah Sadar and Kotchandpur, respectively and in 2012-2013 it was 1.16, 1.78 and 1.28 t/ha, respectively. In Boro, 2013-14 it was evaluated only Shailkupa, Jhenaidah location and yield advantage was 1.56 t/ha. Yield gap in second and third year of Boro season was comparatively higher than that of first year. In those years farmers cultivated mustard after harvesting of T. Aman for getting more profit. That is why, after harvesting of mustard transplanting of Boro rice became late and pest infestation was high in those rice fields. In spite of that situation researcher got better yield by researcher knowledge and experience in the BRRI recommended practice field. On the other hand, farmers got as usual or low yield due to knowledge gap, inexperience and unable to quick decision. For the reason, yield gap of those two years were higher than that of 1st year. Therefore, it was concluded that yield gap depends on knowledge, awareness, choice, economic and social status of farmers. Therefore, in these areas has great opportunity to increase yield and minimize

yield gap especially in Boro season through increase knowledge and awareness about modern rice production practices.

Keywords: Minimizing, Rice, Yield Gap, BRRI recommended practice, Farmer's practice

Rainwater harvesting by rising levee height in transplanted aman rice cultivation

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The experiment was conducted in three different fields at Ailchara, Sadar, Kushtia to explore the possibility of rainwater harvesting for irrigation in T. Aman rice cultivation. Each field was divided into two plots to accommodate two treatments— 15 cm levee height around the rice field (T₁) and farmers' practice (T₂). Thirty-day-old seedlings of BRRI dhan49 were transplanted and each treatment received BRRI recommended fertilizer doses. The daily rainfall was recorded from a rain gauge set up near the experimental field. A 10 cm diameter PVC pipe was placed at each plot and water level was monitored daily. Both the treatments received 595 mm rainfall during growing period of which 242 mm in August, 150 mm in September and 263 mm in October. Monthly rainfall in August and September in 2013 was less than average rainfall in this region and highest daily rainfall was recorded 69.7 mm. Treatment T₁ showed the highest water level fluctuation 4.7–14 cm below ground surface compared to 14–15 cm in T₂. Treatment T₁ maintained standing water for 3 – 9 days more than T₂. At reproductive phase, T₂ faced more drought than T₁ in each field and required 1-2 more irrigation. In field 1, both the treatment T₁ and T₂ yielded 4.8 t/ha. But in the field 2 and 3, T₁ yielded 0.5 t/ha more than T₂. It can be concluded that 15 cm levee height management ensured more moisture than the traditional practices and reduce need of supplemental irrigation as well.

Keywords: Rainwater, Harvesting, Rice, Levee height, Farmer's practice

Performance of BRRI dhan50 under variable planting in cold prone areas of Bangladesh

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Sowing of nursery and transplanting of rice seedlings at the optimum time is very important for obtaining high yield and good quality of kernels. Delayed transplanting adversely affects grain yield, milling recovery and the cooking quality of the scented Basmati rice. Since plant may exhibit its yield potential only when it is exposed to

proper temperature during its growth period. Too low or too high temperature adversely affects the spikelet fertility in rice. Thus, to improve the yield potential of premium quality rice, optimum transplanting time needs to be precisely determined. A series of field experiments were conducted at the Research field of BRRI Regional Station, Rangpur during Boro 2009 - 2010. Banglamoti (BRRI dhan50) was used as a test crop. The planting started from 01 January to 15 March, 2010 at 15 days interval to find out suitable planting time for higher grain yield. The experiment was laid out in a randomized complete block design (RCBD) with three replications using a plot size of 12 m². Thirty-day-old seedlings were manually transplanted at a spacing of 20 × 20 cm with 2-3 seedlings per hill. Fertilizers were used urea for N, triple super phosphate for P and potassium chloride for K and ZnSO₄·7H₂O for Zn at the rate of 120 kg N ha⁻¹, 90 kg P₂O₅ ha⁻¹ and 180 kg K₂O ha⁻¹. N was splitted by: 1/3rd at 20 DAT, 1/3rd at active tillering and 1/3rd at panicle initiation. P was applied at basal. K was splitted equally as basal and top dressing at the panicle initiation stage. At 01 January planting, duration (from transplanting to flowering) was longer (128 days) due to comparatively lower temperature at January. After 01 January planting, duration gradually decreased up to March 15. At 01 January planting, the higher number of panicles (248 per m²) was found and then gradually decreased up to 15 February planting. Higher number of grains (97 per panicle) was found at 01 January planting and then gradually decreased up to 15 February. The heavier grain (22.1g per 1000 grains) was found at 01 March planting and the smaller (19.4g per 1000 grains) was at 01 January planting. The lowest grain yield was recorded at late (15 March) planting situation, which was 2.2- 1.9 t/ha lower than at 01 and 15 January planting respectively but about 1.2 t/ha lower than 01 February planting. This variety gave higher grain yield from 01-15 January planting due to higher number of panicles, higher number of grains per panicle but required higher duration for flowering. To achieve higher grain yield of about 5.0 - 6.0 t/ha, farmers of this region should plant this variety from 01 January to 01 February but little difficult due to cold. However, after harvest of potato (01 March), farmers may cultivate this variety with satisfactory grain yield (about 4.5 t/ ha) in northern region of Bangladesh.

Key wards: Banglamoti rice, Cold prone area, Time of planting

Enhancement of Aus cultivation to face adverse climatic change and food security

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Boro cultivation is becoming very much costly due to high water consumption. Our ground water is decreasing day by day due to climate change, less rainfall, less recharge

of ground water. There is lot of opportunity to produce Aus rice in between Rabi and Kharif II (before T. Aman). Present Government has given emphasis on Aus rice cultivation instead of Boro cultivation in medium to high land to save underground water. Bangladesh Rice Research Institute has taken initiative through Integrated Agricultural Productivity Project (IAPP) to expand Aus area using high yielding Aus rice varieties. Thirty-three demonstrations and two validation trial were carried out in different parts of Rangpur region under the project IAPP during 2014 using BRRI dhan48 to enhance Aus cultivation. Thirty-five aus farmers were selected in different villages of Rangpur region, who generally cultivate Aus rice after harvesting Boro rice or other Rabi crops. The most popular Aus variety BRRI dhan48 was used in all demonstrations and yield was compared with local variety like Parija, Vhadi etc. Adaptive trial of aus was conducted in potato growing area (Mithapukur and Nilphamary Sadar) after harvesting potato. The most popular Boro variety BRRI dhan28 and Aus variety BRRI dhan48 were used in the adaptive trial. The seeding date was 1st week of February and transplanting date was 2nd week of March. Thirty-five-day-old seedlings were used in both varieties. The grain yield was determined through the duplicate crop cut from 5 × 2m area for each farmer's plot. Results revealed that about 3.5 to 6.5 t ha⁻¹ grain yield was obtained from demonstrations which conducted in different farmers' field. The validation trial was conducted in farmers' field at Mithapukur and Nilphamari Sadar using BRRI dhan28 and 48 as Braus after harvesting potato. About 5.0 t ha⁻¹ grain-yield was obtained from BRRI dhan28 while 6.6 t ha⁻¹ was from BRRI dhan48. Two to 3 less number of irrigation was required for BRRI dhan48 due to shorter growth duration (100-105 days). However, 20 to 60% higher grain yield was observed in different farmers' field with BRRI dhan48 over BRRI dhan28. So, it can be concluded that BRRI dhan48 is a high yield potential variety in Aus or Braus season. It can be cultivated after Boro harvest or as Braus after potato harvest.

Key words: BRRI dhan48, Braus, climate change.

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