Research Highlights
2015 - 2016

A. Characterization and Maintenance of Germplasm

Maintenance and characterization of exotic maize inbred lines

Inbred lines are mandatory for hybrid seed production. So development and maintenance of inbred lines which can produce high yielding hybrid varieties is obligatory. Consequently characterization of inbred lines is important to identify a particular variety and maintain seed purity by rouging off type plant. The experiment was conducted with 47 exotic inbred lines (set-I) received from CIMMYT. Among the germplasm both qualitative and quantitative morphological variation were found. Most of the qualitative characters showed distinct variation among the germplasm. Highest variation of quantitative character was found from seed weight, ear height and anthesis-silking interval (ASI).Each inbred lines were selfed by hand pollination and seeds were preserved for future breeding program.

Maintenance of exotic and locally developed maize inbred lines (Set VI & II)
A total of 13 locally developed inbred lines (Set-IV) and another 38 BARI introduced lines (Set-II) were sown during rabi 2015-16 to maintain their quality and purity. Each inbred line was selfed by hand pollination and a total 13.07 kg seeds were produced and preserved for further breeding program.

B. Development of Source Population and Inbred Lines

Genetic diversity in inbred lines of maize

Fifty eight inbred lines of maize collected from CIMMYT Mexico were characterized based on different morphological traits and yield. Multivariate analysis was performed to classify fifty eight genotypes. All the genotypes were grouped into seven clusters. Cluster II and cluster VII were the largest comprising of twelve genotypes each and cluster V was the smallest with four genotypes. Cluster V had the highest intra-cluster distance and Cluster VI had the lowest intra cluster distance. The highest inter-cluster distance was observed between clusters V and VI. The results revealed that genotypes chosen for hybridization from clusters with highest inter cluster distances would give high heterotic F_1 and broad spectrum of variability. It is expected that inbred lines belonging high to medium D^2 value tend to produce high heterosis for yield. Selfed seeds for each of the inbred lines were maintained for future study.

Development of base population in maize (2 Sets)

The experiment was conducted with balanced bulk 5th cycle seeds of two groups, each contained 150 selected ears based on (i) medium height and high yield goal and (ii) dwarf and earliness were planted and random mated in isolation at BARI Joydebpur during rabi 2015-16 for the development of source populations in maize. For the purpose of next cycle of selection, finally 100 ears were selected separately from the two groups and preserved carefully. The balanced bulked seeds of these two populations would be grown separately in isolation for selection of the two desirable source populations in the coming rabi season.

Recycling for development inbred lines of maize (2 Sets)

Seeds of Dream Sweet and Dream Sweet-3 hybrids sweet corn were advanced from S_0 to f S_1 generation in order to develop superior inbred lines of sweet corn. Few variations were observed in different morphological traits among the S_0 lines in each set. The selected plants were selfed and finally 70 and 76 selfed ears were selected from Dream Sweet and Dream Sweet -3, respectively. The selected ears were dried properly and kept them separately in store for advancing them to S_2 generation in the next rabi season.

Advancing s_1 to s_7 generation of field corn, pop corn, sweet corn and baby corn (27 Sets)

The balanced bulk seeds of S_1 lines of Set I: Baby Star, and Set II: Hybrid IM 8013 was advanced to S_2 generation in order to develop superior inbred lines. Variations were observed in different morphological traits among the S_1 lines in each set. The selected plants were selfed and finally 66selfed ears and 50 were selected from set I and set II

respectively. Selected ears were dried properly and kept them separately in store for advancing them to S_3 generation in the next rabi season.

The balanced bulk seeds of S_2 lines of set I (Early and dwarf line), set II (Medium height and high yield goal) setI II (American popcorn), set IV (Swiss pop corn), set V (Super Sweet corn), set VI (9120), set VII (Titan) and set VIII (Multiparent synthesis line) were advanced to S_3 generation in order to develop superior inbred lines .Variations were found among the S_2 lines for different traits. The selected S_2 plants in each line of each set were selfed. Finally 7.6 kg, 3.9kg, 1.7kg, 9.7kg, 1.8kg, 3.3kg, and 6.2 kg selfed seeds were harvested from early and dwarf line, high yielding goal line, American pop corn, swiss pop corn, super sweet, 9120 and from Titan respectively and stored separately for advancing them to S_4 generation following ear to row method in the next rabi season. A part would also be used for making line × tester crossing.

Six sets of S_4 lines balanced bulk seeds of field corn viz. Arun 4, 981 and pinnacle, one set of pop corn variety pop corn Nepaland two sets of sweet corn variety seeda new and BARI sweet corn 1 were advanced to S_5 generation in order to develop superior inbred lines.. Variations were found among the S_4 lines in each set for different traits. The selected S_4 plants in each set were selfed. Finally 3.9kg from Arun4,83 selfed ears from 981,84ears from pinnacle, 5.41 kg from popcorn Nepal, 1.8 kg from seeda new and 2.4 kg from BARI sweet corn1 were selected. Selected materials were stored separately for advancing them to S_5 generation following ear to row method in the next rabi season.

Two set of field corn varieties 981 (29 lines) and Pioneer(30 lines) were advanced to S_5 generation in order to develop superior inbred line(s). Variation was found among the S_4 lines of each set for different traits studied. Selected S_4 plants were selfed. The S_5 seeds from selfed plants were collected and stored for further advancement.

Two sets of S_5 lines of field corn varieties viz. 7074 and 981 and two sets of popcorn varieties PCB10 and Thai popcorn were advanced to S_6 generation in order to develop superior inbred lines. Variations were found among the S_5 lines in each set for different traits. The selected S_5 plants in each set were selfed by hand pollination. Finally 10.20 kg, 6.04 kg, 5.21 kg and 6.78 kg selfed seed from different sets of 7074 and 981 field corn varieties and PCB10 and Thaipop popcorn varieties, respectively were collected. Selected materials were stored separately for advancing them to S_7 generation following ear to row method in the next rabi season. A part of the materials would also be used for line×tester crossing and DII crossing.

Four sets of S_6 lines balanced bulk seeds of field corn varieties viz. Pinacale, QY-11, 900M Gold and Pacific-60 were advanced to S_7 generation in order to develop superior inbred lines. Variations were found among the S_6 lines in each set for different traits. Selected S_6 plants were selfed. Finally 9.73 kg, 26.48 kg, 8.73 kg, and 12.38 kg selfed seed from different sets of Pinacale, QY-11, 900M Gold and Pacific-60, respectively were collected. The S_7 seeds from selfed plants were stored separately for maintenance and future use.

C. Evaluation of inbred lines through line × tester method (9 Sets)

a) Field corn

Set-I: Twenty eight hybrids were evaluated using line (8) × tester (3) method for selection of superior hybrids. Highly significant genotypic differences were observed indicated wide range of variability present among the genotypes. Three female parents and one tester Utn/S_4-6 was good combiner for yield. The crosses with high sca effect for grain yield were evolved from high × low general combiner parents which reveled additive × dominance type of gene action. The cross combinations 7074/S_4-1× Pioneer/S_4-4, 7074/S_4-5× 981/S_4-P-5, 7074/S_4-11× 981/S_4-P-5 and 7074/S_4-13× Pioneer/S_4-4 having higher positive sca effect with high mean values of yield might be used for obtaining high yielding hybrids.

Set II: Twelve S_7 lines of commercial hybrid 900M were crossed with 3 testers in a Line × Tester mating design in 2014-15 and the resulting 36 crosses along with the parents and three checks BARI Hybrid Maize 9 (BHM 9), Pioneer 30V92 and NK 40 were evaluated in a alpha lattice design replicated twice, during rabi, 2015-16. On the basis of GCA effect, two inbred lines namely 9MS/S_7-9 and 9MS/S_7-16 were found to be the best parents as they had significantly desirable GCA effects for most of the characters and they could be used extensively in hybrid breeding program to accumulate those genes. However, three cross combinations 9MS/S_7-16×981/S_3-25,9MS/S_7-9×Pinacle/S_5-4 and 9MS/S_7-16×Pinacle/S_5-4 were found promising according to SCA effect, mean performance and standard heterosis and could be utilized for enhancing hybrid production.

Set III: Ten S_5lines of commercial hybrid NT 6323 were crossed with 2 testers in a Line × Tester mating design and the resulting 20 crosses along with the parents and standard checks BHM 9, NK 40 and 900 M GOLD were evaluated in a alpha lattice design replicated twice, during rabi, 2015-16. Among the parents NT 6323/S_5-21-1-2,

NT 6323/S_5-27-1, NT 6323/S_5-44-1, NT 6323/S_5-49-1 and NT 6323/S_5-50-1 were good general combiners for grain yield and some of the important yield contributing characters. Crosses NT 6323/S_5-50-1 × BIL 79and NT 6323/S_5-27-1 × BIL 28 showed high SCA effects for grain yield along with high mean could be used for variety development.

Set IV: Twelve S_4 lines of commercial hybrid 981 were crossed using as female parent with 2 testers (9MS/S_7-5 and 9MS/S_7-9) as male parent in a Line × Tester mating design to generate 24 crosses and were evaluated with the parents as well as standard checks NK 40 and 900 M GOLD in a alpha lattice design during rabi, 2015-16. Among the lines 981/S_4-17-1, 981/S_4-27-1-1, 981/S_4-31-1,981/S_4-61-1 and one tester 9MS/S_7-9 were good general combiners for grain yield and some of the important yield contributing characters. Cross 981/S_4-17-1 × 9MS/S_7-9 showed positive SCA effects for grain yield along with the highest mean could be used for variety development.

Set V: An evaluation of field corn using Line × Tester method was conducted with 10 selected S_5 lines and 2 testers for grain yield and its components traits to determine the general combining ability (GCA) and specific combining ability (SCA) effects. Highly significant genotypic differences were observed for all the traits under studied except no. of row per ear, indicating wide range of variability present among the genotypes. The inbred line Pac/S_5-17 and Utn/S_5-15 were identified as the best general combiners due to their good combining ability effect for grain yield and other yield components. Significant positive GCA for yield was also observed in Utn/S_5-3 and Utn/S_5-8. The crosses with high SCA effect for grain yield evolved from high × low general combiner parents were reveled additive × dominance type of gene action. Significant positive gca was observed in the crosses, Utn/S_5-15 x 900M/S_7-5, Utn/S_5-3 x 900M/S_7-4, Utn/S_5-14 x 900M/S_7-5, Pac/S_5-10 x 900M/S_7-4, Pac/S_5-9 x 900M/S_7-5 and Pac/S_5-17 x 900M/S_7-5 could be used in future breeding program. The information on the nature of gene action with respective entry and characters might be used depending on the breeding objectives.

Set VI: A line x tester analysis involving forty eight test-crosses generated by crossing 24 S_3 inbred lines of maize with two testers and two standard checks was evaluated at Bangladesh Agricultural Research Institute,Gazipur during rabi 2015-16. The objectives of the study were to estimate general and specific combining ability effects of the inbred lines and to evaluate the test cross performance and estimate the amount of standard heterosis of the hybrids for grain yield and yield related traits. Performances of the resulting testcrosses were evaluated with their parents in a alpha lattice design with 2 replications. Highly significant genotypic differences were observed indicated wide range of variability present among them. Five lines 981 S_3-11, 981 S_3-14, 981 S_3-17, 981 S_3-24and 981 S_3-30 were good general combiner for grain yield and possessed high means also. The crosses with significant and positive specific combining ability effect for grain yield were (Line 18 × BIL22, Line 23 × BIL22, Line 27 × BIL22, Line 7 × BIL28, Line11 × BIL28, Line14 × BIL28, Line 24× BIL28, Line 25 × BIL28, and Line 30 × BIL28). These nine combinations might be used for obtaining high yielding hybrids. The information on the nature of gene action with respective variety and characters might be used depending on the breeding objectives. Among the crosses, crosses Line 24× BIL28 (11.40 t/ha), Line 18 × BIL22 (11.30 t/ha) and Line 25 × BIL28 (11.20 t/ha) showed higher yield, which could be utilized for future evaluation for possible used in maize breeding activities. Estimation of heterosis was carried out using two commercial varieties BHM 9 and NK40. When better performer check BHM9 was used, the percent heterosis for grain yield varied from -23.39 to 4.59%. Among the 48 crosses, 13 crosses exhibited significant and positive and heterosis for grain yield. The highest heterosis 4.6% was exhibited by the cross 981S_3- 24 × BIL28 followed by 981S_3 -18 × BIL22 (3.7%) and 981S_3 -25 × BIL28 (2.8%). respectively. From this study, eight potential hybrids with grain yield above 11.0 t/ha have been identified for further use in maize breeding program after verification of the results. Furthermore, the information from this study could be useful for researchers who need to develop high yielding varieties of maize.

Set VII: Seventeen S_3 lines of maize and 2 testers for grain yield, yield components and other characters to estimate the general combining ability of the lines and specific combining ability effects of the crosses and to evaluate the test cross performance of the hybrids for grain yield and yield related traits. Performance of the resulting testcrosses was evaluated with their parents in alpha lattice design with 2 replications. Highly significant genotypic differences were observed indicated wide range of variability present among them. Five lines Pioneer S_3-15, Pioneer S_3-16, Pioneer S_3-23, Pioneer S_3-29 and Pioneer S_3-30 were good general combiner for grain yield and possessed high means also. The crosses with significant specific combining ability effect for grain yield were Line 6 × BIL28, Line 15 × BIL28, Line 17 × BIL28, Line 20 × BIL28, Line 25 × BIL28, Line 16 × 900MGS_3-9, Line 22 × 900MGS_3-9, Line 23 × 900MGS_3-9, Line 29 × 900MGS_3-9 and Line 29 × 900MGS_3-9evolved mostly from low × low general combiner parents were reveled dominance × dominance type of gene action. These ten combinations might be used for obtaining high yielding hybrids. The information on the nature of gene action with respective variety and characters might be used depending on the breeding objectives. Heterosis estimation was carried out using two commercial varieties BHM 9 and NK40. When standard commercial check BHM 9 was used, the percent heterosis for grain yield varied from -32.02 to 5.83 %. Among the 34 crosses, 2 crosses exhibited significant positive and

heterosis for grain yield. The highest heterosis was exhibited by the cross Pioneer S_3-15 × BIL28 (5.83%) and Pioneer S_3-30 x 900MGS_3-9 (4.4%) respectively. The crosses showing significant positive sca values could be used for variety development.

b) Pop corn

Set I: Seven selected S_4 lines of Pop Corn Burst (PCB) were crossed in a line × tester method with three testers to produce 21 hybrids during robi 2014-15. In the following year, all the hybrids were raised along with their parents and two checks (Thai pocorn and BARI Khoi Bhutta 1) in a alpha lattice design with two replications. The line PCB/S_4-41 was the best among the parents, showing GCA effects for yield and its contributing traits together with popping quality could be used extensively in hybrid breeding program with a view to increase popcorn yield with quality. Furthermore, based on mean and SCA effects of yield and popping quality the cross PCB/S_4-41×Thai/S_4-24 was proved to be the best to increase the grain yield along with quality and could be used for commercial hybrid development.

Set II: Ten S_4 lines of commercial hybrid Thai popcorn were crossed with 2 testers in a Line × Tester mating design and the resulting 20 crosses along with the parents and standard checks BARI Khoi Bhutta 1 and Thai popcorn were evaluated in a alpha lattice design replicated twice to find out the GCA of the parents and SCA of the crosses. The lines Thai/S_4-8 and Thai/S_4-29 were the best among the parents, showing desirable mean and GCA effects for most of yield contributing and quality traits, could be used extensively in hybrid breeding program with a view to increase popcorn yield along with quality. Furthermore, based on mean and SCA effects of yield and popping quality two hybrids viz. Thai/S_4-27×T_2 and Thai/S_4-28×PCB/S_7-7 were proved to be the best to increase the grain yield along with popping quality.

D. Study of combining ability and heterosis study

Study of combining ability and heterosis in maize (6 Sets)

Set I: Eight diverse maize inbred lines were crossed in 8 × 8 diallel fashion excluding the reciprocals and parents. The resulting 28F_1s were evaluated along with four checks (981, BHM-9, NK-40 and Pioneer 30V92) in an alpha lattice with three replications at Gazipur. The parent P_6 was the best general combiner for both high yield and earliness and parent P_2 and P_8 for dwarf plant type. Two crosses (P_3×P_5) and (P_6×P_8) exhibited positive SCA effects for grain yield involved high x low and high x average general combining parents.

Set II: Eight diverse maize inbred lines were crossed in 8 × 8 diallel fashion excluding the reciprocals and parents. The resulting 28 F_1s were evaluated along with four checks (BHM-9 and 981) in an alpha lattice with three replications at Gazipur. Parent P_8 was the best general combiner for yield and most of the yield contributing characters. Parent P_1 & P_4 were P_4& $P_8$the best general combiner for dwarf & earliness in plant. Three crosses (P_1 ×P_4, P_2 ×P_3 & P_4×P_8) showed significant positive & significant SCA effect for yield involving low × low average × average & high × low general combining parents. Two crosses (P_3 ×P_8 & P_4 ×P_8) showed positive and significant heterosis in compare to standard check NK-40.

Set III: The experimental materials comprised of six selected genetically diverse advanced inbred lines developing from six commercial hybrids of different companies. These inbred lines were at different advance stage S_4, S_5 & S_7 designated as P_1 (Pacific60/S_5-5), P_2 (900M/S_7-6), P_3 (QY11/S_5-11), P_4 (900M Gold/S_5-6), P_5 (Uttaran2/S_5-21) and P_6 (7074/S_4-15) and were crossed in a half diallel fashion to obtain seed of all possible 15 single crosses (excluding reciprocals). All the parents, F_1's and three commercial checks hybrids BARI Hybrid Maize-9 (BHM-9), NK-40 and Pioneer30V92 were gown in a randomized complete block design with two replications at Gazipur. The parental lines P_1, P_4 and P_5 were found to be the best general combiner for yield and other characters. The significant positive SCA effects along with high mean and heterosis were found in the crosses P_1 × P_2, P_1 × P_4 and P_4 × P_5andcould be used for commercial variety development after verifying them in different locations.

Set IV: Seven maize inbred lines collected from CIMMYT (International Maize and Wheat Improvement Center) were crossed in a 7×7 diallel fashion excluding the reciprocals. The resulting 21 F_1s were evaluated along with two checks (900M Gold and 981) in an alpha lattice with two replications at Gazipur. The parental lines CML-498 & CML-395 were found to be the best general combiner for yield. The good combiner parents for different trait could be used in hybridization to improve yield as well as with desirable traits as donor parents for the accumulation of favorable genes. The significant positive SCA crosses CML-498×CML-376, CML-498×CML-395 and CML-376×CML-247 along with high mean could be used for commercial variety development after verifying them in different locations.

Set V: Seven diverse maize inbred lines were crossed in a 7×7 diallel fashion excluding the reciprocals. The resulting 21 F_1s were evaluated along with two checks (Shuvra and BARI Hybrid Maize-9) in an alpha lattice with two replications at Gazipur to study combining ability and heterosis in maize for grain yield and yield contributing characters. Parents P_3, P_4 and P_5 were the best general combiner for high yield; parents P_2, P_5, and P_7 for earliness and parents P_1 for dwarf plant type. Heterosis estimation was carried out using two commercial varieties Shuvra and BHM-9. Significant and positive heterosis for yield was observed in $P_1×P_7$, $P_2×P_4$, $P_3×P_6$ and $P_5×P_7$ and could be used for commercial cultivation after varifying in different locations.

Set VI: Seven diverse maize inbred lines were crossed in a 7×7 diallel fashion excluding the reciprocals during the kharif season of 2015. The resulting 21 F_1s were evaluated along with two checks (BARI Hybrid Maize-9 and NK-40) in an alpha lattice with three replications at Regional Agricultural Research Station, Jamalpur in the following rabi season 0f 2015-16. Parents having good combining abilities for yield P4 and P5; early maturity (P1, P2, P6 and P7); short plant and ear height (P6 and P7) and kernel weight (P2, P5 and P1) could be used as donor partners for obtaining high yield and desirable traits. Significant and positive heterosis was observed 24.87% and 19.31% for yield in the cross $P_4×P_5$ compare to check varieties NK-40 and BHM-9. The cross $P_4×P_5$ could be used for variety development after verifying them across the agro-ecological zones of Bangladesh.

Study on combining ability and heterosis in maize over locations

Seven inbred lines of maize viz. P_1, P_2, P_3, P_4, P_5, P_6 and P_7 were collected from CIMMYT-Mexico were crossed in all possible combinations excluding the reciprocals and the resulting 21 F_1s along with 3 commercials hybrids viz. BHM-9, NK-40 and 981 were grown following alpha lattice with two replications in five different environments viz. Gazipur, Burirhat, hathazari, Rahmatpur and Jessore. The parents P_3, P_5 and P_6 were the best general combiner for high yield; parents P_6 for earliness; and parents P_1 and P_2 for dwarf plant type. Significant and positive SCA effect were observed in $P_1× P_5$, $P_3× P_6$, $P_4×P_5$ and $P_5× P_6$ for yield involving high × average and high × low general combining parents. The range of heterosis expressed by different crosses over BHM-9 was from -13.04 to 5.25 percent for grain yield. The better performing four crosses ($P_1× P_5$, $P_3× P_6$, $P_4×P_5$ and $P_5× P_6$) showed good performance over locations.

E. Evaluation of single cross popcorn, field corn & baby corn hybrids

Evaluation of selected single cross maize hybrids

Twenty nine selected single cross maize hybrids and three local checks viz. BHM9, NK-40 & 981 were evaluated at Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during rabi 2015-16 to select better hybrids. Considering yield potentiality E3, E5, E8, E16, E21 & E27 were found promising. Among them E3 was dwarf and E16 was early.

Evaluation of dwarf and early maturing maize hybrids

Eleven single cross field corn hybrids were evaluated along with two commercial checks pacific 339 and NK 40. Significant differences were observed among the genotypes for all the characters studied except thousand grain weight. Considering yield, dwarf and earliness two hybrids BMZ4 x BMZ66 and BMZ15 x BMZ66 were found promising.

Evaluation of promising maize hybrids at different agro-ecological regions of Bangladesh

The present study assessed genotype × environment interaction and stability for grain yield, days to silking and plant height with 32 hybrids across four different locations in Bangladesh during 2015-16. The AMMI model (additive main effects and multiplicative interaction) was used to analyze the genotype-environment interactions over four locations to select the hybrid having higher yield and other potential attributes. Significant variation for genotypes (G), environment (E) and GEI were observed for yield. The environment of Burirhat, Rangpur was very poor but Gazipur, Jamalpur and Jessor were rich for hybrid maize production. Considering the mean, bi and S^2di value for all the hybrids showed different response of adaptability under different environmental conditions.E3, E8 and E20 were high yielder but very unstable. E16 was high yielder and also stable crosses four environments. E19 was most stable but medium yielder.

Evaluation of baby corn hybrids

An experiment was carried out at BARI Research field, Joydebpur during rabi 2015-16 with 14 locally developed baby corn hybrids along with a check variety Baby star to test their performance and select better one(s). All the traits showed significant variation. Seven crosses (BCP 271/S_4-13× BCP 271/S_4-7, BCP 271/S_4-12 × BCP 271/S_4-4, BCP 271/S_4-18 × BCP 271/S_4-6, BCP 271/S_4-18 × BCP 271/S_4-16, BCP 271/S_4-20 × BCP 271/S_4-6, BCP 271/S_4-9× BCP 271/S_4-19 and BCP 271/S_4-20× BCP 271/S_4-19)were selected based on number of cobs per plant, interval of cob harvesting, yield, earliness and other desirable agronomic traits.

Evaluation of selected pop corn hybrids at different agro-ecological regions of Bangladesh

Fourteen locally developed selected popcorn hybrids along with two check varieties of popcorn were assessed for genotype environment interaction (GEI) and stability for selection of the best hybrid in five different locations during rabi 2015-16. The AMMI (additive main effects and multiplicative interaction) model was used to analyze the genotype-environment interaction over five locations to select the hybrid having higher yield and other potential attributes. Regarding genotypes (G), significant variation was found in all the characters except yield while environment (E) was found significant for all the characters. Considering the mean, bi and mean square deviation for all the parameters, it was evident that all the genotypes showed different response of adaptability under different environmental conditions. Among the tested hybrids, PCB12 × T17, PCB13 × T17 and PCB15 × T17 showed the highest yield, good popping quality and stable for across the locations.

Comparative yield trail of imported and local maize hybrids

Imported hybrid seeds play a major role in increasing the area and production of maize in Bangladesh. Every year hybrids maize seeds are imported by different seed companies and these are very much popular amongst the maize grower's community. The experiment was conducted with 14 hybrids evaluated at six locations viz; Gazipur, Rangpur, Jamalpur, Barisal, Jessore and Hathazari following alpha lattice design with 3 replications during 2015-16 to select best stable hybrids among the imported and locally breed hybrids will be benefited to the farmers. The environment Gazipur, Hathazari, Jessore and Jamalpur were poor; but Rangpur and Barisal were rich for hybrid maize production where Rangpur was found highly suitable for hybrid maize cultivation followed by Barisal. Considering the mean, bi and S^2di all the hybrids showed different response of adaptability under different environmental conditions. Among the hybrids IM 8119 produced the highest yield (12.29 t/ha) followed MZ04 (11.28 t/ha) Hybrids MZ04, 981, 9120, 9155, IM8119 and BHM 9 exhibited higher yielding as well as stable over all environments.

F. Adaptive trials

Adaptive trial with low water required white grain hybrid maize in high barind tract

A field experiment was conducted in the farmer's field of FSRD site, Kadamshahar, Godagai, Rajshahi of high barind tract during Rabi season 2015-16 to test the performance of locally developed promising low water required hybrid maize and selection of short stature best one(s) for Barind areas. The experiment was laid out in a randomized complete block design with four location namely, Kadamshahar, Chabbishnagar, Mission More and Dargapra. There were four hybrids viz. P_1xP_4, P_1xP_7, P_2xP_5 and Shuvra in this study. After seedling establishment the hybrids were provided one irrigation before flowering. Shuvra had shortest days both days to flowering (99.50 days) and maturity (134.75 days) but gave the highest plant height and ear height. Hybrids P_1xP_4 and P_1xP_7 produced the shortest plant and ear height. Different hybrids of maize namely P_1xP_4, P_1xP_7 and P_2xP_5 gave highest and similar grain yield ranging from 8.50 to 8.95 t ha^{-1}. At the maturity stage, P_2xP_5 was remained green. The Shuvra gave lowest yield and had a lodging tendency.

G. Variety development of hilly areas

Evaluation of maize hybrids developed by using hilly germplasm in hilly areas

The present study revealed genotype-environment interaction (GEI) and stability for days to tasseling, days to silking, plant height, ear height, number of rows per ear, number of kernel per ear 1000 seeds weight and grain yield of fifteen single cross hybrids developed by using hilly germplasm including three checks across three different districts of Chittagong Hill tracts during 2015-16. Highly significant variations were observed for most of the characters such as days to tasseling, days to silking, ear length, 1000 seed weight, no. of kernels per ear and grain

yield. Considering the mean, bi, Wricke's ecovalence and mean square deviation, five genotypes such as LG/S4-5-4×LG/S4-15-1(4.09 t/ha), P1×P7 (9.10 t/ha), LG/S4-9×LG/S4-2-1 (3.76 t/ha), LG/S4-14-6×LG/S4-14-3 (3.68 t/ha) and LG/S4-3-2×LG/S4-2-1 (3.65 t/ha) were found stable over locations. On the other hand, the genotypes P1×P4 (7.43 t/ha), BHM9 (6.47 t/ha) and LG/S4-15-2×LG/S4-15-1(3.32 t/ha) recorded as highly unstable.

Adaptive trial with low water required white grain hybrid maize in hilly areas

The experiment was carried out to determine the performance of six white grained maize genotypes for yield and other agronomic characters and stability that were grown in three environments viz. Khagrachari, Ramgharh and Hathazari during rabi 2015-16. All the genotypes showed significant differences for days to tasseling, days to silking, plant height, ear height, ear length, number of row per ear, 1000 seeds weight and yield across the environments except Hathazari, where only plant height, ear height and number of row per ear showed significance differences. Shuvra was the tallest (197cm) one and P1xP2 was the dwarf (164cm). Shuvra also bears the highest value (100cm) for ear height while Q1xQ2 had the lowest (73cm) ear height. The hybrid P2xP5 had bigger sized ear (18cm). Bold seeded entry was recorded as Q1xQ2 followed by P2xP5 where P1xP2 bears the smaller sized seeds. The hybrid P2xP5 showed better performance but it ranked 4 out of six genotypes for yield stability therefore, is suited for favorable environment and the hybrid P1xP2 and P1xP7 the 2nd and 3rd yield scorer are also suited for favorable environments. None of the genotypes are stable over environments.

H. Maize biotechnology

Selection criteria, evaluation and associated genomic regions for multiple stress tolerance (salinity, water logged, low-p) in maize

A total of 29 commercial hybrid and 30 inbred lines were evaluated in saline (NaCl, 12 dSm^{-1}) and normal condition and 25 maize germplasm were also evaluated for seedling traits in hydroponic under LP (2.5×10^{-6} mol L^{-1} of KH$_2$PO$_4$) and normal phosphorus (NP) (2.5×10^{-4} mol L^{-1} of KH$_2$PO$_4$) conditions and in a hydroponic culture at green house. Ten days old maize seedling was transplanted to hydroponic pot where they received salinity treatment for 18 days and the data were collected. Analysis of variance (ANOVA) showed significant of all genotype and highly significant of treatment for maximum root and shoot length, leave area, shoot dry weight and total dry matter. All parameters using under study of seedling decreased under salt treatment except chlorophyll content of some genotypes were shown higher SPAD value than control. Cluster analysis placed the 29 hybrid into 5 main groups among those cluster, groups three showed the highest number mean values for number of green leaves, maximum shoot length, leave area, shoot dry weight and total dry matter. Base on the analysis, proline was the most tolerant hybrid after that 9120-paloan, kaveri-25 KCO and very susceptible genotypes were heera, raza and karehi-50.

In phosphorous evaluation, the first two principal components (PCs) explained about 91.13% of the total variation among lines for the eight maize seedling traits. The relative magnitudes of eigenvectors for the first principal component was 59.35%, explained mostly by total dry matter (TDM), shoot dry weight (SDW), root dry weight maximum root length (MRL) and MSL. Genotype × traits (G×T) biplot revealed superior genotypes with combinations of favorable traits. The Euclidean genetic distance ranged from 0.61 to 29.33, indicating the high levels of variability among the inbred lines. The first three PCs explained more than 79% of total genetic variation. The G×T biplot revealed superior genotypes with combinations of favorable traits. Some outstanding genotypes with higher value of most RNS traits were identified. These lines could be of potential use for improvement of LP tolerance in maize. P deficiency in plants triggers many transcriptional, biochemicals, and physiological changes that ultimately help the plants absorb P from the soil or improve the P use efficiency. Substantial genetic variation in P efficiency exists among the maize genotypes and a number of QTLs controlling traits for P efficiency have been identified in maize, and it is expected that the integration of systems biology with high-throughput, high-dimensional and precision phenotyping will contribute to the development of maize varieties tolerant to LP stress.

Oxidative stress tolerance mechanism in maize seedlings under salinity stress

Susceptible genotypes of maize showed higher oxidative damage than tolerant one. Catalase (CAT) was not efficient in reducing (H$_2$O$_2$) in maize under salinity. Non-enzymatic antioxidants like ASA and GSH and enzymatic antioxidant like peroxidase (POD), glutathione peroxidase (GPX) and monodehydroascorbate (MDHAR) were important contributor to salinity tolerance. Proline and glyoxalase partially contributed to the tolerance.

I. Stress Breeding: Abiotic stress tolerant variety development

Demonstration of selected HTMA hybrids at different agro ecological regions

Five HTMA maize hybrids developed and selected under Heat Tolerant Maize for Asia (HTMA) project ;one BARI developed hybrid viz. BHM9; and four imported hybrid maize viz. 981, NK-40, Pioneer 30V92 and Kaveri 50 used as checks were evaluated in five locations viz., Gazipur, Rahmatpur, Jessore, Ishurdi and Burirhat to test the performance of the tested hybrids across environments in rabi season and to select the better performing one(s) having higher yield potentiality with desirable agronomic characters. Although none of the tested hybrids out yielded the best check variety (981)(10.67 t/ha) but two yellow grain hybrids, namely HTMA 19(10.32 t/ha) and HTMA 22(10.20 t/ha) and one white grain hybrid (HTMA 21) out yielded rest four checks. Another white grain hybrid, HTMA 14(9.93t/ha) out yielded two checks viz. Pioneer 30V92 (9.91 t/ha) and Kaveri-50 (9.85 t/ha). Among the tested hybrids, only HTMA 14, was found moderately high yielder as well as lodging resistant. Considering overall mean grain yield and other desirable characters four hybrids viz. HTMA 14, HTMA 19, HTMA 21and HTMA 22 were found most promising and hence could be selected for commercial cultivation across ecologies in Bangladesh. The seed company people also showed their keen interest to take forward the best-bet hybrids of HTMA for licensing, followed by seed production and large-scale scale-out among maize farmers.

Phenotyping of the test crosses under optimal temperature at Rahmatpur (AS2BH-110, AS2BH-211, AS2BH-313, HTAMTC-72)

Fifty four crosses of field corn received under HTMA project along with six check hybrids 981, NK 40, Pioneer 30 V 92, 900 MG ,BHM 7 and BHM 9 were evaluated at Regional Agricultural Research Station, Rahmatpur, Barisal during kharif 2015 to develop heat stress tolerant lines. The genotypes were evaluated in alpha lattice design replicated twice. Considering plant height , ear height, maturity and yield ZH15376 in trial AS2BH 110; ZH137991 in trial AS2BH 211; ZH141588 and ZH138021 in trial AS2BH 313; ZH141212 in trial HTAMTC 72; Z543-135, Z543-312 and; Z543-80 in trial HTAMTC 42; Z574-69 in trial HTAMTC- 62; Z543-15 and Z543-402 in trial HTAMTC 82;Z543-165 and Z543-220 in trial HTAMTC 13;Z543-319 in trial HTAMTC-23; ZH141953 and ZH141682 in trial HTAMTC 33 and Z574-126 in trial HTAMTC 52 were selected for further evaluation.

Phenotyping of HTMA hybrids under heat stress in Jessore (MPS3TC-212, MPS3TC-112, AS3BEHS-125 ANDAS3BMHS-125)

Six hundred ninety maize hybrids including three local check varieties received from CIMMYT, India under Heat Tolerant Maize for Asia (HTMA) Project were studied at the Regional Agricultural Research Station, Jessore during the kharif-1 season of 2015. Significant variations were observed for most of the traits studied. Among the crosses considering yield and other contributing traits including heat stress tolerance the best hybrids were entry 159 (8.73 t ha^{-1}) and 98 (8.46 t ha^{-1}) in trial MPS3TC-212, ZH141590 (7.55 t ha^{-1}) and ZH141591 (7.70 t ha^{-1}) and ZH141590 (7.57 t ha^{-1}) in trial ABS3BEHS-125 and ZH111948 (12.93 t ha^{-1}), ZH116108 (12.38 t ha^{-1}), ZH137890 (12.07 t ha^{-1}), VH11130 (11.99 t ha^{-1}) and ZH14399 (11.94 t ha^{-1}) in trial ABS3BMHS-125.

Phenotyping of HTMA hybrids under heat stress at Ishurdi (HTAMTC-14, HTAMTC-24, HTAMTC-34, HTAMTC-43, HTAMTC-53, HTAMTC-63, HTAMTC-73, HTAMTC-83, MPS4TC-110 and MPS4TC-210)

Performance of 1344 crosses received under HTMA project from CIMMYT, India including four local check varieties were studied at the Regional Agricultural Research Station, Ishurdi, Pabna during the kharif-1 season of 2015. High heritability was observed for days to pollen shedding, days to silking and kernel yield. Among the crosses considering yield and other traits including heat stress tolerance the best hybrids were Z543-82(8.34 t ha^{-1}) and Z543-79 (8.29 t ha^{-1})in trial HTAMTC-14; Z543-376 (11.08 t ha^{-1}) and Z543-356 (11.0 t ha^{-1}) in trial HTAMTC-24; Z543-96 (8.59 t ha^{-1}) and Z543-10 (8.41 t ha^{-1}) in trial HTAMTC-43; Z574-68 (11.61 ha-1), Z574-64 (11.22 t ha-1), Z574-65 (10.89 t ha-1) and Z574-155 (10.84 t ha-1) in trial HTAMTC-63; Z574-78 (11.63 t ha^{-1}) , Z574-1(10.01 t ha^{-1}), Z574-157 (9.73 t ha^{-1}) and Z574-70 (9.72 t ha^{-1}) in trial HTAM TC-73; Z574-183 (10.80 t ha-1), Z574-12 (9.98 t ha^{-1}), Z543-386 (9.92 t ha^{-1}), Z543-183 (9.88 t ha^{-1}) and Z543-38 (9.85 t ha^{-1}) in trial HTAMTC-83.

Adaptive trial of selected heat tolerant HTMA field corn hybrids in High Barind Tract

A field experiment was conducted in the farmer's field of FSRD site, Kadamshahar, Godagai, Rajshahi during rabi season 2015-16 to find out the suitable variety of heat tolerant hybrid maize for obtaining higher yield and economic return in High Barind Tract. The experiment was laid out in a randomized complete block design with three

replications. There were four hybrids viz. HTMA19, HTMA22, 981 and NK40 in the study. All the hybrids matured with the same duration. The plant height and ear height was the highest in 981 while NK40 produced the shortest plant and ear height. The highest grain yield was obtained from 981 (10.26 t ha^{-1}) and lowest one in NK40 (8.45 t ha^{-1}) while HTMA19 and HTMA22 showed similar and intermediate yield performance which were 10.01 and 9.85 t ha^{-1}, respectively.

Multi location trial of the selected ATMA hybrids under optimal temperature

Combined analysis was carried out for grain yield, days to tasseling, days to silking, plant height ear height and 1000 grain wt. with sixteen selected ATMA hybrids and two checks across different locations. Analysis of variance for different characters showed the presence of genetic variabilities among the tested entries. From the overall mean yield and other desirable characters three entries viz. E_5, E_7 and E_{14} were found suitable across two locations.

J. CIMMYT program

Evaluation of CIMMYT acid soil tolerant tropical hybrid maize trial

An evaluation of fifteen maize hybrids received from CIMMYT, Columbia developed for tolerance to acidic soils with high aluminium toxicity were evaluated along with three checks NK40, BHM 7 and BHM 9 at the experimental fields of Regional Agricultural Research Station (RARS), Akbarpur and Hill Agricultural Research Station, Khagrachari during rabi, 2015-16. Significant differences were observed among the genotypes against different parameters in both the locations except both plant and ear height at Khagrachari and only ear height at Akbarpur, indicating presence of variation in the genotypes and locations. The entry G15 gave the highest yield (10.68 t/ha) in Akbarpur while G14 was the highest (10.13 t/ha) in Khagrachari. Again genotype G7 performed lowest (6.44 t/ha) in Akbarpur for yield while the same was against G18 (5.84 t/ha) in Khagrachari location. But considering overall mean performance of the two locations, the genotype G15 yielded highest (9.92 t/ha) followed by G14 (9.83 t/ha) and G5 (9.76) whereas the best check G16 (NK40) produced overall mean yield 8.09 t/ha. Therefore, the entry G15, G14 and G5 were considered as stable yielder over the locations live through acidic soil.

K. Nutritional maize breeding

Evaluation of quality protein maize (QPM) hybrids

Twenty four double and three way cross quality protein maize hybrids were evaluated along with two commercial checks Pacific 60 and BARI hybrid maize 9 in a Alpha Lattice Design with two replications. From the overall performance two hybrids one double cross $(Q_6 \times P_2) \times (P_4 \times P_6)$ and one three way cross $(P_1 \times P_4) \times P_2$ were found promising and needs to verify them at different locations.

L. Production of new hybrids

Production of single cross field corn hybrids following diallel fashion

Three sets of crosses following diallel fashion were made to produce hybrid seeds. Total 84 crosses were produced in three sets of diallel crosses. Among them, 78 crosses produced seeds. In set I, 4.61 kg seeds were obtained from 28 crosses. In set II, among 28 crosses, 22 crosses produced 3.79 kg seeds while in set II, 28 crosses produced 9.40 kg seeds. The produced F1 seeds of each hybrid were stored separately after selection. The produced single crosses would be evaluated in the coming rabi season in target areas.

Production of single cross hybrids following line × tester method

Six sets (set I consists of 44 S3 lines of PNL as lines and BIL 79 and BIL28 testers where as set II consists of 37 S3 lines of 981 as lines and BIL 79 and BIL28 testers of line × tester crosses were made. Set III contains 40 non-QPM crosses produced by following 20 lines and 2testers and set IV contains 40 QPM crosses produced by following 20 lines and 2testers. Set V contains 64 crosses from 16 lines and 4 testers, Set VI contains 78 crosses from 39 lines and 2 testers and Set VII contains 42 crosses from 14 lines and 3testers. Four hundred and twenty six crosses produced 93.68 kg seeds among which set I, set II, set III, set IV, set V, set VI and set VII produced 31.56 kg, 26.85 kg, 4.79 kg, 6.33 kg, 8.31 kg, 8.35 kg and 7.31 kg seeds, respectively. The produced hybrid seeds will be used for evaluation in the next rabi season.

Production of single cross hybrids through north carolina design II fashion

One set of test cross following 7×7 North Carolina Design II. Total 49 crosses were made and 8.62 kg F_1 seeds hybrids were produced. These hybrids will be evaluated in the next rabi season to select promising one(s).

M. Maintenance and seed increase of parent/inbred lines, hybrids, composite & OPV's

Total 3107 kg seeds were produced of the parents of different types of hybrids and stored for further use. Among them 4 kg for maintenance, 177 kg from selfed bulked, 201 kg from parent lines of BARI developed hybrid, 590 kg for parent lines of low water required and 252 kg for HTMA hybrids.

Production of selected hybrids of promising crosses of saline, drought, excess moisture tolerant maize

In these experiments hybrid seeds of promising crosses were produced to evaluate in next season. Total 137 crosses were produced and from these crosses 170.52 kg seed were harvested. Moreover, 64 kg seeds of male parent of BARI Hybrid Maize 13cross were produced. These seeds will be used in evaluation or in hybrid production in next year trial.

Seed production of BARI maize hybrids

Hybrid seed is one of the prime factors for increasing area and production in the country. Total 2031 kg hybrids seeds of 3 BARI maize hybrids viz. BARI hybrid maize-5, BARI hybrid maize-7 and BARI hybrid maize-9 were produced at different locations in proper isolation condition maintaining female and male ratio 4:2. At flowering stage, the plants from female rows were detasseled before pollen bursting and ears were collected from female plants, sorting, processed and stored for next year use and distribution.

Maintenance and seed production of BARI composite maize varieties

Total 2038 kg seeds of 6 composite varieties (Barnali, BM-5, BM-6, BM-7, Mohor, Khoibhutta and BARI Baby corn-1) were produced at different locations in proper isolation condition maintaining female and male ratio 2:1. At flowering stage, male flowers (tassel) from female lines were detasseled and seeds were collected from the female plants and after sorting and processing stored them for next year use.

N. Technology transfer activities

During 2015-16, the Plant Breeding Division of BARI arranged on training program for 30 scientists and five field days for dissemination of technologies among farmers.

Barley, Millets & Sorghum

Hybridization of barley

The experiment was conducted at Bangladesh Agricultural Research Institute, Joydebpur during rabi season 2015-2016 to develop early, high yielding hull-less barley variety. Seven parental lines were crossed in a half diallel fashion Among 21 crosses, 15 crosses produced seeds which will be used for confirmation trial in next year.

Evaluation and selection in different filial generation

Selected bulk method was followed during selection in different segregating generation. Selection was done based on earliness, short stature, hull-less and high yield. In F_2 generation 9 plants from 2 crosses, in F_3 generation 17 plants from 2 crosses, in F_4 generation 6 families out of 6; in F_5 & F_6 generation 2 families out of 2 were selected.

Preliminary yield trial of barley

The experiment was conducted at BARI, Joydebpur, during rabi season 2015-16 to evaluate 10 barley lines. Considering earliness, yield and yield contributing characters 4 barley lines viz. INBON-15/40, AGER/12, Atahualpa and IBON-HI-15/21 were selected for next year advance yield trial.

Advance yield trial of hull less barley

Combined analysis was carried out for grain yield, days to Heading, days to maturity, plant height, tiller per plant, spike length, grains per spike and thousand grain weight with six lines including one check viz. BB-6 across 2 (two) different locations viz. Gazipur and Ishwardi, during rabi (2015-2016) to find out the suitable genotypes for next

year yield trial. Analysis of variance for different characters showed the presence of genetic variabilities among lines. From the overall mean yield and other desirable characters two entries viz. E-2/15 and F6 were found suitable across location.

Regional yield trial of hull less barley

Combined analysis was carried out for grain yield, days to Heading, days to maturity, plant height, tiller per plant, spike length, grains per spike and thousand grain weight with Five lines including one check viz. BB-6 across 2 (two) different locations viz. Gazipur and Ishwardi, during rabi (2015-2016) to find out the suitable genotypes for large plot yield trial. Analysis of variance for different characters showed the presence of genetic variabilities among lines. From the overall mean yield and other desirable characters two entries viz. BHL-21 and 6-B-952482 were found suitable across locations.

Observation trial of proso millet gerplasm

The experiment was conducted at BARI, Joydebpur, during rabi season 2015-16 to select better performing proso millet germplasm. Considering earliness, yield and yield contributing characters 68 proso millet were selected from the 126 proso millet germplasm for next year trial. Among the genotypes, entry 5 and 6 were registered for minimum days to maturity (96 days), the trait most desirable. Entry 3 and 20 (2.41 t/ha) exhibited the highest yield followed by entry 4 (2.32 t/ha), entry 5 (2.27 t/ha) and entry 1 (2.13 t/ha).

International barley yield trial high input condition

Performance of 25 barley genotypes were investigated at the research field of plant breeding division of BARI, Gazipur, during rabi 2015-16 to find out the suitable genotypes for large plot yield trial. The genotypes differed significantly for different traits except No. of tiller per plant and length of spike. Among the genotypes, entry 5 and 6 was registered for minimum days to maturity (96 days), the trait most desirable one. Entry 3 and entry 20 (2.41 t/ha) exhibited the highest yield followed by entry 4 (2.32 t/ha), entry 5 (2.27 t/ha) and entry 1 (2.13 t/ha).

International barley observation nursery- high input conditions (IBON-HI)

The experiment was conducted at BARI, Joydebpur, during rabi season 2015-16 to select better performing barley lines. Considering earliness, yield and yield contributing characters 13 lines were selected from the 139 barley lines for future breeding program.

International naked barley observation nursery (INBON)
The experiment was conducted at BARI, Joydebpur, during rabi season 2015-16 to select better performing hull-less barley lines. Considering earliness, yield and yield contributing characters 5 lines were selected from the 75 barley lines for preliminary yield trial.

Breeder seed production of barley

To maintain the purity of the released barley varieties, total 348 kg of breeder seed of seven barley varieties viz. BARI Barley 1, BARI Barley 2, BARI Barley 3, BARI Barley 4, BARI Barley 5, BARI Barley 6 and BARI Barley 7 were produced in 4 different locations.

Breeder seed production of millets
Breeder seed is essential for maintaining purity of the variety. Total 142.5 kg breeder seed of Kaon and Cheena were produced at four locations in last year.

Seed increase of selected foxtail millet, finger millet, pearl millet and sorghum germplasm
The experiment was conducted at BARI, Joydebpur, during rabi season 2015-16 to increase seeds of selected foxtail millet germplasm. Total 5.7 kg seeds were produced from 8 selected foxtail millet germplasm and local check. In addition a total 0f 26.1 kg seeds were produced from 10 selected finger millet germplasm, 2.5 kg seeds were produced from 9 selected pearl millet germplasm and total 4.5 kg seeds were produced from 5 selected sorghum germplasm for next year trial.